Quantified Health: A Feasibility Study on a Sensor-Based Feedback and Assistance System in Cardiology, Oncology and Orthopaedics

Anne Grohnert[1], Michael John[1], Benny Häusler[1], Christian Giertz[1], Mirko Wolschke[2], Jana Liebach[2], Rona Reibis[3], Anne Klemmer[3], Lisa Konrad[4], Silke Kollath[4] and Jan C. Zoellick[5]

[1]*Fraunhofer FOKUS, Kaiserin-Augusta-Allee 31, 10589 Berlin, Germany*
[2]*Orthopaedics and Oncology clinic, Reha-Zentrum Lübben, Postbautenstraße 50, 15907 Lübben, Germany*
[3]*Kardiologische Gemeinschaftspraxis am Park Sanssouci Potsdam, Zimmerstrasse 7A, 14471 Potsdam, Germany*
[4]*Theraphysia GmbH, Hellersdorfer Straße 77, 12619 Berlin, Germany*
[5]*Charité - Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Charitéplatz 1, 10117 Berlin, Germany*

Keywords: Mobile Assistance Systems, Sensor-Based Feedback, Telemedicine, Digital Care, Everyday Care.

Abstract: This paper reports the results of the Quantified Health project that developed a complex, digitally supported intervention. The project provides insights into how a sensor-based system can be organizationally integrated into the existing workflows of everyday treatment. The concluding pilot study took place in three medical facilities and addressed patients of orthopaedic, oncologic and cardiologic diseases in an in- or outpatient therapeutic setting. As a study result from the user's perspective, it is very appreciated to objectify the patient's health related behavior. Care providers considered it positive that they received more data from patients' everyday lives and that the improved data situation can lead to more sustainable care. On the other side, the time required to integrate a new digital application into the tightly scheduled daily treatment routine was perceived as a hindering factor. Nevertheless, the results of the study show that a more generic sensor-based assistance system could be used for different diseases and cross sectoral. Furthermore, the constant contact with therapists increases patients' motivation to engage in health-preserving activities (self-regulation).

1 INTRODUCTION

In order to maintain or optimize the success of temporary rehabilitation measures, longer-term sustainable therapy is required. Particularly after an inpatient stay, patients necessarily do not economize movement sequences and control exercise limits under everyday conditions (Thimmel et al., 2018). During rehabilitation, the patient is subject to constant supervision by doctors and therapists. In contrast, after rehabilitation, the patient may increasingly fall back into habitual behavioural patterns. In the case of heart and pulmonary diseases, but also in the field of oncology and orthopaedics, most patients often have fears and inhibitions when they return to work or everyday life. This leads to the patient avoiding regular physical activities such as walking or cycling. However, excessive intensity of exercises can also have serious consequences for the patient: Patients who were previously very active in sports often exert themselves too much despite their limited physical functionality.

Individualized therapy can help to strengthen the general health condition and body awareness and to consolidate the therapeutic progress already achieved during rehabilitation. The possibility of objectifying the own behavior with support by sensory feedback and assistance systems offers a great opportunity for patients to permanently change their own behavior (Plaete et al., 2015). This helps patients to manage better with everyday life and to exert themselves more economically in their regular routines. By improving their mobility in daily routines, patients experience an increase in their quality of life, which motivates them to live healthier and more sustainable (self-motivation and self-control).

Especially in times like Covid 19, telemedical feedback and assistance systems help to reduce physical contact between patients and doctors while maintaining therapeutic measures and treatment quality (Omboni et al., 2022). Patients are supported in their daily routines and healthcare professionals retain control of the treatment process through

Grohnert, A., John, M., Häusler, B., Giertz, C., Wolschke, M., Liebach, J., Reibis, R., Klemmer, A., Konrad, L., Kollath, S. and Zoellick, J.
Quantified Health: A Feasibility Study on a Sensor-Based Feedback and Assistance System in Cardiology, Oncology and Orthopaedics.
DOI: 10.5220/0012431100003657

In *Proceedings of the 17th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2024) - Volume 2*, pages 628-637
ISBN: 978-989-758-688-0; ISSN: 2184-4305

integrated feedback functionalities without the need for physical presence.

Thus, the "Quantified Health" project focused on investigating the factors and structures of telemedical assistance systems that are both beneficial and detrimental to the acceptance, use and satisfaction of users, i.e. care providers and patients. The system was testet with a variety of indications from different medical disciplines in order to figure out how a telemedical assistance system can contribute to cross-indication, cross-specialty and cross-sector treatment processes.

To assess the feasibility and usability of the Quantified Health system an accompanying pilot study was carried out at the rehabilitation-center in Lübben (oncology, orthopaedics), the cardiology practice at Sanssouci Park and at the orthopaedic practice Theraphysia. For this purpose, 56 patients were recruited during their stay in the participating clinics or by the outpatient facilities and were supervised by medical staff who were consulted about this care approach in form of interviews.

