Collection of Requirements and Expectations for a Sensor-Based Telemonitoring System for ACL Repair Rehabilitation

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***Abstract*—One of the most frequent knee injuries is the rupture of the anterior cruciate ligament (ACL). With modern surgical reconstructive procedures, the patient can resume daily activities and sports. Effective rehabilitation is essential for restoring the patient's functional ability and reducing the risk of reinjury. This thesis examines the viality of telemonitoring and tracking data of the knee joint for use in rehabilitation following anterior cruciate ligament reconstruction (ACLR) surgery, as well as the specifications that should be imposed on the product in this situation. Through qualitative expert interviews and a quantitative survey, it was determined what doctors, physiotherapists, and patients wanted from a sensor-based system used in the rehabilitation process following ACLR surgery as well as the clinical setting in which such a system would be used. The research's findings have been evaluated, explained, and placed in their proper context. According to those who participated in the interviews, thigh circumference measurements, accelerometers for monitoring patient activity, strain-active sensors for measuring knee circumference, textile integrated temperature sensors in a knee brace for measuring skin temperature and calculating joint axis angles all met the criteria for the quantitative investigation. The findings showed that prescribed rehabilitation protocols are highly standardized, and that the current tendency in therapy should be to tailor exercise regimens to the patient's constitution during the stages of wound healing and to offer the physical therapist greater latitude. A telemonitoring system must offer patients the opportunity to actively participate and interact in order to increase motivation. Psychological factors and the patients' self-assessment can be queried and quantified with questionnaires as patient reported outcome measures. Possibilities for recording these parameters and ensuring patients' comfort include using a potentiometer to sense the angle in the knee joint, an integrated strain sensor to gather circumference changes brought on by swelling, and a micro electromechanical sensor to track steps and distance traveled.**

***Index Terms*—anterior cruciate ligament, tele rehabilitation, monitoring, ACL rupture, sensor.**

I. Introduction

LIGAMENTOUS knee injuries [1] are extremely common. In Germany, a rupture of the anterior cruciate ligament is one of the most common sports injuries, occurring at a rate of 46 per 100.000 inhabitants [2]. The patient's range of motion (ROM) and quality of life remain severely restricted after surgery. To enable patients to return to their previous levels of activity without restrictions, knee injuries must receive adequate rehabilitation.

ACL injuries have far-reaching epidemiological consequences, such as an increased risk of knee osteoarthritis [3]. Following surgery, ACL stability and load-bearing capacity may not be fully restored. Re-injury of the ACL or other knee structures, muscle weakness, or functional weakness may occur [4], [5], [6]. Andrade et al. [7] demonstrated that replacing the ACL with an implanted tendon reduces the risk of secondary damage while improving knee joint stability. This reconstruction method is now considered the gold standard in the treatment of ACL injuries. The surgical procedure and rehabilitation program are chosen by the person in charge, usually an orthopedic surgeon, trauma surgeon, or sports medicine specialist, based on the patient's functional goal and whether other structures are affected in addition to the ACL. The desire to do sports again is the most common reason for ACLR [6]. Returning to high-impact sports like handball, soccer, rugby, etc. quadruples the risk of re-injury [4].

Rehabilitation is a critical component of regaining functional abilities following surgery [8] and should begin as soon as possible. Physiotherapy aids in the restoration of knee joint mobility and normal movement execution. Rapid recovery is critical for joint stability restoration and the prevention of secondary damage [9], [10], [11]. Full ROM and pain relief are usually achieved within six to nine months. Using telerehabilitation to treat clinical conditions such as stroke, cancer, and cardiac and pulmonary disorders could result in improved patient satisfaction and health outcomes, according to studies [12], [13], [14]. Moreover, telemonitoring promotes greater spatial and temporal flexibility for patients, as measurements and exercises can be performed outside of physiotherapy sessions.

