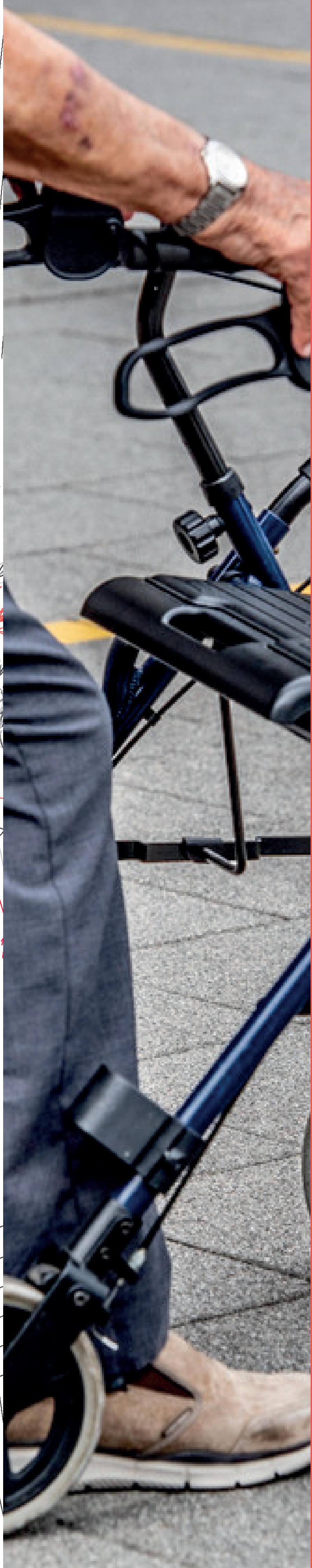

BACHELOR THESIS

TECHNICAL MEDICINE

CONTINUOUS MONITORING OF FUNCTIONAL RECOVERY OF FRAIL ELDERLY PEOPLE AFTER TREATMENT OF A HIP FRACTURE, MAKING USE OF THE DATA OF THE MONITOR DEVICES 'FITBIT CHARGE HR AND MOX' IN ORDER TO OPTIMISE THE REHABILITATION PROCESS

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UNIVERSITY OF TWENTE
FACULTY OF SCIENCE AND TECHNOLOGY
BACHELOR TECHNICAL MEDICINE

ZIEKENHUISGROEP TWENTE
PROJECT 'UP AND GO NA EEN HEUPFRACTUUR'
SAMENWERKING ZORGT VOOR KWALITEITSSLAG

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Abstract

Background In the Netherlands, each year, 17,000 people are hospitalised after a hip fracture. Almost one out of three hip fracture patients deceases within the first year after surgery. This mortality rate could be decreased by improving the rehabilitation process. Nowadays, the rehabilitation process of elderly hip fracture patients is monitored by clinimetric tests, but continuous monitoring could be a valuable addition. The purpose of this study is to determine how the monitor devices Fitbit Charge HR and MOX can be used to continuously monitor functional recovery of frail elderly hip patients to optimise the rehabilitation process.

Methods Qualitative research is set up to determine the definition of functional recovery and to compose parameters that are useful for continuous monitoring of functional recovery of elderly hip patients. This qualitative research consists of literature research and conducted interviews on healthcare specialists and patients. Additionally, a quantitative research was set up. This consisted of an experiment, in order to determine whether the formulated parameters can actually be measured by the monitor devices. A *GERonTologic simulator (GERT)*, an age simulation suit, was used in order to evaluate whether progress in rehabilitation of functional recovery can be monitored.

Results The parameters that can be measured by the monitor devices Fitbit Charge HR and MOX, are: number of steps, heart rate, classification and intensity of activities. When the subject was walking with a walker, the Fitbit attached to the wrist showed a very low correlation and the Fitbit attached to the ankle a high correlation between the counted steps of the observer and the counted steps by the Fitbit. Within most subjects, when wearing GERT, the heart rate increased while the intensity of the performed activity maintained approximately the same value. The increased heart rate was higher in 15 of the 24 cases for 'with GERT' than 'without GERT' during walking, with a mean rank of 13.17. When a patient was doing activities of daily living, the increased heart rate was higher 'with GERT' than 'without GERT', in 11 of the 15 cases, with a mean rank of 7.95.

Discussion Safety and independence, mobility, balance and resilience are important parameters which were not evaluated in this study, due to the restrictions of technology specifications of the monitor devices. For this reason the definition of functional recovery formulated in this study, does not cover the entire content. As young healthy subjects were included, GERT was used in order to simulate a not functionally recovered elderly patient, by increasing the fatigue. However, the included subjects obviously differed from frail elderly patients with a hip fracture, due to the fact that the included parameters can be affected by aging. Besides this, the study population was very small. Results showed a difference between 'with GERT' in comparison to 'without GERT' in heart rate increase for relatively equal intensities. Despite this, further research needs to be done to apply this for continuously monitoring of elderly people.

Conclusion Functional recovery is returning to the premorbid living situation by achieving a safe and independent performance of their personal targets of physical functioning, with a low fatigability. The parameter heart rate increase is promising in continuously monitoring functional recovery of elderly hip fracture patients, and is therefore a useful parameter for further research. Also, the measured number of steps and intensities can give an indication of functional recovery, by gaining more insight into the active minutes of a patient. To conclude, a combination of the Fitbit Charge HR and the MOX is recommended to continuously monitor functional recovery of a hip fracture patient during the rehabilitation process.

Contents

1 Introduction

Fall-induced injuries, especially hip fractures, in persons aged 65 years and older are a major public health problem. Each year in the Netherlands, 17,000 people[1] are hospitalised because of a hip fracture. This incidence is expected to increase in the coming years, due to the aging population and increasing frailty.[2–4] In the Netherlands, approximately 85% of all hip fracture patients[5] has an age of 65 years or older, of which nearly 70%[5] is female. Approximately one third of the patients is characterised with comorbidities,[4] polypharmacy,[6] low body mass index,[3] malnutrition[3] or frequent falling.[3] These factors cause elderly hip fracture patients to be more frail in comparison to elderly people without a hip fracture. Frailty[3,6] is a geriatric condition that describes a decrease in physiological reserves and organ functioning and causes therefore an increased risk of complications, hospitalisation and mortality. Mortality rates of elderly people who underwent surgery for a hip fracture are tremendously high. On average, almost one out of three[7,8] hip fracture patients deceases within the first year after surgery. After surgery, patients will endure an intensive rehabilitation process in order to functionally recover and possibly return to their premorbid living situation. However, one year after hip fracture treatment, 20% to 90% of the elderly people still experience disabilities[1] in activities of daily living (ADL), which is defined as functional decline. In order to improve functionality after a hip fracture, it is important to get more insight into the functional recovery during the rehabilitation process.

In order to optimise the rehabilitation process of elderly hip fracture patients, the "Up&Go after a hip fracture" project was set up by Ziekenhuisgroep Twente (ZGT). This project has provided a multidisciplinary care path that monitors the rehabilitation process of a patient at fixed moments by clinimetric tests. Clinimetric tests[9] are a collection of tests to assess physical functioning, mobility, adverse events, and cognitive impairment of elderly people. These tests give an indication of a patient's progress during the rehabilitation process. However, these tests are static, administered in a low frequency and can be influenced by all kinds of circumstances. To gain a more reliable impression into the general situation of a patient and progress during the rehabilitation process, continuous monitoring could be an addition.

Therefore, the purpose of this study is to examine the ability to continuously monitor functional recovery of hip fracture patients during their rehabilitation process by making use of ambulatory monitor devices. The monitor devices involved in this study, are the Fitbit Charge HR, Fitbit Zip and MOX. These devices gain insight into the activity pattern of elderly people. For example, both Fitbits[10,11] give the number of steps taken and the MOX[12] gives information about daily activities and distinguishes different movements by intensity and classification of activities. Additionally, the Fitbit Charge HR[10] has the ability to measure heart rate.