2 RECENT WORK

Due to our knowledge, the approach of using a telemedical assistance system across all indications and sectors has not yet been adequately considered. Research has already been conducted on sensor-based feedback and assistance systems for individual indications. Naeemabadi et al., 2020 provide an overview of studies of sensor-based feedback systems that were used for specific indications in the field of orthopaedics (e.g. knee and hip endoprosthetics). Eichler et al., 2019 investigated the use of a system for movement therapy with real-time feedback based on optical sensor technology in an evidence study, but also for specific indications in the field of orthopaedics. For cardiological diseases, Kumazawa et al., 2022 examined the use of a training system with computer-generated animations and Zhong et al., 2023 provide an overview of the long-term effects of cardiac remote rehabilitation for patients with coronary heart disease. In a systematic review, Brick et al., 2023 state that further research with more diversified samples, common measures of disability and pragmatic study designs are needed in the field of oncology to advance telemedicine in cancer rehabilitation due to the heterogeneity of the diseases.

Algarni et al., 2022 found in a survey of patient perceptions of tele-rehabilitation across indications that most patients are very or moderately confident that therapists can successfully assess and treat their problems using tele-rehabilitation. Wang et al, 2023 also used a survey to investigate the intention to use and factors influencing the use of telerehabilitation to treat patients with cross-indication rehabilitation needs. Both studies did not consider the provider's perspective.

In addition to the studies mentioned above, the “Quantified Health” project investigated whether and how a telemedicine system with specific functions can be used across indications and sectors. The evaluation of the technical feasibility and the acceptance of the system from the perspective of providers and patients were central to this research.

3 QUANTIFIED HEALTH SYSTEM

The Quantified Health system consists of several components (see Figure 1). On the one hand, there is the mobile patient app, which can use different commercially available wearables as a data source and, on the other, the therapy application for medical staff to view the patient's individual data. The Quantified Health Server serves as a central data collection point and makes the data available to the applications via secure transport.

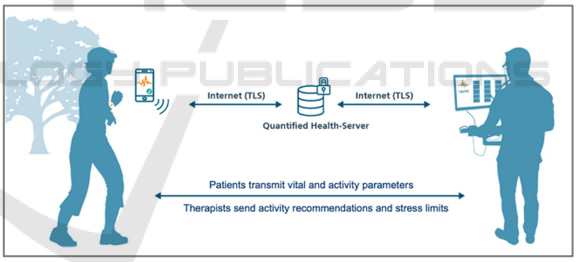

Figure 1: System components of the Quantified Health system.

3.1 Quantified Health App

The mobile component for patients consists of an app and body-closed sensors in form of a smartwatch. There are also input options for weight, blood pressure and general well-being. The current vital and activity parameters are displayed on the smartphone app in the form of color-coded value fields. Similar to a traffic light system, the colors of the fields provide real-time feedback on the preset range of the vital parameters, which are determined by the physician or therapist. For example, the value field for heart rate turns red if the heart rate rises above an individually defined limit.

The training plan that the patient has agreed with their doctor provides an overview of the goals that have been set. The patient can switch between everyday and training mode. There are 4 different training categories available in the training mode: Running, cycling, ergometer and an individual training plan with various gymnastics exercises. Training explanations also show statistics and progress in relation to the current training plan. Various vital and movement parameters are also recorded in training mode, such as the number of steps, distance covered and heart rate. The users can describe their current condition in the diary. There is also the option of rating the current mood on a scale of 1 to 10 in the event of sudden indisposition. If required, the current location (e.g., at home or at work), the feeling of stress and specific symptoms are also queried.

For simple and direct communication, e.g., if doctors and therapists have noticed a health risk or persistent stress, the app provides a bilateral communication option in form of video conferencing.

3.2 Therapy-Application

The therapy application for doctors and therapists is a tool with a graphical interface that medicals can use to create and edit health data records for patients (Patient Management System - PMS). These data records contain information about patients (socio-demographic data, medical history) and training plans (e.g., recommendations for the number of steps). The healthcare professional can set individual load limits for everyday and training modes (e.g., individual heart rate limit). In addition, training results and relevant vital and activity data are graphically processed and aggregated in the therapy application so that the attending physician/therapist can identify any trends in the patient's state of health. For example, the average stride length and speed when running and cycling are determined from the movement data of the training mode. The training results and therapy-relevant data stored in the system can also be used to adapt individual therapy plans as part of a suggestion system.

3.3 Quantified Health-Backend

The Quantified Health-Server stores all data of the telemedical therapy and training system, i.e., participating patients, therapists, therapy plans and training results. It is also responsible for the synchronization and persistent storage of data from all subsystems involved (mobile systems, therapy application). The data collected and stored in the project context are master data, health data and identification data. These data are subject to special protection requirements and are safeguarded by state-of-the-art technical and organizational measures in accordance with the GDPR.