Continuous monitoring systems based on wearable sensors and advanced communication technologies [15] provide a platform for telehealth and self-management interventions [16]. Since an individual's gait pattern is strongly correlated with their health condition, the ability to continuously and precisely identify abnormal locomotion patterns [16] can facilitate a more individualized approach to treatment. The clinician can retrieve movement data and make intervention decisions in real time and from any location [15]. Micro electro mechanical systems (MEMS) based on miniature motion sensors such as accelerometers, gyroscopes, and magnetic field sensors are commonly used to measure activity signals in sensor-based monitoring systems [17], [18]. They can be incorporated into textile fibers, clothing, and bands, or attached directly to the body [19].

The successful use of telemonitoring applications in other diseases and the current state of the art in sensors for the

acquisition of motion data specifically in the knee joint form the basis for the research question of how this technology can be used as precisely as possible for the rehabilitation of knee joint injuries, specifically surgery after ACL injuries, and what requirements should be placed on the product in this context.

This work focuses on the injuries of the anterior cruciate ligament and the associated surgery for reconstruction because of the frequency of this type of ligament injury and a large number of scientific publications regarding this topic. The basis of this research is a theoretical concept of a telemonitoring system and how it could be developed and constructed based on the state of the art. In the fundamentals part, this will be elaborated.
The impact of evaluating and identifying the user requirements on the development process of a product is significant. Therefore, the identification of the requirements is essential for the development of a telemonitoring system and will be carried out in the scope of this work.
The main questions to be asked are - What properties and capabilities the system must have, how the use case looks like, and with what measure these requirements can be specified? One reason for analyzing the requirements is, on the one hand, to determine the expectations of the individual stakeholders. In this case, the stakeholders are the patients who use the system and the physicians and therapists who receive the collected data and use it to make decisions about the course of therapy. Only when their needs are clear a system can be developed that meets these expectations. On the other hand, identifying and analyzing the requirements of the telemonitoring system is the greater chance of a successful outcome of the development process.
The primary scientific source for the theoretical basis of this study is publications from scientific journals in the fields of medicine and sensory science. Official guidelines on the process of rehabilitation of knee joint injuries also play an important role. This thesis aims to determine the potential for the use of telemonitoring and tracking of movement data in the knee joint for application in rehabilitation after reconstruction surgery of the anterior cruciate ligament.
On the one hand, this thesis answers the question of which methods in the rehabilitation of cruciate ligament injuries can be supported, simplified, or replaced by a telemonitoring system. On the other hand, the technical and functional requirements of such systems will be evaluated and analyzed. The expectation is that the availability of more strain-related data over a continuous period will draw a more accurate picture of the status of the injury and the progress of the rehab, which will help decision makers such as physicians and physical therapists make decisions and promote patient satisfaction and cooperation in the rehab process.

II. Telemonitoring System

Telemonitoring is the examination, diagnosis, and monitoring of patients using telemetry devices. The emphasis is on the wireless data transfer of medical measuring instruments to important locations, such as a doctor's office. Philippe Bardy [20] defines it as continuous or uncontinuous monitoring that enables a healthcare expert to remotely assess patient data and make medical judgments.

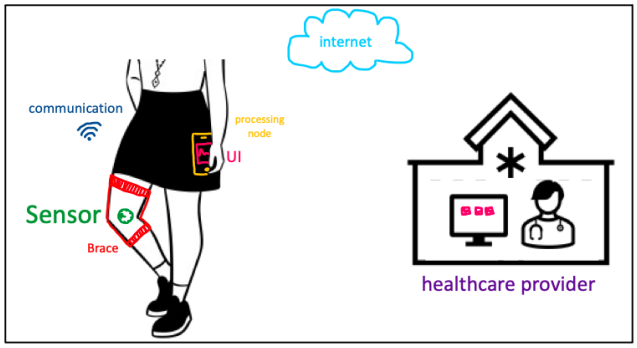

Figure 1: Overview of the components of a telemonitoring system for the knee joint

Figure 1 depicts the pertinent components of a telemonitoring system using a knee monitoring system as a hypothetical example. A sensor attached to a knee brace measures the joint's activity. A wireless communication protocol transmits the data to the home gateway's processing node. The signal is caught, stored, examined, and presented. The data is communicated to the healthcare practitioner over the internet [15].
In the research of Anker et al. [21], telemonitoring systems have been categorized as nonreactive data collection devices (e.g., event recording devices), those with a delayed analysis and decision structure (e.g., only during office hours), those with a continuously operating analysis and decision infrastructure, and complex systems that integrate invasive and noninvasive data.
Remote health monitoring based on non-invasive and wearable sensors, actuators, and modern communication and information technology provides a cost-effective solution that allows healthcare practitioners to remotely monitor critical vital signs, access health status, and provide feedback [9].