Although, the three monitor devices can give insight into the activity pattern of elderly people, this information cannot directly be related to the functional recovery of patients yet. Therefore, the purpose of this study is to give an answer to the main question which is formulated as follows: "How can the data of monitor devices Fitbit Charge HR, Fitbit Zip and MOX, be used for continuous monitoring of functional recovery in order to optimise the rehabilitation process of frail elderly people after treatment of a hip fracture?".

To answer the main question, both qualitative and quantitative research are done. Firstly, qualitative research is done to define functional recovery and to formulate useful parameters for continuous monitoring of functional recovery. This is done by literature research and conducting interviews on patients and healthcare specialists. Secondly, quantitative research is done in order to indicate whether the monitor devices are able to measure the formulated parameters during an experiment on healthy subjects. In the end, a proposition is given about the possible implementation of the monitor devices to continuously monitor functional recovery of hip fracture patients.

2 Research purpose

In this study it is evaluated how functional recovery can be continuously monitored by the monitor devices: Fitbit Charge HR, Fitbit Zip and the MOX. This is done by giving answer to the main question and several sub questions, which are formulated in *Figure 1* below.

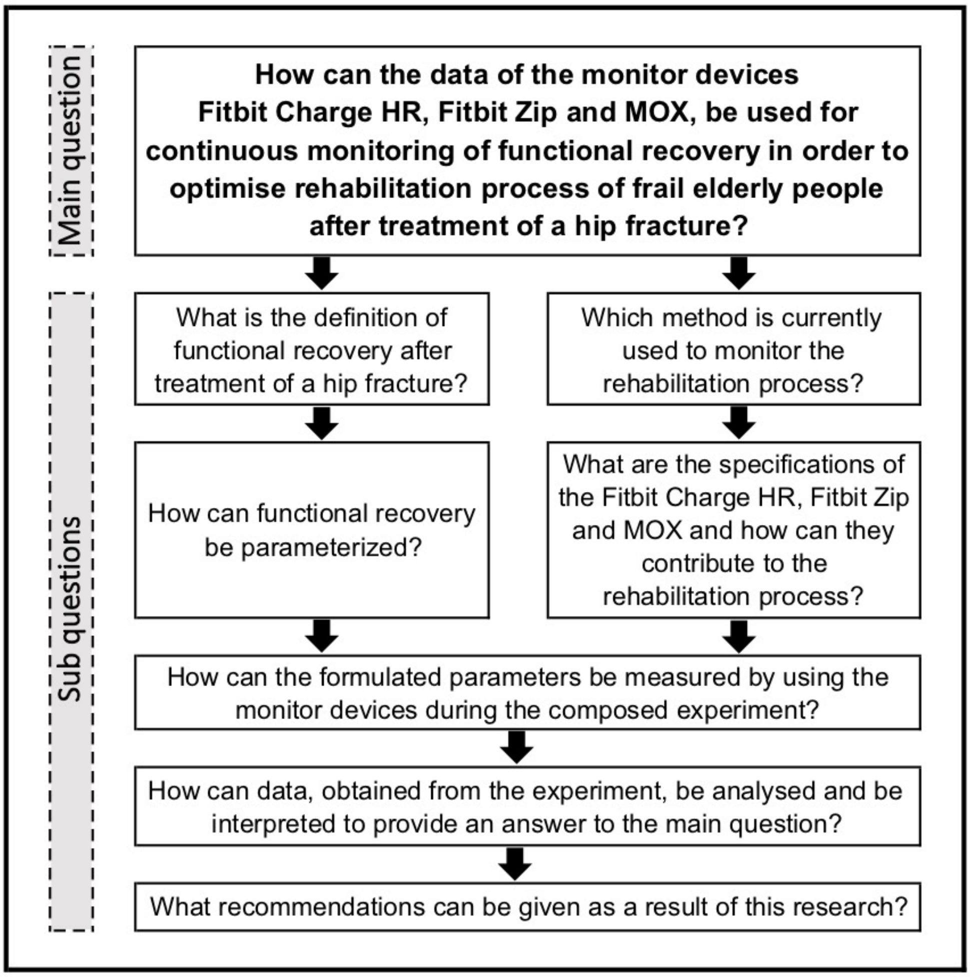


Figure 1: *Flowchart of the main and sub questions in this study*

Hypothesis

It is hypothesised that the definition of functional recovery varies for every hip fracture patient. A patient is probably functionally recovered[13] when he/she is able to return to his/her premorbid living situation. As each living situation is different, every patient has their own wishes and targets to achieve within the rehabilitation process.

Concerning the specifications of the monitor devices, it is hypothesised that heart rate, active minutes per day and classification and intensity of activity are the most useful parameters for continuous monitoring of functional recovery. Heart rate in combination with the classification or intensity of an activity, probably says something about functional recovery of a patient. Unfortunately, none of the monitor devices is able to measure all of the above mentioned parameters. Therefore it is hypothesised that the most optimal way to continuously monitor functional recovery is by combining the three monitor devices:

- **Heart rate** can only be monitored by the Fitbit Charge HR;
- **Classification and intensity of activity** can only be monitored by the use of the MOX;
- **Active minutes per day** can be determined by evaluating the data of the MOX, Fitbit Zip and Fitbit Charge HR.

3 Background

3.1 Anatomy of the hip joint

The hip joint is a ball and socket joint[14] and forms the connection between the free lower limb and the pelvic girdle, which are the two functional components of the lower limb. The pelvic girdle consists of the os coxae, which is ventrally connected by the pubis symphysis and dorsally connected by the os sacrum. The os coxae, also known as the major hip bone, consists of three parts: os ilium, os ischium and os pubis. These three primary bones are separated by a Y-shaped triradiate hyaline cartilage which forms the location of the fusion of the os ilium, os ischium and os sacrum, which subsequently forms the acetabulum (see *Figure 2A*).

The acetabulum[14] is a hemispherical hollow located at the lateral part of the os coxis and forms the socket of the multiaxial ball and socket hip joint. The height of the acetabular rim results in a spacious cavity for the head of the femur, which is the ball of the synovial ball and socket joint. The head of the femur consists of approximately two thirds of a sphere and is, except for the fovea, entirely covered by cartilage.

The artery that provides blood[15] to the hip joint is the external iliac artery which branches into the lateral and medial circumflex femoral arteries. Subsequently, the lateral and medial circumflex femoral arteries (see *Figure 2B*) branches into the retinacular arteries, which are the major arteries for blood supply of the head of the femur. The artery to the head of the femur traverses the ligament of the head and is a branch of the obturator artery. The vein for blood drainage of the femur is the femoral vein.