4 MATERIALS & METHODS

The aim of the "Quantified Health" project was to pilot and evaluate a complex, digitally supported intervention from a user perspective in three medical facilities across different diseases and sectors of the german health care system. The use of a mobile sensor-based assistance system was tested, which accompanies patients with cardiological, orthopaedic and oncological diseases in their everyday life as part of follow-up treatment or aftercare.

Physiological deficits were determined and based on sensory data, everyday stress situations were analysed in real-time under medically and therapeutically defined aspects and the patients obtained immediate feedback on their state of health. The medical staff was involved by receiving vital and movement data from patients and by providing feedback (e.g., manual modifications of activity recommendations by the doctor and therapist providing care) to the patients. This should help the patient to manage better their health condition and experience greater economy under physiological load.

The 56 patients were recruited in the 3 facilities in different ways (e.g. by direct communication, by a displayed presentation explaining the study objective and procedure installed on the practice TV screen in waiting room), but based on similar inclusion and exclusion criteria:

- Resilience according to the health status (e.g. oncology: no metastases, orthopaedics: no acute ischialgia, cardiology: no unstable cardiac arrhythmia)
- Compliance required for physical activity (e.g. extracardiac comorbidities or orthopaedic limitations)
- Necessary affinity for technology (suitable mobile device, available e-mail address, digital questionnaires)

In all three facilities, separate appointments were made with the patients for patient information and education, data protection information, declaration of consent, technical training and the creation of patient data.

For the data collection, patients were provided with a smartwatch with sensors for measuring vital and movement parameters for a period of 3-5 months. As the data is particularly sensitive data under the GDPR, appropriate technical and organizational measures were implemented to protect the data. The basis for data processing on the side of the patients was based on a consent. In accordance with the principle of data minimization, data was only collected for the purpose of treatment within the study and evaluated pseudonymously. Data transmission was encrypted in accordance with current security standards. All ethical and regulatory requirements were safeguarded by obtaining an ethics vote. The study was also published in the German Clinical Trials Register.

The vital and movement parameters were evaluated at a total of four measurement points (upon enrolment (implementation and baseline), on transition from supervision by the medical institution to sole responsibility (approximately 4 weeks after enrolment), 13 weeks after enrolment (end of the intervention period), optional follow-up 21 weeks after enrolment) and the subjective evaluation of the tool was recorded in questionnaires.

The analyses included data from training sessions that took at least 600 seconds (Bull et al., 2020) and were within the time frame of enrolment (t0) to 13 weeks after enrolment (t2). Training sessions between t2 and t3, as well as training sessions lasting 300-600 seconds, were considered separately. Trainings after t3 and with a duration of less than 300 seconds were not considered.

In addition to standardized socio-demographic questions, validated scales were used as questionnaires (Van der Laan et al., 1997), (Venkatesh et al., 2003), (Davis et al., 1989), (Borg, 1998), (Bullinger, 1995), (Neyer et al., 2012), (Stoyanov et al., 2016), (Parmanto et al., 2016). In parallel, guided, semi-structured interviews were conducted with two practitioners from each of the three different medical facilities to obtain an assessment of the system's everyday viability on the side of the care providers.

The evaluation concept therefore used elements from process-oriented formative evaluation research (qualitative interviews) and effectiveness-oriented summative evaluation research (quantitative app and questionnaire data), which together assessed the progress and feasibility of the Quantified Health application.

5 RESULTS

The results presented below are based on data recorded by the system. This necessarily represents a reduced section of reality. It does not include, for example, training units and steps that were completed without using the system or training units that were carried out with the system but were insufficiently synchronized and transmitted.

A total of 56 people took part in the feasibility study. They were on average 46 years old (SD = 16.58 years); 55% were female. Table 1 shows the socio-demographic characteristics of the participants at the three facilities.

Table 1: Socio-demographic characteristics of the study sample by institution.

	Total	Onco.	Cardio.	Ortho.
N	56	21	18	17
Age (M, SD)	46.45 (16.58)	38.29 (10.39)	58.56 (14.22)	43.35 (18.23)
Gender (fem.)	55%	76%	33%	53%
BMI (M, SD)	26.40 (4.64)	26.05 (4.44)	26.03 (4.19)	27.28 (5.49)

5.1 Training Frequency

A total of 1053 training sessions with a duration of ≥600 seconds were recorded for the 56 participants over a period of 13 weeks. This corresponds to an average training frequency of M = 1.45 training sessions (SD = 2.33) per week. There were two outliers with 8.23 and 13.38 training sessions per week. No training was documented for eight participants. Excluding these ten patients resulted in an average weekly documented number of training sessions of M = 1.29 (SD = 1.43). The average training frequency of all participants varied depending on the time point and showed a decreasing trend with increasing duration of participation. The training frequency in the first weeks of participation was thus significantly higher than the training frequency at the end of the intervention period. Figure 2 shows the progression of the training sessions over time.