III. Methods

In this study, an exploratory mixed-methods approach is used. This combines qualitative and quantitative research methods. Mixed-methods designs include triangulation, integration, design explanation, and experimentation. Exploratory studies provide a first impression or overview of a topic without prior research. They are often used to inform future research. Exploratory research questions help us learn about a topic without preconceived notions.
In an exploratory study design, the qualitative approach comes before the quantitative approach. First, a theory is developed, which is then validated with quantitative data. For data collection, expert interviews were chosen for the qualitative part and a survey was chosen to gather data from a predetermined sample of respondents. For this purpose, a guided, semi-structured interview with three surgeons and

five physiotherapists and a quantitative online patient survey were conducted. The experts interviewed were selected based on their expertise in the field. For the quantitative study, a questionnaire was distributed to 55 individuals who had suffered a tear of the ACL with subsequent rehabilitation as a result of a sports accident.

IV. Results

A. Expert Interviews

In the qualitative part of the study, professionals in ACLR rehabilitation were asked about common processes and challenges and what a telemonitoring system must meet to be employed successfully in this process. With the help of summarizing content analysis, the experts' answers were split into inductively created categories and condensed to a manageable short text. The resulting corpus is provided below. Participants of the expert interviews are all ACLR decision-makers. The population consists of three surgical physicians and five postoperative physical therapists. The interviewed physiotherapists have years of post-ACL reconstructive experience. Postoperative care is their main purpose. Most of their treated patients come from a recreational or professional sports background.
Rehab depends on the patient's goals. This restores the pre-injury status quo. This may be to return to a (high-impact) sport (RTS) or to conduct daily duties pain-free. Experts consider therapy complete when the knee's anatomical stability and flexion and extension are restored. RTS should restore balanced strength ratios between injured and unaffected sides to prevent ACL rupture. According to specialists, precise surgery and effective physiotherapy are vital for successful ACLR rehabilitation. The patient's motivation and vision on the treatment are key. Bravery or fearfulness influence the individual progress. Trust between therapist and patient requires willingness and obedience from the patient. Cooperation and communication between professions are also vital. The surgeon and physiotherapist must coordinate their treatment. Framework elements include the availability of therapy appointments and the practice's equipment. Limitations are structural, such as a lack of therapists and limited health insurance coverage, and external, such as age, fitness level, and intrinsic drive. Poor communication might also limit success.

The surgeon determines the proper protocol based on the surgical method and the presence or absence of concurrent injuries, such as a meniscal tear, or modifies the protocol if necessary. Choose In many instances, hospitals adopt standardized protocols, particularly for ACLR patients. In smaller facilities, the patient's circumstances are taken into greater regard while selecting a scheme. In general, the recommendations are very uniform, and the particular patient receives little consideration. The protocol acts as the physiotherapist's guide. They can refer to it during therapy follow-up. The interviewing surgeons favor an early return to full weight-bearing following surgery. The intensity is automatically regulated by the patient's pain perception. In the ensuing steps, based on biomechanical models and the physiological healing phase, the treatment is administered in time-specified phases with set ROM angles to develop strength and flexibility. The treatment of competitive athletes differs from that of normal patients due to the higher intensity of therapy administered to competitive athletes. To proceed with the plan, objective values such as the assessment of wound healing must be evaluated, as well as whether the goals of the respective phase (e.g., a squat can only be performed when flexion of 90 degrees has been attained).