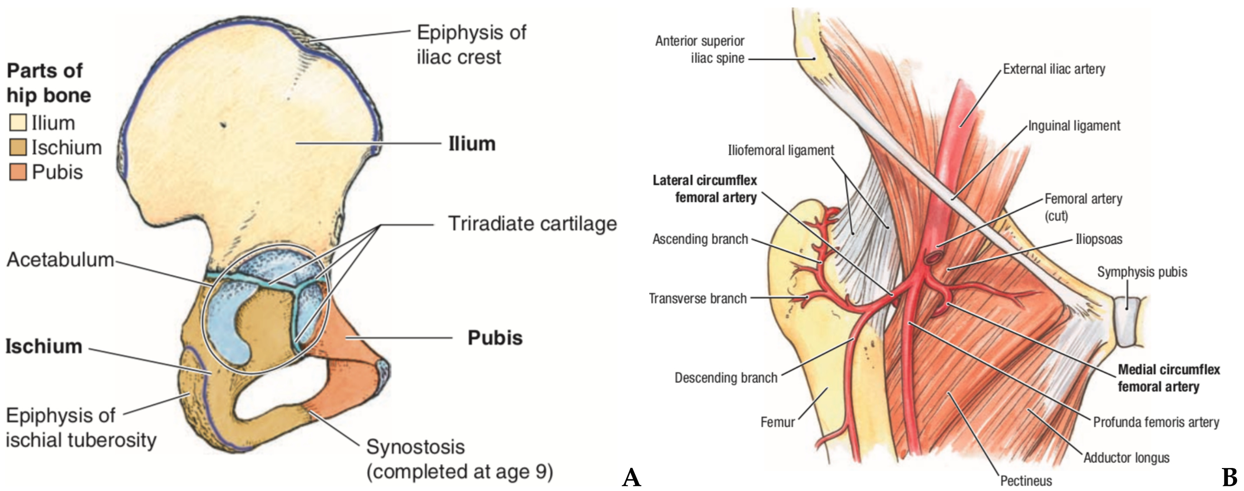


Figure 2: *A: Anterior view of the hip bone.*[15] ***B****: Medial and lateral circumflex femoral arteries.*[15]

3.2 Physiology of the hip joint

The main function[16] of the hip joint is providing stability over a wide range of movement. Besides the gleno-humeral joint, the hip joint is the most movable joint[17] in the human body. The entire weight[17] of the upper body is transmitted through the os coxae to the femur. The synovial ball and socket joint allows the hip to move in a tremendous range of movements, such as flexion/extension, circumduction, abduction/adduction and medial/lateral rotation. Each movement[17] is a result of a contraction or relaxation of the muscles on either side of the hip joint.

3.3 Pathophysiology of the hip joint

Obtaining a hip fracture can be the result of a decline in bone mineral density (BMD). BMD is related to loss of estrogens[18] and testosterone.[19] These hormones are the key regulators of bone metabolism[18–20] because of their effects[21] on osteocytes, osteoclasts and osteoblasts. A loss of estrogen and testosterone causes a decline in BMD[18] and subsequently, may result in a hip fracture. Because of the menopause and the accompanying loss of ovarian estrogens, the high number of women[5] with a hip fracture can be explained.

3.4 Treatments

Regarding hip fracture treatment, four surgeries are possible. From a surgical perspective,[22] there are certain special considerations in this population including the type of fracture, osteoporosis, pre-existing arthritis, age, activity level, and overall health that contribute to the type of surgical fixation performed. Hip fractures can be divided into two types of fractures: an intracapsular fracture, also known as a collum femoris fracture, and an extracapsular fracture. Extracapsular fractures[23] can be subdivided into a trochanteric fracture and a subtrochanteric fracture.

The following treatments[24] are provided in ZGT Almelo (see *Figure 3*):

- Hemi-athroplasty: The femoral head is replaced by a prosthesis;
- Multiple screws: Placed in the femoral neck;
- Dynamic Hip Screw[25] (DHS): Using a screw, held in place by a metal plate, in the femoral neck;
- Proximal Femoral Nail Antirotation[26] (PFNa): Using a PFNa nail and a blade, the femoral head is retained.

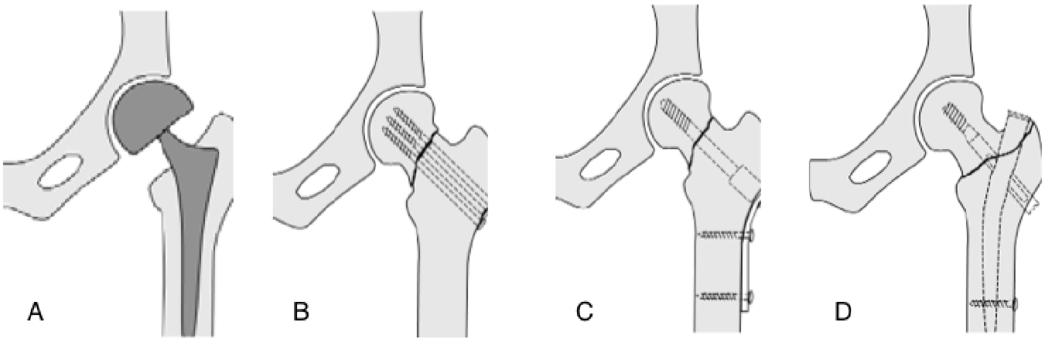


Figure 3: *Possible surgeries[24] for a hip fracture.*
A*: Hemi-athroplasty* ***B****: Screws* ***C****: DHS* ***D****: PFNa*

In case of a hip fracture, the following postoperative complications[27] can occur: delirium, anemia, CAUTIs, pneumonia. In principle, a re-intervention[28] rarely takes place, unless an infection occurs or if the head of the femur collapses after a complete prosthesis.

3.5 State-of-the-Art of the rehabilitation process

After treatment, it is important to monitor the rehabilitation process of a specific patient. By gaining more insight into a patient's progress, better feedback can be given to enable the patient to return to his/her premorbid living situation.[29] This insight is currently obtained by conducting clinimetric tests.[9] The created timeline of these clinimetric tests is a part of the Up&Go Project, in order to evaluate the patient's progress on fixed moments.

Up&Go Project

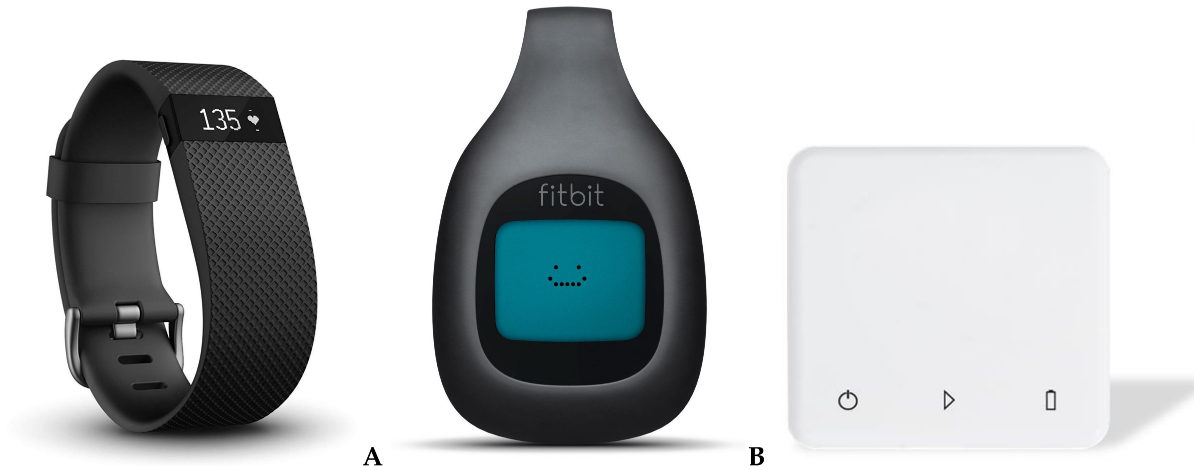
Current developments in improving the rehabilitation process are made in the "Up&Go after a hip fracture" project[30] which is set up by ZGT, various nursing homes and the University of Twente. The purpose of the "Up & Go after a hip fracture" project[30] is to improve healthcare for elderly people after a hip fracture by optimising their rehabilitation process. The institutions participating in this project have provided a multidisciplinary care path that monitors the rehabilitation process of a hip fracture patient on fixed moments by established clinimetric tests.