5.2 Feasibility - Dropout

For eight of the 56 participants, no training was documented (14%). Beyond that, for 17 people (30%), no training was recorded from week 5 no onwards; after two thirds of the time (8 weeks),

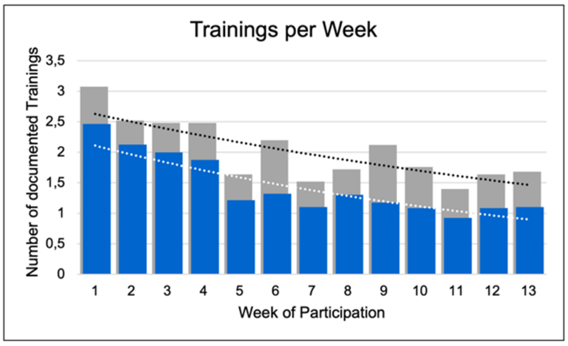

Figure 2: Number of documented weekly training sessions over the 13-week intervention period. The blue bars show the unadjusted data of all participants (n=56) incl. dropouts and outliers. The gray bars show adjusted data of participants who trained continuously (n=25) excluding dropouts and outliers. The training target of two training sessions per week was mainly achieved in the first weeks of participation.

training was recorded for a further four people (7%). This left 27 people (48%) whose training sessions were recorded by the system after 8 weeks. Looking only at those participants for whom training sessions were recorded up to the end of the 13-week period (n = 25), the training frequency was at the targeted level (M = 2.01; SD = 1.59).; meaning just under half of the participants completed training sessions over the longest period of the project. Dropout rates of up to 30-50% are not uncommon in feasibility studies (Fjeldsoe et al., 2010 & Pfaudler et al., 2015). Figure 3 shows the remaining patients since the beginning, after 4 weeks and after 8 weeks, broken down by indications.

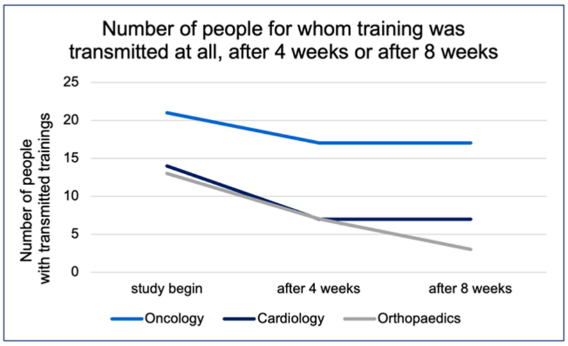

Figure 3: Number of people for whom training sessions were documented up to 4 weeks, for whom training sessions were documented after 4 weeks of participation and for whom training sessions were still documented after 8 weeks of participation.

5.3 Therapy Success

Health-related well-being was measured using the SF-36 with the subscales physical health and mental health (Bullinger, 1995). A total of 49 participants submitted at least one questionnaire; 12 participants responded at one measurement time point, 23 participants responded at two measurement time points and 14 participants responded at each of the three measurement time points. Table 2 shows the mean values of the two subscales physical and mental health for the three institutions at the three measurement points. The corresponding mixed models show a good model fit for physical health (ICC1 = .76) and mental health (ICC1 = .53). In both cases, the initial values of the participants vary significantly (physical: $t(67) = 26.37$, $p < .001$; mental: $t(82) = 27.22$, $p < .001$). Both physical health ($t(55) = 2.58$, $p = .013$) and mental health ($t(60) = 2.01$, $p = .049$) increased over time, similar to the individual findings of other studies on the use of telerehabilitation for specific indications (Jaswal et al., 2023; Eichler et al., 2019).

Table 2: Mean value of physical and psychological well-being by measurement time and therapeutic facilities.

		Total	Onco.	Cardio.	Ortho.
t_0	Physical (N)	41.27 (34)	42.90 (15)	37.18 (11)	43.83 (8)
t_1	Physical (N)	45.21 (34)	49.72 (13)	42.50 (12)	42.28 (9)
t_2	Physical (N)	45.96 (32)	46.99 (15)	45.35 (11)	44.49 (6)
t_0	Psychological (N)	44.80 (34)	43.38 (15)	47.35 (11)	43.98 (8)
t_1	Psychological (N)	47.49 (34)	43.35 (13)	51.79 (12)	47.74 (9)
t_2	Psychological (N)	48.68 (32)	49.58 (15)	48.58 (11)	46.64 (6)

5.4 Subjective Assessment of the Patients

After Van der Laan et al., 1997 usefulness and satisfaction can describe tendencies of acceptance and rejection on a cognitive and emotional level. Figure 4 provides information on the ratings according to medical indication in the value spectrum -2 (low acceptance) to +2 (high acceptance). Both dimensions are in the positive range of the scale. The system was therefore rated as useful and satisfactory and confirms the findings of Algarni et al., 2022 regarding the positive perception of telemedicine treatments by patients. Usefulness was more pronounced than satisfaction across all indications. Between t1 and t2, the cardiology participants rated the system as more useful. Satisfaction increased in cardiology but decreased in oncology and orthopaedics.