There are a variety of manual and digital devices available to assist patients and physiotherapists in regaining range of motion and strength after surgery. Immediately after surgery, ice is applied to the surgical site to minimize swelling over the first few days. Then, a tape measure is used to record the decrease in thigh circumference resulting from the reduction in swelling. The skin temperature of the wounded knee is measured and monitored with a thermometer, as a warm knee indicates inflammatory activation in the area. As the pain prohibits the knee from directly bearing weight, crutches and crutches are used to assist the patient in carrying weight. A motion splint operated by an electromotor passively and continuously trains the joint's movement in the patient's home during the initial weeks following surgery. An orthosis limits the angle of early phase flexion; the angle can be restricted. Frequently used is a restriction to 60 or 90 degrees as the primary limit. During the period of increasing strength and mobility, a manual or digital goniometer is used to measure the patient's range of motion (ROM) and digital force measurement. Frequently, this is combined with electrotherapy to stimulate specific muscle groups via an electromuscular stimulation (EMS) device. The Y Balance Test is used to measure the mobility of the patient. The patient demonstrates his leg-length-related manual reach in multiple spatial orientations. The Functional Movement Screen (FMS) evaluates and tallys various movement patterns, such as squats, for each leg. The Limb Symmetry Index is used to assess the symmetry of the force using a semi-quantitative method that classifies strength capabilities and contraction on a scale of 1 to 5. It reflects the patient's performance in a lateral comparison during workouts such as the Hop Test. According to the comments, no applications or other platforms are utilized by patients. In the practice of a single one, of the interviewed surgeons, patients can receive instructions and information via videos and articles. This information is exclusively accessible to the patient and is formatted for remote assistance. For internal documentation, physiotherapists utilize practice-provided software or openly accessible platforms such as Google Sheets, which enables the documentation of discussed information and, if appropriate, the sharing of this information with the patient. All professionals concur that patient participation is essential. The physiotherapist will typically question about the patient's subjective pain perception. This is possible using a numerical analog scale (NAS) or a visual analog scale (VAS), a graphical rating system. In therapeutic settings, questionnaires are utilized less frequently since patient compliance is required

and their completion is not always possible or worthwhile. The experts report, however, that they consider the use of such standardized questionnaires to be extremely important, as reference values are created, one can refer to patient statements to increase their motivation, and goals can be visualized more clearly and serve as a memory aid for patients and therapists. The frequency with which these questionnaires should be administered depends on the therapist's mood and may be influenced by the patient's anxiety level. The experts recognized potential for questionnaire data to serve as evidence for the scientific examination of whether monitoring might genuinely boost patient happiness, so laying the groundwork for comparability. An interviewed physician has indicated the approaches of Lysholm and Tegner, the International Knee Documentation Committee (IKDC) score and the Knee Injury and Osteoarthritis Outcome Score (KOOS) scale are considered in their work. In addition, according to one psychotherapist, it is useful to identify underlying Kinesiophobia. Subjective measurement is especially important at the beginning of therapy.

Following is a brief explanation of the need for a telemonitoring system for the knee joint and the initial associations of specialists with this phrase. The experts foresee a system in which the patient creates input data and the physician receives output data based on the appearance of the patient's motions. Additionally, the patient should obtain a useful result; hence, the system should not be overly complex. In addition, the collected data must be reproducible and the system must be cost-effective. One physician envisions a database with a feedback mechanism that provides the patient with clear instructions and directions. Physio 5 presents the telemonitoring system, according to their understanding, as a means of bridging the physical distance in order to learn about the patient's symptoms and track their continual improvement. In addition, to be able to strengthen cooperation with patients and monitor their development, as well as to provide video call support between patients and physiotherapists. No expert was able to offer any experience with the use of such systems, even for other joint injuries. Only the observation that some patients use smartwatches to monitor personal (sporting) activities has been made. During the interviews, one of the most significant issues was what data a telemonitoring system should collect in order for its output to be beneficial to the individuals involved. The consensus of the experts was that the emphasis should be on measuring mobility. In conclusion, the following responses can be listed: The ROM angle, swellings, temperature, subjective sensation about general stability, pain and tension, the activity and movement volume, strength (quadriceps contraction).