Clinimetric tests

Diverse clinimetric tests[9] are performed by healthcare specialists and measure a variety of parameters linked to functional recovery of a patient. Clinimetric tests are performed at fixed moments during the rehabilitation process, to provide healthcare specialists more insight into a patients' progress or decline. Clinimetric tests are able to gain insight into physical functioning, nutrition, cognition and comorbidity. For example, parameters for physical function, like balancing, sitting to standing, gait and gait speed can be measured by the 'Time Up and Go test' and the '10 Meter Walk Test'. A list of all clinimetric tests with their purposes and parameters can be found in *Appendix A: Clinimetric tests*.

3.6 Technology specifications

In this study the monitor devices, Fitbit Charge HR, Fitbit Zip and MOX (see *Figure 4*), are intended to use to track activity of a person. Both Fitbits have the ability to track the activity by counting the number of steps. The MOX tracks the activity by measuring the intensity and classification of activities.



A B C

Figure 4: *Monitor devices.*
***A**: Fitbit Charge HR*[31] ***B**: Fitbit Zip*[32] ***C**: MOX*[33]

General Fitbit

The Fitbit[34] uses a 3-axis accelerometer to understand the movements of a person. When the accelerometer is attached to the body, the device will turn acceleration into data. To determine the steps taken, distance traveled and calories burned, the device provides information about frequency, duration and patterns of movement.

An algorithm for step counting is used in the Fitbit devices.[34] This algorithm is designed for measuring movements by using a threshold. When the motion and its subsequent acceleration measurement meets the threshold, the movement can be counted as a step. The walking distance is measured through the Fitbit by multiplying the number of steps by the stride length of the person. The Fitbit estimates the stride length of a person by using his/hers height and sex, and estimates the calories burned by using age, sex, height and weight of a person.

Fitbit Charge HR

The Fitbit Charge HR,[35] which is attached to the wrist, has a battery life of approximately five days and is sweat, rain and splash proof. However, the device is not water-resistant during swimming or showering.

The Fitbit Charge HR[10] is able to track the following data:

- Number of steps;
- Current heart rate;
- Floors climbed;
- Calories burned;
- Distance covered;
- Active minutes;
- Detailed heart rate history;
- Time and quality of sleep (quality is based on the movement during sleep).

The Fitbit Charge HR stores detailed minute-by-minute data for the past seven days and daily summaries for the past thirty days. The heart rate can be divided into four heart rate zones according to the default settings of the Fitbit. In order to make a personal division of this heart rate zone, the personal maximum heart rate (HR_{max}) is calculated. This is done by the most widely used formula:[36] $HR_{max} = 220 - [age]_{patient}$.

The heart rate zones[10] are stated as follows:

- **Zone 1** The heart rate is 50% below the HR_{max}. The assumption will be that the patient is in rest;
- **Zone 2** The heart rate is between 50% and 69% of the HR_{max}. The assumption will be that the patient is exercising on a low-to-medium intensity;
- **Zone 3** The heart rate is between 70% and 84% of the HR_{max}. The assumption will be that the patient is exercising on a medium-to-high intensity;
- **Zone 4** The heart rate is 84% or higher of the HR_{max}. The assumption will be that the patient is exercising at high intensity.

The number of climbed floors[10] is counted by an altimeter because it has the ability to detect elevation. The Fitbit Charge HR registers three meters of elevation as climbing one floor. However, it does not register when the person is going down one floor.

Fitbit Zip

The Fitbit Zip Wireless Activity Tracker[11] contains a clip which makes sure that it can be easily attached to a shirt, pocket, bra, pants, belt or waistband. The Fitbit Zip is able to track the following data:

- Number of steps;
- Traveled distance;
- Calories burned.

The Fitbit Zip[11] has a battery life of approximately six months and is sweat, rain and splash resistant, however it is not waterproof. It stores data minute-by-minute for seven days and creates daily summaries for thirty days.

MOX

The MOX[12] has the ability to measure the level of physical activity and posture movement accurately during activities of daily living. The MOX[12] can be attached to several places on the body (waist, pockets, thigh, bra, lower back etc.), is waterproof and has a battery life of seven days or more. Additionally, the device does not have buttons and only displays LEDs indicating the status of the device. The internal memory of the MOX is 2GB, which leads to a data storage of a maximum of two weeks. The data output of the MOX device is raw accelerometer data in the $x-, y-$ and $z-axis$, which can be transmitted to a user interface: *IDEEQ 2.0 Data Acquisition Platform*. This user interface converts the raw data by algorithms into activity intensity (counts per second) and classification of activity.

This activity[12] can be classified in:

- Sedentary activity (laying down and sitting);
- Standing activity;
- Low, medium and vigorous physical activity (LPA, MPA, VPA).

4 Method

The purpose of this study is testing whether the monitor devices are able to continuously monitor functional recovery of a hip fracture patient. At first, functional recovery needed to be defined and parameterized. Secondly, the ability of the monitor devices to measure functional recovery was tested. Therefore, a mixed method involving qualitative and quantitative research was used. Qualitative research was executed through literature research and conducting interviews to define and parameterize functional recovery. Subsequently, to test the ability of the monitor devices to measure functional recovery, quantitative research was executed by performing an experiment on healthy subjects.

4.1 Method of literature research

Literature research was done to delve into the definition of functional recovery. In addition, parameters which characterise functional recovery, were set up. Since, functional recovery has a definition with multiple meanings, many different parameters are related. Only the parameters which can be continuously monitored by at least one of the three monitor devices, were included in this study.

During literature research, the following databases were used:

- *Scopus*;
- *PubMed*;
- *Google Scholar*.

4.2 Method of interviews

To complete the definition of functional recovery, interviews were conducted on healthcare specialists and patients. Besides that, there were two other reasons for conducting interviews during this study. At first, it was intended to provide an overview of the rehabilitation process from the perspective of patients and healthcare specialists. Secondly, the interviews were used to clarify the targets a patient wants to achieve during their rehabilitation process.

The interviews were conducted on:

- 3 physiotherapists;
- 5 patients;
- 1 (trauma) surgeon;
- 1 nurse practitioner.

This population consists of stakeholders who were all involved in the rehabilitation process of hip fracture patients in a different way. Therefore, it was possible to draw a conclusion based on various opinions.

Questions for the interviews on patients and healthcare specialists were composed separately to gain information from different perspectives. As the interviews were conducted in Dutch, questions are written in Dutch. Composed questions for patients and healthcare specialists can be found in *Appendix B: Composed questions for the interviews*.

4.3 Method of experiment

An experiment was set up to determine whether the monitor devices are able to continuously monitor functional recovery, which is defined by literature research and interviews. Therefore, subjects were intended to wear three monitor devices during the experiment: the Fitbit Charge HR, Fitbit Zip and MOX. However, the Fitbit Zip was not available during the execution of the experiment. Instead of the Fitbit Zip, an extra Fitbit Charge HR attached to the ankle was included because this Fitbit may show other results compared to the Fitbit attached to the wrist.

Each measurement took place within approximately two hours per subject. The population consisted of eight subjects, four men and four women. As elderly people are a frail population, it was decided to not include them into this experiment. Therefore, students of the *University of Twente* and *Hogeschool Saxion* were included. The exclusion criteria for the participants were heart diseases, knee-, ankle- and hip problems. Every participant had an age between 20 and 25 years old. Only if the subject had signed an informed consent prior to the experiment, he/she was allowed to participate in the study.

In this experiment the group of subjects who performed the activities, consisted of young subjects. In order to be able to simulate the population of elderly people an GERonTologic simulator[37] (GERT) was used, also known as an age simulation suit (see *Figure 5*).