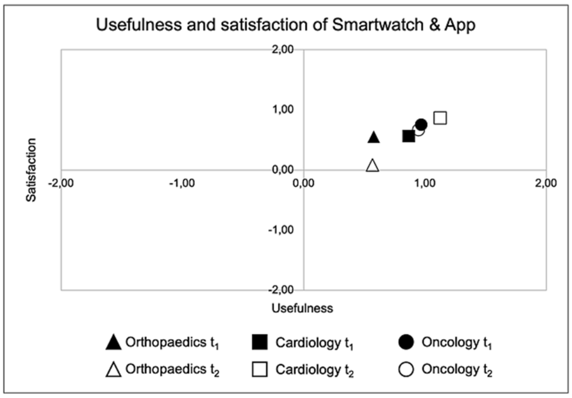

Figure 4: Evaluation of usefulness and satisfaction at t1 (N=34) and t2 (N=32) by medical institution. The scale ranges from -2 (low usefulness/satisfaction) to +2 (high usefulness/satisfaction).

Another measure of usefulness in the value range 1 (low usefulness) to 5 (high usefulness) coupled with usability (Venkatesh et al., 2003 & Davis et al., 1989) produced a similar picture with positively assessed usefulness. Usability was rated higher than usefulness across all medical institutions. Effects between t1 and t2 were negligible.

Of all questionnaire participants at t1 (N=34), those who also completed the questionnaire at t2 (N=22) evaluated the system as more useful than those who did not complete the t2 questionnaire (N=12) ($M = 1.02$ vs. $M = 0.48$; $t(32) = 2.08$, $p = .046$ and $M = 3.59$ vs. $M = 2.93$; $t(32) = 2.60$, $p = .014$). There were no significant differences between the two groups in terms of satisfaction and usability.

5.5 Perspective of the Care Providers

The six interviews with the supervising therapists (two in each medical institution), were used to discuss (1) the care context (2) the expectations of and towards patients and conflicts, (3) technologies in everyday working life, (4) the introduction, everyday use and evaluation of the quantified health system and (5) the potential of digital care in the respective rehabilitation setting. These results were described in the evaluation report (Zöllick, 2023) and are summarized below.

In an initial step, the patients' expectations were compared with the services provided by the facility. The summary of statements of medical care providers involved in the project reflects the complex treatment situation of lifestyle-changing therapy measures.

All participating therapeutic facilities use a variety of technical devices in their daily work for therapy and administration. Examples include digital patient files, video calls as a method for consulting, tablets and VR glasses. At the same time, therapists emphasized the importance of the therapeutic hand as an important tool. In addition to the benefits for patients, the most important criterion for the use of technology was emphasized as making work easier for medical staff (Zöllick, 2023, p.17).

Therapists generally consider the easy usage and operability as well as the reliability of the collected data to be central to the acceptance of additional IT systems in everyday treatment. These are the basic prerequisites for therapists to provide patients with valid feedback (Zöllick, 2023, p. 17f.), similar to the findings of Wang et al., 2023 that the reliability of data also plays a significant role in the acceptance of telemedicine on the part of patients. Particularly regarding the reliability of the data in the Quantified Health system further potential for improvement has been noted. Due to data protection requirements, the project also involved duplication with other existing IT systems, which required additional time. For instance, the facility's own documentation system had to be maintained in addition to the Quantified Health PMS. Nevertheless, the advantages of the Quantified Health PMS were emphasized as an additional source of information and the possibility of monitoring and closer interaction with patients (Zöllick, 2023, p.18).

The different expectations and approaches of patients were identified as a potential source of conflict with regard to their therapy and recovery process. On the one side they range from the idea that a massage works miracles, relieves pain and that a certain amount of healing will occur over time with the help of medication, up to those patients who want to be informed precisely about their status and their healing prognosis on the other side. The treatment approach to patients must therefore be individualized and sometimes insistent. From the perspective of care givers patients are expected to be motivated to participate and to reflect on how their own lifestyle contributes to health problems (Zöllick, 2023, p.16). Conflicts therefore arise on the one hand at the level of patients' false expectations, which often result in a lack of adherence. For some patients, retirement requests can also prevent an active attitude towards the rehabilitative measures (Zöllick, 2023, p.17).

These different expectations of the patient's individual recovery process have an impact on adherence: while adherence to treatment can still be effectively ensured in an inpatient facility due to the strict treatment plan, this appears to be much more difficult for less adherent patients in an outpatient setting. The therapists' limited personnel resources also complicate the scheduling of appointments and thus the flexible and intensive continuation of therapeutic measures (Zöllick, 2023, p.17).