The experts have been questioned regarding the format in which the collected data should be made accessible to them. Based on their comments, the following list of requirements was compiled:

- Linking to patient record
- Hospital Information System Display (HIS)
- Coloring system for norm and cutoff values
- Access for patients to the system
- Sharing option to the physiotherapy practice
- Tables and graphs as overview of progress or regress
- Patient avatar to facilitate scenario transfer
- Data accessibility via app and web browser

The experts have not identified a specific user demographic for the system. Rather, it is of interest to all ACLR patients who possess a certain level of interest. Thus, it is possible to produce valuable data for comparing different groups and healing processes of various surgical methods. Due to the fact that vigorous sports activities are the leading cause of injury, the majority of patients are young and athletic. The specialists believe these patients to be more tech-savvy. Even though they are not considered to be problematic patients, their interest in data is typically a useful factor. Anxiety patients are mentioned as a potential target population in Physio 3, as understanding and monitoring the motions done can offer them with comfort. A physiotherapist responded, "The overconfident patients who want to move through as soon as possible, but who can be slowed down by this" in response to the question of whether he had a specific, particularly suitable target group in mind. Experts' opinions about the appropriate usage of the system range between the first four postoperative weeks and at the earliest the sixth week postoperatively. Physicians Some also find the method effective following conventional physiotherapy, three to six months to one year after surgery, to complement exercise treatment.

B. Patient Survey

There were 55 participants in the survey. When their cruciate ligament ruptured, more than two-thirds of respondents (69 %) were between the ages of 20 and 40. All participants reside in Germany (78 %) and Austria (100 %) (22 %). When asked in what situation the rupture of the cruciate ligament occurred, all participants (100 %) identified athletics as the cause. Participants were asked about their simultaneous and secondary injuries. There were no such injuries among two-thirds of the population. In addition to the ACL injury, 18 of the 55 individuals reported secondary or concomitant injuries. Most consequential injuries (56 %) were ACL tears in the same or opposite leg. Six patients reported knee injuries, while one had contralateral knee lesions. One person over 40 with knee osteoarthritis was injured. Six people had other knee injuries, and one reported the opposite knee. One participant over 40 with an ACL damage developed knee osteoarthritis.

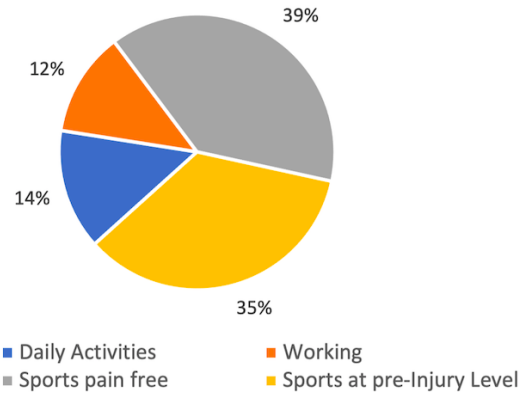

Figure 2: Rehabilitation goals of the patients

Figure 2 shows the rehabilitation goals of the patients. The majority of patients want to get back into sports. In this sense, resuming athletic performance at pre-injury levels is almost as crucial as being able to play sports without pain. The ability to undertake daily activities (14%) and employment (12%) without limits is not the key desire for the majority. Patients were asked how well they believed they were cared for during their recovery and what could have been done better. Seventeen percent of those polled are dissatisfied with the rehabilitation services they received. All respondents, including those who felt well supported, suggested the following improvements: Adaptation of the training plan to the person and their life situation (in terms of age and basic fitness); A higher intensity, individual training plan, adjusted to the patient's level of progress; More individual and intensive care and not being left alone in the treatment too early; Integration of the patient into the treatment and the ability to participate proactive.