Figure 5: *GERonTologic simulation (GERT)[37] offers the opportunity to younger people to experience the impairments of elderly people.*

GERT integrates different components to limit movement,[38] create joint stiffness[37] and loss of strength.[37] This creates similar effects to the restrictions experienced by the elderly people. Components of the GERT suit are divided into modules:[38] torso, arm, leg and head modules. The torso module consists of a weight vest, which reduces mobility in the pelvis and spine, increases physical load and affects stability. Adding weight to the torso, affects breathing of the subject, which will lead to earlier fatigue. The arm module consists of elbow wraps and weight cuffs around the wrists, which limits movement of shoulder, elbow and wrist. The leg module consists of knee wraps and weight cuffs around the ankle. This module restricts movement and adds forces to the hip, knee and ankle joints, which will install fatigue. The head module consists of goggles, hearing protection and a cervical collar. Since this module affects the sensory capacities of a patient, which do not say something about functional recovery of a hip fracture patient, the subjects in this study did not wear this module.

The purpose of the experiment is to define whether progress in rehabilitation of a patient can be monitored. As functional recovery of elderly people probably goes very slowly, it may be more difficult to identify this. To simulate greater differences in functional recovery, this study makes use of two extremes. These extremes were defined as a 'fit patient' and a 'non-fit patient'. In this study, a 'non-fit patient' can be seen as a patient that is not completely functionally recovered and a 'fit patient' can be seen as a patient who is completely functionally recovered. The subjects performed all activities twice. Firstly, they performed the activities as a 'fit patient' without wearing GERT and secondly, they performed the activities as a 'non-fit patient' by wearing GERT.

5 Results

5.1 Results of literature research

In literature, functional recovery[13] is defined as "recovering the loss of function due to acute illness and iatrogenic complications of hospitalisation". However, literature research has shown that multiple factors influence the functional recovery of a patient, and therefore the definition. Factors such as mobility, external and internal load, perceived exertion and fatigue, help determine the definition of functional recovery of hip fracture patients.

Mobility

Mobility[39] is defined as the ability to move safely and independently. It is therefore a fundamental part for patients to participate[40] in the community by means of physical and mental functioning. Mobility recovery[41] of a hip fracture patient is challenging, because surgery and hospitalisation lead to dramatic decline in muscle power on the side of the fracture. This is associated[42] with poor standing balance, slower gait speed and increased risk for fall-induced injuries.

Most common mobility functions,[43] like walking independently (with or without walker), are executed within the first few months after discharge from hospital. However, the more challenging mobility functions[43] require a recovery period of up to one year after discharge. The more challenging mobility functions, for example climbing stairs, require more strength and balance than common functions. During rehabilitation, mobility is currently measured by various clinimetric tests,[9] for example FMS, FAC, TUG and 10MWT, as mentioned in the state-of-the-art.

Perceived exertion

Perceived exertion[44] is defined as "subjective intensity of effort, strain, discomfort, and/or fatigue that is experienced during physical exercise". It is also known as the perception of effort or sense of effort. Perceived exertion plays a crucial role in endurance performance, rehabilitation and human behaviour.

Perceived exertion[44] is a powerful tool to prescribe and monitor exercise during a rehabilitation programme. It[44] can be measured by use of the psychophysical scales, such as the 'Borg Rating of Perceived Exertion (RPE) scale'. Borg's RPE[45] can be seen as a valid and inexpensive tool for monitoring intensity experienced by a patient during exercise. Research has shown that Borg's RPE strongly correlates with the heart rate.[45] A disadvantage of the Borg's RPE is that it is a subjective test that cannot be continuously monitored by monitor devices, however heart rate can be measured.

Perceived exertion[44] is used to control and monitor internal training load (ITL). ITL is the relative physiological and psychological stress imposed. Barely any research has been done into training load in elderly people, however research[46] in athletes has been done. This research describes the terms external and internal training load in order to explain perceived exertion. Whenever a specific amount of external training load (ETL) is exposed to athletes, the ETL may be the same for every athlete, while the ITL is different for every one of them.[46] This will probably be the same in hip fracture patients. The rehabilitation exercises, the ETL, that a patient needs to perform, can cause a different ITL for every patient. Progress in perceived exertion may be a sign of progress in the rehabilitation process. The most commonly used methods[47] to monitor ITL are estimations based on heart rate. Therefore, it is important to measure heart rate to gain insight into the perceived exertion and ITL.

Fatigue

Perceived exertion[44] is exacerbated in the presence of physical fatigue or mental fatigue. Fatigue[48] is a complex phenomenon with a variety of definitions, often dependent upon the population under which they occur. One of the most common definitions[49,50] of fatigue was proposed by Edwards, and states that fatigue is a "failure to maintain the required or expected force (or power output)". Fatigue is associated with mortality[51] and is a reason[52] for patients to not achieve an independent basic mobility level, therefore they are not able to functionally recover. Other factors[53] that can affect fatigue are the intensity and duration/frequency of an exercise.

In addition to fatigue, fatigability is also correlated to functional recovery. Fatigability[54] is a characteristic of an individual which describes how fatigued he or she feels when performing activities. Fatigability[54] is correlated with physical activity, physical function deficits and self-reported fatigue. Fatigability[55] could be a result from an increased energy cost of daily activities which causes a reduction in reserve energy capacity. A reduced energy capacity means that elderly people need to expend a greater proportion of their maximum energy for daily activities and life support. Walking is a common daily activity for elderly people. Elderly with gait dysfunctions, for example a hip fracture, expends greater effort on performing daily activities than elderly without gait dysfunctions. Therefore, elderely with a hip fracture are more likely to perceive fatigability. Furthermore, studies[54,56,57] are beginning to show that a person with a higher level of fatigability, has a worse physical function. Both the fatigue and fatigability exacerbate a patient's perceived exertion.[44]

5.2 Results of interviews

All conducted interviews including the answers, can be found in *Appendix C: Questions answered by healthcare specialists and patients*.

During the interviews[28,58,59] came forward that every patient has his/her own personal targets to achieve during the rehabilitation process. The vision of healthcare specialists and patients on targets of physical functioning that patients want to achieve during the rehabilitation process, is relatively the same. It was decided to divide these targets into common, less common and least common targets which can be found in *Table 1* below. In addition, during an interview[28] with Dr. J.H. Hegeman and Dr. E. Folbert, they mentioned the definition of functional recovery as a patient's mobility based on his/her targets.

Common targets	**Less common targets**	**Least often targets**
Returning home	Riding a bycicle	Driving a car
Independently going:	Stair climbing	Deep sea diving
- to the toilet;	Walking long distances (outside)	
- outside;	Doing groceries	
- to bed;		
Changing clothes		
Walking short distances (outside)		

Table 1: *Patients' targets to achieve, according to the interviews.*

According to healthcare specialists,[59,60] it is good to gain insight into how and whether patients perform the exercises when not being in one of the physiotherapy appointments. They think this is important because during these appointments, patients try as hard as they can, while there is a possibility that the patient will sit on a chair for the rest of the day. This means that there is a chance that the physiotherapy appointment is the only moment of the day where they are physically active. In addition, for some patients it is difficult to put in words how they experience the therapy sessions and what they do during the rest of the day. This is due to the fact that they are cognitively impaired.[28,60] Concluding, when only these physiotherapy appointments are used to evaluate the patient's ability of performing physical activity, a misleading conclusion about the patient's functioning, and therefore progress in rehabilitation, can be drawn. According to the healthcare specialists, better feedback about exercises and a patient's progress in rehabilitation can be given through continuous monitoring.

During interviews[28,58] patients indicated that they are afraid of falling again after the hip fracture. This fear probably results in a changing gait and less walking. Hence, the improvement of balance plays a fundamental role during the rehabilitation process.

During interviews,[59] physiotherapists also indicated that patients can only go home when they are able to perform their daily activities independent and safe. The TUG,[9] as mentioned in clinimetric tests, is a test to evaluate independent and safe walking and sit-to-stand and stand-to-sit transfers. This test, which is based on a patient's gait and balance,[61] is currently used to confirm that patients can actually perform their daily activities in an independent and safe way. The safety and independence of performing an activity by a hip fracture patient is thus very important according to physiotherapists.