Nevertheless, checking the effectiveness of training and therapy appears to be a motivator for therapists when using additional, data-based therapy systems, as the data can also be used to better explain their effective training areas to patients (Zöllick, 2023, p.19). The future of digitalization in therapeutic care is seen in the integration of different digital documentation systems. From the therapists' perspective, it would be desirable for all data, from patient administration and service provision documentation to the patients' medical parameters, to be integrated into one system. Such a reliable, integrated database would potentially reduce visits to the doctor and facilitate therapeutic work. It would also enable the transition between the inpatient and outpatient sectors and between medical and therapeutic therapy measures. Such a system also offers potential for new healthcare professions, e.g., digitally supported prevention and rehabilitation (Zöllick, 2023, p. 20).

6 DISCUSSIONS

Based on the results of the previous chapter, the research questions initially posed in the project are discussed below and lessons learned and recommendations for action are derived from them. The piloting of the Quantified Health system corresponds to a feasibility study and was intended to answer the question to which extent a telemedical assistance systems can be used across indications and sectors. Therefore, the added value and barriers, particularly for patients but also for the care providers involved, were examined. As mentioned above the lessons learned described below are based on the preparation for and discussions during the final event at Fraunhofer FOKUS as well as the feasibility evaluation by Charité Universitätsmedizin Berlin.

6.1 Different System Usage According to Health Care Sector and Professional Groups

Based on the feedback from the care providers involved and the accompanying evaluation study, one generic telemedical assistance and care systems can generally be used across different indications.

For instance, in the outpatient sector, telemedical assistance and care systems can be used primarily for preventive purposes and to support therapy. Medical professionals gain a deeper insight into the patient's state of health and activities based on everyday and training data. Based on these data they can adapt therapy measures accordingly. Patients are more strongly motivated (positive pressure) to exercise adequately, i.e., sufficiently and in a controlled manner. They gain additional therapy opportunities alongside their conventional therapy.

In inpatient and rehabilitative area, telemedical assistance and support systems can be especially used in aftercare. This ensures regular contact between therapists and patients, which contributes to the sustainability of inpatient therapy measures. Since aftercare does not necessarily have to be provided following an inpatient stay, such systems can help to close this gap.

The application of the system across different sectors also showed that inpatient care represents a good entry point for the use of such systems, as there is longer-term contact with patients on site and therefore more time for recruitment and referral to the system. When care providers use the system, it should be noted that different professional groups (sports therapist, physiotherapist, doctor, study nurse) may use the underlying system differently: Sports physicians and sports scientists focus more on training planning and training control, physiotherapists pay close attention to the quality of exercise execution, cardiologists primarily focus on monitoring of vital signs.

6.2 Configurability for the Indications Is Required

Nevertheless, the various application contexts in the Quantified Health project, different needs of the addressed indications (orthopedics, oncology, cardiology) or sections (outpatient practices, inpatient facilities) result in the need of different configuration of data types and system functionalities. For example, activity data (e.g., steps) and certain vital signs such as pulse are required for all indications. However, special values such as weight or the Borgscale (current feeling of exertion) are used to varying degrees in the individual indications. The same applies to special system functionalities. For example, everyday values are decisive in the cardiology field, whereas the focus in the oncology and orthopedic fields is on the training mode. In order to keep telemedical assistance systems simple and reduce complexity as much as possible, they should be configurable by the medical staff providing care for the indication-specific use, so that certain functions and the recording of special values can be modularly adapted to the specific application. The easy-to-understand aggregation of measurement and therapy data in the form of a traffic light system, for example, is essential for therapists and doctors.

6.3 Data Insight and Data Processing Motivate both Patients and Care Providers

Safety in everyday life can be restored and increased using telemedical assistance and care systems. For a particular group of patients, the use of telemedical assistance and support systems increases motivation to resume adequate physical activity. A certain self-efficacy for the participants can be derived from this. The patients' desire for a fine-grained insight into their own health data and its progression (on a per-day basis and statistically as an overview) was established. However, it needs carefully to be considered to which extent big volumes of available personal health data can be meaningfully presented on the sometimes very small displays of consumer devices needs to be examined further. On the medical side, optimizations of visualization (e.g., as a traffic light system) and data aggregation can also increase efficiency and thus make work easier for doctors and therapists. Not every recorded health date is relevant for the further course of treatment.

6.4 Integration or Connection to Existing Systems Increases Acceptance in Everyday Life

Naeemabadi et al., 2020 concluded that telemedical assistance systems must be easy to use for patients. It also turned out that, in addition to the desire for ease of use and operability, there is also a need to combine telemedical services with existing systems.

Fitness wristbands and smartwatches are often already available in the consumer sector. Any further additional component as a data source is less desirable. This means that telemedical systems should be developed in such a way that they can also communicate with common components from the consumer sector as a data source. On the medical side, the various facilities already have a patient management system (PMS). A redundant software component for pure patient management is not welcome, as it increases the documentation effort. Instead, it should be possible to integrate the results and recorded data of the additional digital health application into the existing PMS. This means that additional telemedical modules should be integrated into the existing PMS via open easy-to-use interfaces.