The reasons for deploying a telemonitoring system have been ranked based on the degree to which patients view each reason as an incentive. The most important thing for respondents is to have a general awareness of stress limits and be able to more precisely identify their acute strain in this regard. In addition, having continuous values as opposed to a single snapshot throughout a physiotherapy session was commonly cited as a reason for the purpose to adopt. Almost all respondents are interested in gauging personal success. Some patients feel that utilizing the device can ease their symptoms, which include a loud cracking sound and general knee discomfort. The most requested features (49 percent) for a telemonitoring system are a wiki area with information about the injury and rehabilitation symptoms and a questionnaire, which is displayed to patients via the system's interface and asks about their state and is saved for progress documentation. Patients would also appreciate a component of the platform that allows them to add free notes that may be used as reminders for future enquiries, for instance. Twenty percent of respondents would like to communicate with other sufferers through a forum. The following are patient suggestions and ideas in response to the open inquiry regarding the implementation of a telemonitoring system:

- Identifying and treating muscular deficiency
- Informing individuals about the effects of the female cycle on mobility issues
- Evidence of ligament healing and integrity
- Effective data visualization
- Status display: compares status to reference values and objectives
- Assistance and reimbursement from healthcare insurers
- A hotline for individuals seeking information on the healing process
- Optimisation of training via films or recommendations that suggest exercises based on time or the healing process
- A mobile application that gives a summary of monitoring data

During the phase of strength and flexibility training, 73 % of respondents indicated that they would consider using it. 44 percent believe that the RTS time is an appropriate time.

V. Discussion

To investigate the requirements of physicians, physiotherapists, and patients for a sensor-based telemonitoring system to support rehabilitation after ACLR, mixed-methods research was used to analyze current processes and challenges in rehabilitation after ACLR, personal experiences and expectations regarding telemonitoring, and the potential use of a sensor-based telemonitoring system for the knee. A guided, semi-structured expert interview with eight experts and a quantitative online survey were undertaken for this aim. This methodology was selected since the objective is to collect data on a topic that has not yet been formally documented in this manner.

The interviewees were chosen due to their competence in the topic. Physiotherapists are the executing profession as well as prospective supervisors, users, and educators of a telemonitoring system during rehabilitation following ACLR. Surgeons are the decision-makers for the measures. Therefore, physicians with slightly different backgrounds and application areas were selected. The interviewees were recruited from the researcher's personal network via third parties, and their socioeconomic background therefore impacted to some extent. Theoretically, saturation of all researched categories was reached after interviewing eight experts, as the findings for each analyzed category were repeated in the material. After attaining this saturation, it is appropriate to initiate the quantitative survey. For the quantitative investigation, a questionnaire was sent to 55 persons who had sustained a rupture of the anterior cruciate ligament and subsequent rehabilitation as a result of a sports injury, and who were representative of three age groups (up to 20 years, 20-40 years, and 40 years and older). Since the majority of respondents are between the ages of 20 and 40, the conclusions are mostly applicable to this age range and left representative ACL tears that occurred during sports. On this premise, it is possible to assert that the results would be identical if the quantitative study were replicated, so assuring the study's external validity.

Telemonitoring can enhance rehabilitation for physicians, physical therapists, and patients, as proven by exploratory mixed-methods research. Research question: The following product specifications reduce patient anxiety and enhance the efficiency of physician and physiotherapy processes. The sensors will measure knee flexion and extension in degrees, knee swelling by measuring thigh circumference 20 centimeters above the knee, knee skin temperature to monitor inflammation after surgery, and patient movement in kilometers. A potentiometer for sensing the angle in the axis of the knee joint, a textile integrated strain sensor for capturing circumference changes due to swelling, and a MEMS sensor for monitoring steps and distance traveled are suitable options for capturing these measurements and ensuring the patient's comfort. To incorporate psychological components into rehabilitation, the mobile application must provide subjective pain self-assessment surveys and personal goals. The VAS, IKDC, and