5.3 Results of experiment

Utilising the results of literature research and interviews, the experiment can be set up in detail. First, the final definition of functional recovery is given. Second, this definition is parameterized. In the *Section 5.3.1 Parameters* the defined parameters and how they can be used for continuous monitoring are discussed in detail. Subsequently, the measurement protocol has been elaborated and the test phase is set up. Thereafter, the data analysis describes how the data from the experiment is analysed.

According to the results of literature research and interviews, the following conclusion about the definition of functional recovery can be drawn:

"Functional recovery of a hip fracture patient is returning to the premorbid living situation by achieving a safe and independent performance of their personal targets of physical functioning, with a low fatigability".

5.3.1 Parameters

Because of the definition of functional recovery, the following parameters are measured in order to be able to monitor functional recovery of a hip fracture patient:

- Heart rate;
- Active minutes and classification of activities;
- Intensity of activities;
- Number of steps.

Heart rate

Heart rate[47] is a measure of physiological response. Resting heart rate has been promoted as a marker for fatigue. An increase[62] in heart rate is associated with increased physical activity and a decrease[62] is associated with recovery. Heart rate recovery[63] is an indirect marker of the autonomic functioning. Changes[63] in heart rate, on the other hand, may offer a practical way of quantifying physiological effects of exercise.

The measured heart rate of the included subjects can say something about the perceived exertion of a patient.[64,65] Currently, perceived exertion is measured by Borg's RPE,[45] as mentioned in results of literature research. However, research[45] has shown that Borg's RPE strongly correlates with heart rate. Perceived exertion is, therefore, in this study measured by monitoring heart rate by use of the Fitbit Charge HR.

Active minutes and classification of activities

Research[66] has shown that active minutes of a patient are associated with enhancing functional recovery, increased muscle mass,[67] improved balance[68] and fewer falls.[69] Fear of falling is also associated with functional recovery and has therefore, a negative influence on the rehabilitation process. During the interviews[58] patients also indicated that they are afraid of falling again after the hip fracture which results[28] in a changing gait and less walking. Therefore, in order to improve the patient's recovery, more active minutes will lead to[41] an improved balance and fewer falls, which will subsequently improve functional recovery. To say whether functional recovery is achieved, it is useful to monitor progress in active minutes per day.

Research[70] has shown that extended physiotherapy (60 minutes per day and an unsupervised home program after discharge) reduces the chance of falling for elderly hip fracture patients by approximately 25%, in comparison to standard physiotherapy (30 minutes per day and no unsupervised home program). However, healthcare specialists[59,60] do not know if the patients are actually executing their home program. Hence, it is important for healthcare specialists to gain more insight into the activity of the patient and what kind of activities they do. By classifying the activities of the patient, the healthcare specialists gain more detailed information about the level of physical activities. During the experiment, it will be determined if the MOX displays the active minutes and classification of the activities correctly.

Intensity of activities

According to the World Health Organization:[71] "Intensity refers to the rate at which the activity is being performed or the magnitude of the effort required to perform an activity or exercise". Hence, the intensity of an activity describes the rate of performing the activity or exercise. Furthermore, after the treatment of the hip fracture, the patient has to do exercises[72] to be able to recover. Initially the patient has to perform exercises in bed, then perform these exercises in a chair, after that while standing and eventually while walking. So, the intensity of these exercises is increasing as long as the patient's functioning is increasing as well. These exercises are given by the physiotherapists and they determine the intensity of these exercises. Hence, a patient will be more functionally recovered when he/she is able to perform more intense activities during the rehabilitation process. The intensity of activities can be measured by the MOX and is given in counts per second (cps) or counts per minute (cpm).

Number of steps

In addition to gain insight in active minutes of the patients, it is also important to count the number of steps to say something about functional recovery. It is important for the patient to be active during the day, by walking for example. Not walking very often has adverse effects on the progress of the rehabilitation process of hip fracture patients. By monitoring the number of steps physiotherapists will be able to give patients specific feedback.

It is possible to encourage patients to perform more exercises by setting goals. For example, by agreeing with the patient that he/she must walk a certain number of steps per day. Unfortunately, healthcare specialists[60] have noticed that the number of steps of the Fitbit Charge HR is not equal to the patient's taken steps. An explanation for this is that the monitor attached to the wrist will not experience acceleration when the elderly people are walking with a walker. To determine if the Fitbit Charge HR is accurate when counting the number of steps, this parameter is tested during the experiment.

5.3.2 Measurement Protocol

As it is clear which parameters are able to monitor functional recovery continuously and which activities are important for patients, the measurement protocol can be set up.

The activities which are performed by the subjects, are based upon the common targets of the patients as mentioned in the results of interviews. The following activities are performed during the experiment:

1. **Walking**
   Walking is the most common target of all patients because this is the most important[40] exercise for a patient to be able to continue participating in and contributing to the community.
2. **Activities of daily living**
   After the rehabilitation process, most elderly people want to be able to live independently again.[59] Therefore, it is important for a patient to regain the ability of getting in and out of bed, going to the toilet and sitting and standing.
3. **Climbing stairs**
   Although stair climbing is not one of the most common targets, it is an activity that is more difficult for patients to perform during the rehabilitation process, because it requires more strength and balance.

To be able to perform these activities and to monitor the parameters, the following instruments are used:

- Fitbit Charge HR (2x, one attached to the wrist and one attached to the ankle);
- MOX (attached to the upper leg with a plaster);
- *IDEEQ 2.0 Data Acquisition Platform*;
- Walker;
- Crutches;
- Sweatpants;
- Bed;
- Chair;
- Stairs;
- Stopwatch;
- Tape measure;
- Journal;
- Age Simulation Suit (GERT).

To make the performed activities in the experiment more comparable to the situation of elderly people, a walker, crutches and a slow step frequency are used. During rehabilitation, the ITL, experienced by a hip fracture patient when performing a specific activity, will probably decrease over time when a patient is functionally recovering. To simulate progression during the rehabilitation process of a hip fracture patient, every subject performed the experiment with and without GERT. The use of GERT will raise the ETL[48] of the healthy subject, which means that the needed amount of labour performed by the subject is raised. This will probably lead to a higher perceived exertion and therefore a higher experienced ITL. Thus, GERT, which actually raises ETL, was added to this experiment to raise the ITL experienced by the healthy subject. This is done in order to simulate functional recovery of a hip fracture patient during the rehabilitation process.

Additionally, a number of things are important throughout the experiment:

- Data is reported in a journal by using several schedules. This makes it easier to find which activity is performed at what moment in the data of the monitor devices afterwards. These schedules can be found in *Appendix D: Schedules of the experiment*;
- Total time of execution of an activity is recorded by noting the local time at both the beginning and end. Local time is based on a global clock in the Netherlands. The reason of using the local time, is that the MOX and Fitbit Charge HR report all of the data at the same local time;
- It is important that the subject waits until the heart rate returns to less than 50% of the HR_{max} before an activity is repeated or a new activity is performed. This is called the recovered heart rate ($HR_{recovered}$) This made the heart rate data more comparable. This is done by having the subject sit on a chair after an activity and measure the heart rate by using the Fitbit Charge HR attached to the wrist;
- It is important to prevent too many influences on the measured parameters. One way to do this is to ensure that no one will talk, unless necessary, during the performance of an activity;
- To keep the experimental design equal for all subjects, the dominant wrist and leg is used to wear both Fitbits. Besides that, the MOX is applied to the dominant leg. The side of the leg with the MOX is defined as the nondisabled leg. This is applied to every subject.