6.5 Creation of New Jobs and Professional Fields

The deployment and use of telemedical assistance and feedback systems requires more attention from physicians and therapists. This means that they cannot be integrated into the daily workflow without additional resources (time/staff). Telemedical assistance and care systems contribute less to increasing efficiency and resource optimization. Rather, they improve the quality of therapy and aftercare by creating added value for both patients and healthcare professionals. Thus the use of such systems results in additional costs for medical care. In order to integrate telemedical therapy measures into daily treatment routines an additional job or job profile must be created, the so-called tele-therapist or tele-physician. This professional position is characterized by the fact that both technical skills and medical expertise are required. Depending on the indication and functionalities used in such systems (e.g., video conferencing), psychological support may also be required, as certain patient groups (e.g., oncology) not only require movement during aftercare, but also make use of face-to-face discussions with therapists.

During the project, it became obvious that a private practice cannot offer digital care around the clock. Due to the low volume of patients, it may not be efficient in the outpatient sector to have one tele-therapist per each care facility. In order to close this gap in the health care system a flexible service structure should be created, which can be provided by a central service provider to be set up. Connected tele-therapists or tele-physicians could support several established medical practices via telemedicine centers. The services offered via a center should differentiate between a kind of on-call service (e.g., for the psychological care of oncological patients) and selective support in everyday life (e.g., when discussing therapy goals for cardiological or orthopaedic patients).

7 CONCLUSIONS

In summary, the functions provided by the Quantified Health system were sufficient for all indications. Although commercially available systems (fitness wristbands, smartwatches, PMS) also provide separate functions, they do not yet act as an integrated medical approved system from a technical perspective. Regarding the target groups, however, these functions must be weighted differently. For example, an explicit training mode may not be necessary in cardiology, as everyday values are increasingly monitored during the process of treatment. Configuration options should therefore be integrated into the Quantified Health App or PMS in order to adapt the system to the respective indication and the media skills of the end user.

In principle, the acceptance of the Quantified Health system was given among end users. Future applications of the system are possible in the area of prevention (e.g., to control high blood pressure), after an acute event (e.g., in inpatient rehabilitation or aftercare) but also for treatment of chronic diseases in order to modulate lifestyle in everyday life. However, a certain degree of affinity with technology was a prerequisite for the use of the Quantified Health system. It became clear that the large number of functions provided can lead to users being overwhelmed by the possible system operations. Especially in inpatient aftercare, the additional support in everyday life is perceived as a benefit for patients and fills a gap in the healthcare system. The acute event is often a starting point for lifestyle-changing activities following inpatient treatment. Constant contact with the doctor or therapist increases the patient's motivation. In the outpatient setting, especially for chronic patients, this process is much more protracted and sometimes problematic, because behavior patterns that have been practiced over long term have to be changed.

The project also revealed that an additional digital system would be difficult to integrate into existing workflows under the current working conditions. New tele-workstations for tele-doctors and tele-therapists should be created here. The care providers were consistently positive about the fact that they would receive more data from patients' everyday lives and that the improved data situation could also provide motivation for the sustainable care of patients.

Integrated solutions with well-bridged interfaces in particular allow medical care providers and patients to supplement prevention and rehabilitation measures and therefore have considerable social and economic potential. The project results of Quantified Health can be used to develop a reference architecture (description of the technical components and process recommendations) for digital aftercare in everyday life for the indications of cardiology, oncology and orthopedics. Initial concepts for a standardized, cross-indication open telehealth platform already exist.

In order to be able to define business models, the next step would be to determine not only the targeted, medical examination of effectiveness but also the economic efficiency. Business models can then be derived from these results. Future work on cross-indication teleassistance systems should therefore focus on

- Technical adaptation and optimization in accordance with the lessons learned and recommendations for action,
- the audit of effectiveness and efficiency and
- the requirements for inclusion in standard care by providing an accounting code.

ACKNOWLEDGEMENTS

This work was supported by the project DiBeA funded by the German Federal Ministry of Health based on a decision of the German Federal Parliament (Bundestag) under funding ID ZMI1-2521TEL20A.

REFERENCES

Algarni, F. S., Alshammari, M. O., Sidimohammad, U., Khayat, S. A., Aljabbary, A., & Altowaijri, A. M. (2022). Tele-Rehabilitation Service from the Patient's Perspective: A Cross-Sectional Study. Journal of Patient Experience, 9, 23743735221130820.

Borg, G. (1998). Borg's perceived exertion and pain scales. Human kinetics.