the Tampa Scale for Kinesiophobia TSK accurately quantify patient anxiety. Smartphones and tablets require applications. A web-based version is required if not. His graph should be connected to data. Tables and graphs are required to display values. Graphs should color-code norm, threshold, and outlier ranges so that a patient's improvement or regression may be quickly identified, and a time span allocated. According to Ferrari et al. [22], Bluetooth's feasible network topology, wireless communication range, and effectiveness in connected sensors, medical equipment, and consumer devices such as smartphones make it a good telecommunications technology. A wiki section on ACL injuries and rehabilitation, a space for personal notes, and a forum for reference and collaboration should be added for patient education. It is desired to observe the connection between activities and data. The study's findings diverge from previous research. Regaining mobility is the objective . Telemonitoring should be utilized three weeks after surgery, not at the stage of return to sports. Professionals must connect, support, and communicate in ways that go beyond the mind. Physiotherapists utilize it as well. According to Paterno et al. [4], up to 30 % of young, active patients rupture their ACL again after five years post ACL resection. The majority of respondents wish to return to sports. Assuming that all survey participants tore their ACL while playing sports, returning to sports as a rehabilitation objective only applies to recreational athletes. Surprisingly, the acquired data can be used to investigate the effect of surgical procedure on healing. Unexpected. Researchers, patients, physiotherapists, and physicians gain from sensor-based telemonitoring. Physician interviews highlighted the significance of orthosis in ACLR therapy. In the first few weeks after surgery, this is ineffective. The implant remains intact, while the orthosis serves to remind the patient of the knee injury. The monitoring of flexion angles using sensors and patient compliance, according to specialists, renders orthosis unnecessary in some circumstances. This was validated by Hanzlková et al. [23]

VI. Conclusion

The goal of this thesis was to gain a deeper understanding of the difficulties that patients and physiotherapists encounter on a daily basis, as well as the structural obstacles that prevent rehabilitation. Additionally, the survey results were used to identify the goals that each of the different process participants wished to accomplish (doctors, physiotherapists, and patients). The conclusions that were drawn from the discussion of this thesis and the requirements that were derived for the knee telemonitoring system from it are supported by this. This also provides the basis for the knee telemonitoring system requirements that were concluded.

The objective and subjectively performed functional and psychological measurements, as well as the issue of what information needs to be gathered with a telemonitoring system, were all topics of the qualitative expert interviews that were conducted as part of this study. A crucial step in the process of regaining mobility is keeping track of the patient's range of motion. The flexion and extension of the knee joint should have produced this value. By comparing the size of the affected upper limb with the temperature in degrees Celsius after surgery, the level of swelling is assessed. Users are also interested in a record of the patient's overall activity, according to the examination's findings, especially if this record can be connected to numerical values.

The use of a telemonitoring system during the period of recovering strength and mobility after ACLR is particularly intriguing, according to the research's findings. It is interesting for treatment and therapy, as well as the controlled return to intense sports for the decision-making of caring specialists and the improvement in patient satisfaction, that this system can record data from roughly 3-6 weeks postoperatively up to one year after surgery. The study also revealed that all patients can use the system equally, so it shouldn't be further restricted.

Individual experiences with the rehabilitation process, familiarity with tracking, desires for usage requirements, and specific digital features of a potential system were all investigated in the quantitative patient survey. The findings of this study demonstrate how crucial it is for patients to be involved in the process and have some say in how it progresses. The mobile app's wiki pages on ACL clinical pathologies and rehabilitation procedures, a discussion board for users to share information on, and routine surveys of subjective self-assessment in the form of standardized questionnaires can all be used to achieve this. These patient-reported outcome measures are suggested for integration in a telemonitoring system: the VAS scale for pain perception, the IKDC questionnaire for functional assessment, and the TSK to quantify kinesiophobia. The results of the survey are primarily applicable to this target group because all of the respondents ruptured their ACL while playing sports. It should be noted that this target population accounts for the majority of specific injuries and, in particular, the ACLR surgery and subsequent rehabilitation.

The most crucial features of the sensors that have been created and are currently being used in scientific research projects. Thigh circumference measurements, MEMS-based accelerometers for recording patient activity, measuring the circumference of the thigh with a strain-active sensor, measuring skin temperature with textile integrated Resistance Temperature Detector (RTD) sensors in a knee brace, and calculating the angles in the joint axis of the knee have all been highlighted as meeting the needs of those who were interviewed. Additionally, it has been noted that thigh circumference measurements satisfied the needs of the interviewees. As a result, it is possible to suggest these sensors as suitable parts for further investigation into this subject.