Table 2 and 3 show the execution of the experiment in detail for all phases. Every subject performed this protocol twice. Initially, it was done without GERT and thereafter with GERT, as mentioned in method of experiment.

Phase	Parameters	Method to measure these parameters	Time (min)
1	Heart rate in rest	During phase 1: The person needs to sit down on a chair and a stopwatch is started. While sitting on a chair, the heart rate value needs to be closely monitored. After 2 minutes, the average heart rate will be calculated. This heart rate is assumed to be the resting heart rate. After phase 1: The persisted heart rate value is noted in the journal.	**6**
2 Gait	Duration of activity Heart rate (in rest, average during exercise and after exercise) Number of steps (observer and Fitbit wrist/ankle) Classification Intensity	Before phase 2: Before the start of activity 2, the heart rate should have a value less than the $HR_{recovered}$. The exact value of the heart rate should be noted in the journal. During phase 2: At the start of the activity, the current local time is noted in the journal. The subject is intended to walk 50 meters back and forth from A to B with a walker. This activity is performed for two minutes and will be repeated three times at step frequencies of 50, 100, 145 steps per minute. These various speeds are determined during the test phase and indicated by a metronome. After phase 2: When activity 2 has been performed, the current local time is noted again. Besides that, the measured heart rate and total walking distance should be noted in the journal right after the performance of the activity. Once the heartbeat has reached the $HR_{recovered}$, activity 2 is repeated at a different speed.	**20**

Table 2: *Measurement protocol part 1*

3 Activities of daily living (ADL)	Duration of activity Heart rate ($HR_{recovered}$, during exercise and after exercise) Number of steps (observer and Fitbit wrist/ankle) Classification Intensity	<u>Before phase 3:</u> The subject wears a sweatpants in order to simulate 'going to the toilet'. Before the start of phase 3, the heart rate should have a value less than the $HR_{recovered}$. The exact value of the heart rate is noted in the journal. <u>During phase 3:</u> At the start of the activity, the current local time is noted in the journal and a stopwatch is started. Thereafter, the following ADL activities are executed: *Getting out of bed* *Walking 30 metres at a speed of 80 steps per minute to a chair* *Take sweatpants off and stand to sit sitting* *Sits for 5 seconds (representing going to the toilet)* *Sit to stand and put on sweatpants* *Walking 30 metres at a speed of 80 steps per minute to bed* *Getting in bed* Time of the stopwatch will be noted in the journal at the start of every new activity described above. <u>After phase 3:</u> When phase 3 has been performed, the current local time is noted again. Besides that, the measured heart rate should be noted in the journal right after the performance of the activity. Once the heartbeat has reached the $HR_{recovered}$, activity 3 is repeated.	**20**
4 Climbing stairs	Duration of activity Heart rate ($HR_{recovered}$, during exercise and after exercise) Classification Intensity Climbed height	<u>Before phase 4:</u> Before the start of activity 3, the heart rate should have a value less than the $HR_{recovered}$. The exact value of the heart rate is noted in the journal. <u>During phase 4:</u> At the start of the activity, the current local time is noted in the journal and a stopwatch is started. The subject is intended to go 12 steps upstairs, wait five seconds and go 12 steps downstairs on a speed of 82 beats per minute indicated by a metronome. Climbing the stairs is performed by using one crutch in the way that elderly people learn during rehabilitation process.[59,73] This is as follows: When going upstairs, the crutch must remain standing while the subject puts the foot of the undisabled side on the next step. Then put the crutch and the leg of the disabled side on the next step. When going downstairs, the feet are placed in the other order. So at first put the leg of the disabled side together with the crutch on the next step and then the leg of the undisabled side. Every time the subject reaches the end of the stairs and starts a new climb, the time of the stopwatch will be noted in the journal. As well as the number of climbed height. <u>After phase 4</u> When activity 4 has been performed, the current local time is noted again. Besides that, the measured heart rate should be noted in the journal right after the performance of the activity. Once the heartbeat has reached the $HR_{recovered}$, activity 4 is repeated.	**10**

Table 3: *Measurement protocol part 2*

5.3.3 Test phase

The purpose of the test phase is testing the set-up of the experiment and testing the parameters of each monitor device. This test phase is performed by one subject who is a healthy woman of 21 years old with an average weight. During this test phase, measurements of all phases are taken which means that the protocol is executed to make sure it is efficient and correct.

In addition to the experiment protocol, the step frequencies of phase 2 are defined during the test phase. This is done by letting the subject walk at various step frequencies while monitored by MOX. Additionally, the metronome frequency is determined for phase 4 to make the activities standardised. This frequency is based on the comfortable step frequency to climb stairs by making use of a crutch for this subject.

5.3.4 Data analysis

In this section, it is described how the parameters mentioned in the *Section 5.3.1 Parameters* will be analysed. In order to be able to analyse these parameters, all data is imported in several programmes. The MOX data was imported in *IDEEQ 2.0 Data Acquisition Platform* and then exported to Excel. In addition, the data from Fitbit and the journal was imported into Excel for every phase. After gathering all the data, *IBM SPSS Statistics Version 25* was used to analyse all data. Because of the small population, outliers may not easily be filtered out of the data.

Number of steps

To analyse whether the number of steps can be accurately measured by Fitbit, the measured steps of Fitbit were compared to the number of steps measured by observer. To compare these variables, a correlation graph and a correlation coefficient were used. The steps measured by the observer were assumed to be the gold standard.

The total number of steps given by the Fitbit, were given in steps per minute. As the subjects did not began the activity at the exact start of a minute, it was decided to take the total number of steps measured by the Fitbit during the entire activity. It was assumed that besides the performance of the activity, no other steps were taken. The journal was used to pick out the minutes corresponding to the time of execution of the activity. After that, the measured number of steps in this time span were added together. The observed number of steps during the same time span was also added together. This was done in order to be able to compare the number of steps measured by the Fitbit to the observed number of steps within the same time of activity.

Before the correlation between the number of steps measured by Fitbit could be compared to the observer, normality of the measured steps was tested. For phase 2, distinction was made between the three speeds (50 bpm, 100 bpm, 145 bpm) and between 'without GERT' and 'with GERT' which led to six different histograms. For phase 3 a distinction was made between 'without GERT' and 'with GERT', which led to two different histograms.

Subsequently, *Spearman Correlation Coefficient* was used to determine the accuracy of the device. Also a correlation graph, with 'number of steps observer' on the x-axis and 'number of steps Fitbit' on the y-axis, was made. A distinction was made between the two states, 'without GERT' and 'with GERT' and between the Fitbit attached to wrist and Fitbit attached to ankle. This led to four correlation graphs for phase 2 and four correlation graphs for phase 3.

Unlike phase 3, the subjects used a walker during the performance of the activity in phase 2. This was likely to affect the correlation, especially for the Fitbit attached to the wrist. Because this Fitbit does not experience acceleration when a walker is used. Therefore, the *Spearman Correlation Coefficients* outcomes for Fitbit ankle and Fitbit wrist of phases 2 en 3 were compared. To test whether the accuracy of the Fitbit attached to the wrist was affected by the use of a walker, a *Wilcoxon test* was performed on the number of steps measured by Fitbit wrist and ankle for phases 2 and 3.

Heart rate

Heart rate can be a practical way of quantifying physiological effects of training. If an activity costs the hip fracture patient a lot of effort, the heart rate measured by Fitbit will probably increase.[44] Therefore, it was analysed whether the group with GERT had a higher heart rate during the same activity than the group without GERT.

The monitor devices MOX and Fitbit measure data in real (local) time, which makes it more complex to compare data at different times. To be able to compare the two states, specific minutes were assigned to every activity. This means, that the minute prior to the start of an activity, in other words the minute in rest, was quantified as minute 1. Performing an activity was for example minute 2, 3, 4, 5 and then recovery from activity was minute 6 and 7. In this way, the corresponding heart rates for every minute and thus every situation (rest, activity, recovery) could be compared for the two states.