Brick, R., Padgett, L., Jones, J., Wood, K. C., Pergolotti, M., Marshall, T. F., ... & Lyons, K. D. (2023). The influence of telehealth-based cancer rehabilitation interventions on disability: a systematic review. Journal of Cancer Survivorship, 17(6), 1725-1750.

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., ... & Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. British journal of sports medicine, 54(24), 1451-1462.

Bullinger, M. (1995). Der deutsche SF-36 Health Survey. Ubersetzung und psychometrische Testung eines krankheitsubergreifenden Instruments zur Erfassung der gesundheitsbezogenen Lebensqualitat [Translation and psychometric testing of a questionnaire on subjectively perceived quality of life]. Zeitschrift fur Gesundheitswissenschaften, 3, 21-36.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. Management science, 35(8), 982-1003.

Eichler, S., Salzwedel, A., Rabe, S., Mueller, S., Mayer, F., Wochatz, M., ... & Völler, H. (2019). The effectiveness of telerehabilitation as a supplement to rehabilitation in patients after total knee or hip replacement: randomized controlled trial. JMIR rehabilitation and assistive technologies, 6(2), e14236.

Fjeldsoe, B. S., Miller, Y. D., & Marshall, A. L. (2010). MobileMums: a randomized controlled trial of an SMS-based physical activity intervention. Annals of behavioral medicine, 39(2), 101-111.

Jaswal, S., Lo, J., Sithamparanathan, G., & Nowrouzi-Kia, B. (2023). The era of technology in healthcare: an evaluation of telerehabilitation on patient outcomes—a systematic review and meta-analysis protocol. Systematic Reviews, 12(1), 1-7.

Kumazawa, N., Koyama, S., Mukaino, M., Tsuchiyama, K., Tatemoto, T., Tanikawa, H., ... & Tanabe, S. (2022). Development and preliminary evaluation of a tele-rehabilitation exercise system using computer-generated animation. Fujita medical journal, 8(4), 114-120.

Naeemabadi, M., Fazlali, H., Najafi, S., Dinesen, B., & Hansen, J. (2020). Telerehabilitation for patients with knee osteoarthritis: a focused review of technologies and teleservices. JMIR Biomedical Engineering, 5(1), e16991.

Neyer, F. J., Felber, J., & Gebhardt, C. (2012). Entwicklung und validierung einer kurzskala zur erfassung von technikbereitschaft. Diagnostica.

Omboni, S., Padwal, R. S., Alessa, T., Benczúr, B., Green, B. B., Hubbard, I., ... & Wang, J. (2022). The worldwide impact of telemedicine during COVID-19: current evidence and recommendations for the future. Connected health, 1, 7.

Parmanto, B., Lewis Jr, A. N., Graham, K. M., & Bertolet, M. H. (2016). Development of the telehealth usability questionnaire (TUQ). International journal of telerehabilitation, 8(1), 3.

Pfaudler, S., Hoberg, E., & Benninghoven, D. (2015). Internetbasierte Nachsorge für Patienten nach multimodaler orthopädischer Rehabilitation–Machbarkeit und Akzeptanz. Physikalische Medizin, Rehabilitationsmedizin, Kurortmedizin, 25(02), 81-89.

Plaete, J., Crombez, G., DeSmet, A., Deveugele, M., Verloigne, M., & De Bourdeaudhuij, I. (2015). What do general practitioners think about an online self-regulation programme for health promotion? Focus group interviews. BMC family practice, 16, 1-11.

Stoyanov, S. R., Hides, L., Kavanagh, D. J., & Wilson, H. (2016). Development and validation of the user version of the Mobile Application Rating Scale (uMARS). JMIR mHealth and uHealth, 4(2), e5849.

Thimmel, R., Schubert, M., & Viehmeier, S. (2018). Übergreifende Aspekte zum Reha-Prozess. Rehabilitation: Vom Antrag bis zur Nachsorge–für Ärzte, Psychotherapeuten und andere Gesundheitsberufe, 217-228.

Van Der Laan, J. D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. Transportation Research Part C: Emerging Technologies, 5(1), 1-10.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. MIS quarterly, 425-478.

Wang, M. Y., Chen, H., Gong, C., Peng, X. M., Zhong, Y. B., Wu, C. M., ... & Wu, Y. Q. (2023). Understanding the use intention and influencing factors of telerehabilitation in people with rehabilitation needs: a cross-sectional survey. Frontiers in Public Health, 11.

Zhong, W., Liu, R., Cheng, H., Xu, L., Wang, L., He, C., & Wei, Q. (2023). Longer-Term Effects of Cardiac Telerehabilitation on Patients With Coronary Artery Disease: Systematic Review and Meta-Analysis. JMIR mHealth and uHealth, 11, e46359.

Zöllick, J. (2023). Evaluationsbericht „Quantified Health - Bericht über eine dreimonatige Machbarkeitsstudie zu einem sensorbasierten Feedback- und Assistenzsystem in drei Reha-Settings“, projektinternes Dokument, 30 S.