This research will serve as a foundation for future research and development of systems that, in the event that they are able to fulfill the requirements that have been outlined, will serve a use case and have a market target group. It is a repository for scientific data. Research is another possible application for it. The framework for product management can be found here. The intended viewers have been chosen.

a use case that is easy to understand In addition to that, both the functional and technical requirements are specified. The next step is the creation of the product.
This research has a variety of potential applications. It is the basis for the research and development of systems that, if they satisfy the stated requirements, serve a use case and have a market target group. It refers to a database that can be utilized for additional scientific investigation. Additionally, it can serve as a resource for future scientific investigation. This is the phase in which the foundation for product management is laid. The chosen target demographic has been determined. The use case is presented in a manner that is easily understood. In addition, detailed functional and technical specifications are provided. The next step in the process is the creation of the actual product.
The experts have not identified a specific user demographic for the system. Rather, it is of interest to all ACLR patients who possess a certain level of interest. Thus, it is possible to produce valuable data for comparing different groups and healing processes of various surgical methods. Due to the fact that vigorous sports activities are the leading cause of injury, the majority of patients are young and athletic. The specialists believe these patients to be more tech-savvy. Even though they are not considered to be problematic patients, their interest in data is typically a useful factor. Anxiety patients are mentioned as a potential target population in Physio 3, as understanding and monitoring the motions done can offer them with comfort. A physiotherapist responded, ”The overconfident patients who want to move through as soon as possible, but who can be slowed down by this” in response to the question of whether he had a specific, particularly suitable target group in mind. Experts' opinions about the appropriate usage of the system range between the first four postoperative weeks and at the earliest the sixth week postoperatively. Physicians Some also find the method effective following conventional physiotherapy, 3-6 months to one year after surgery, to complement exercise treatment.

55 individuals participated in the survey. A little more than half of responders (56%) are male, and more than two-thirds (69%) were between the ages of 20 and 40 when their cruciate ligament ruptured. All of the participants currently reside in Germany (78%) and Austria (22 percent). When asked in what situation the cruciate ligament rupture occurred, all participants (100%) cited athletics as the cause of the injury. Participants were questioned regarding their concurrent and secondary injuries. Two-thirds of the population had not sustained such injuries. On the other hand, 18 of the 55 participants responded affirmatively to the question of whether they had had any secondary or concurrent injuries in addition to the ACL injury. The most common subsequent injury (56 percent of the 18 people with a subsequent or concurrent injury) was an ACL rupture or an ACL rupture in the opposite leg. Six patients reported injuries to other structures in the same knee, while one individual reported injuries to the opposite knee. One person in the over-40 age group at the time of injury was also diagnosed with knee osteoarthritis. Six people reported injuries to other structures in the same knee, while one person reported harm to the other knee. One person in the age group older than 40 at the time of their ACL damage was subsequently diagnosed with knee osteoarthritis.

The majority of patients aim to return to sports. In this context, regaining athletic performance at the same level as before the injury is almost as important as being able to play sports without pain. Being able to perform everyday activities (14%) and work (12%) without restrictions is not the primary goal for the majority. Patients were asked how well they felt cared for during the rehabilitation process and what could have been done better. Seventeen percent of respondents are unhappy with the rehabilitation services they received. The following are improvement ideas from all respondents, including those who felt well supported: Adaption of the training plan to the person and their life situation (in terms of age, and basic fitness); A higher intensity, individual training plan, adjusted to the patient's level of progress; More individual and intensive care and not being left alone in the treatment too early; Integration of the patient into the treatment and the possibility to participate proactively; Better communication between patient, physiotherapist, and physician; Longer rehabilitation period; Higher frequency of appointments for training, control, and receiving feedback; Obligatory follow-up training; Coverage by health insurance companies of more appointments; Education about the injury and rehabilitation procedures; Targeted performance testing as a completion for particular phases.

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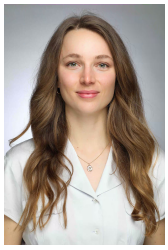

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