During phase 3, every subject performed the activity three times without GERT and three times with GERT. Therefore, the average heart rate during these three measurements within one state was calculated per minute per subject. For every subject, the difference between heart rate for the activity with and without GERT was shown in a plot including on the x-axis duration of activity in minutes and on the y-axis mean heart rate measured by the Fitbit attached to the wrist. This graph makes it possible to visualize heart rate in rest, maximum heart rate and heart rate increase and decrease.

To be able to calculate increase in heart rate during activity, the following formula was used:
$HR_{increase} = HR_{max}\text{-}HR_{min}$

HR_{max} and HR_{min} are formulated by the researchers based on a combination of the journal that was kept during the experiment and the data of the Fitbit. The start time and duration of activities were noted in the journal and were then combined to the Fitbit data. The minimum heart rate, right before the start of the activity, was taken as HR_{min} and the maximum heart rate during activity was taken as HR_{max}. After having calculated $HR_{increase}$ for phase 2, phase 3 and phase 4, the normality of the data was tested. A *non-parametric Wilcoxon test* was performed to test whether there is a significant difference between the two states.

MOX divides various activities into classifications.[12] To be able to test whether there is a difference between heart rate of both states per classification, the mean heart rate per classification per subject was calculated. Thereafter, a *Wilcoxon test* was used on the data. However, MOX did not measure classification 1 to 5 for every subject. Sometimes the MOX did not register a classification at all during 'without GERT' and did register this classification while performing the same activity 'with GERT'. To be able to make these classifications comparable, the data that was only registered in one of the two states was filtered out. Classification 1 was only measured for two subjects during both states, for this reason this classification was not included during the *Wilcoxon test*. All data in which the heart rate was equal to zero, was also filtered out of the data. These were inaccurate measurements and would influence the results.

Intensity and heart rate

If a patient performs the same activity during rehabilitation and the perceived exertion decreases, this may be a sign of functional recovery. To analyse whether the monitor devices are able to measure this principle, a plot of intensity measured by MOX and heart rate measured by Fitbit was made over time. A plot including on the x-axis 'time', on the left y-axis heart rate and on the right y-axis intensity. The time that was used was the real local time, in which the MOX and Fitbit measured their data.

Intensity of activities

The continuous monitoring of a patient's intensity can be an indication for what activity the patient is performing during the day. To find out which activity corresponds to which intensity in this experiment, the activities and corresponding times were written down in the journal. Subsequently, every activity was linked to an intensity of MOX on exact the same time. Afterwards, an overview in average intensities per performed activity during experiment was made.

To check whether the MOX assigned the correct classification to an activity, the average classification during phase 2 for every subject and step frequency was calculated. The test phase determined which step frequency belongs to which classification. The lowest frequency should equal the LPA classification, the middle frequency should equal MPA and the highest frequency should equal VPA.

To check whether the intensities measured by MOX were correctly corresponding to the performed activities, the intensity was plotted over time. This time was based on the assigned minutes described in the *Section Heart rate of 5.3.5 Findings of results*, so that every subject performed the same activity in the same minute. For example, in minute 1 every subject was in rest and in minute 3 everybody was walking. In the graph, every subject was included, and therefore every line represented one of the 8 subjects. When a graph showed a large degree of overlay between all subjects, this meant that the intensity measured by MOX was around the same value for every subject for the same activity.

5.3.5 Findings of results

Test phase

The step frequencies of the metronome for phase 2 were determined from *Figure 6* and are as follows:

- **Speed 1 (LPA)**: 50 bpm
- **Speed 2 (MPA)**: 100 bpm
- **Speed 3 (VPA)**: 145 bpm

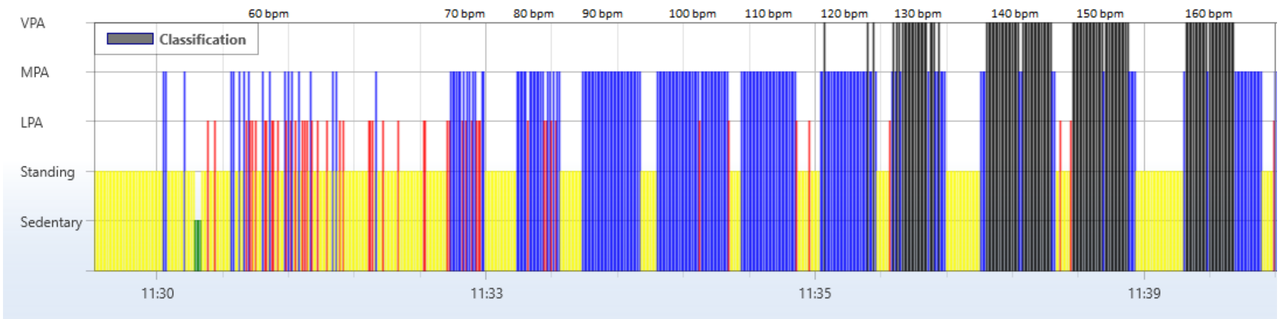


Figure 6: *Classification of the MOX over time with corresponding step frequencies.*

Number of steps

For phase 2 and phase 3, the number of steps counted by observer and measured by the Fitbits are not normally distributed. The histograms which confirm this assumption are mentioned in *Appendix E and F: Results normal distribution*.

To be able to test the accuracy of the Fitbit a *Spearman Correlation Coefficient* is calculated for the number of steps measured by the Fitbit and the observed number of steps. In *Table 4* an overview of the correlation coefficient is given. In phase 2 the lowest speed gives a significant (p = 0.017) correlation of 0.802 for the Fitbit attached to the wrist. The Fitbit attached to the ankle gives a significant (p = 0.039) correlation of 0.774 for speed 2 'without GERT'. In phase 3 every correlation is significant.

	Speed	State	Fitbit	Spearman Correlation Coefficient	Sig. (2-tailed)
Phase 2	1	Without GERT	Wrist	0.802	0.017
			Ankle	-0.345	0.402
		With GERT	Wrist	0	0
			Ankle	0.089	0.834
	2	Without GERT	Wrist	-0.056	0.905
			Ankle	0.774	0.039
		With GERT	Wrist	-0.050	0.907
			Ankle	0.256	0.540
	3	Without GERT	Wrist	-0.275	0.509
			Ankle	0.50	0.207
		With GERT	Wrist	0.049	0.909
			Ankle	0.429	0.289
Phase 3		Without GERT	Wrist	0.621	0.014
			Ankle	0.707	0.016
		With GERT	Wrist	0.899	0
			Ankle	0.627	0.012

Table 4: *Spearman Correlation Coefficient of the number of steps during phases 2 and 3.*

A *Wilcoxon test* is performed to analyse the differences between the number of steps measured by Fitbit attached to the wrist and Fitbit attached to the ankle. For phase 2, there is a significant (p = 0.00) difference between the Fitbits. In 141 of the 298 cases the Fitbit attached to the ankle shows a higher number of steps. In 32 cases the Fitbit attached to the wrist shows a higher number of steps and in 125 cases the measurements are equal. However, there is no significant difference (p = 0.96) between these Fitbits for phase 3.

In *Figure 7*, the correlation between the number of steps observed by observer and measured by the Fitbits is shown for phase 2. The Fitbit attached to the wrist shows a very low correlation with the observer. The Fitbit attached to the ankle shows a higher correlation and is clearly divided into three groups of steps: 100 steps, 200 steps and 250-300 steps. The remaining correlation graphs for phase 2 can be found in *Appendix G: Results of correlation*.

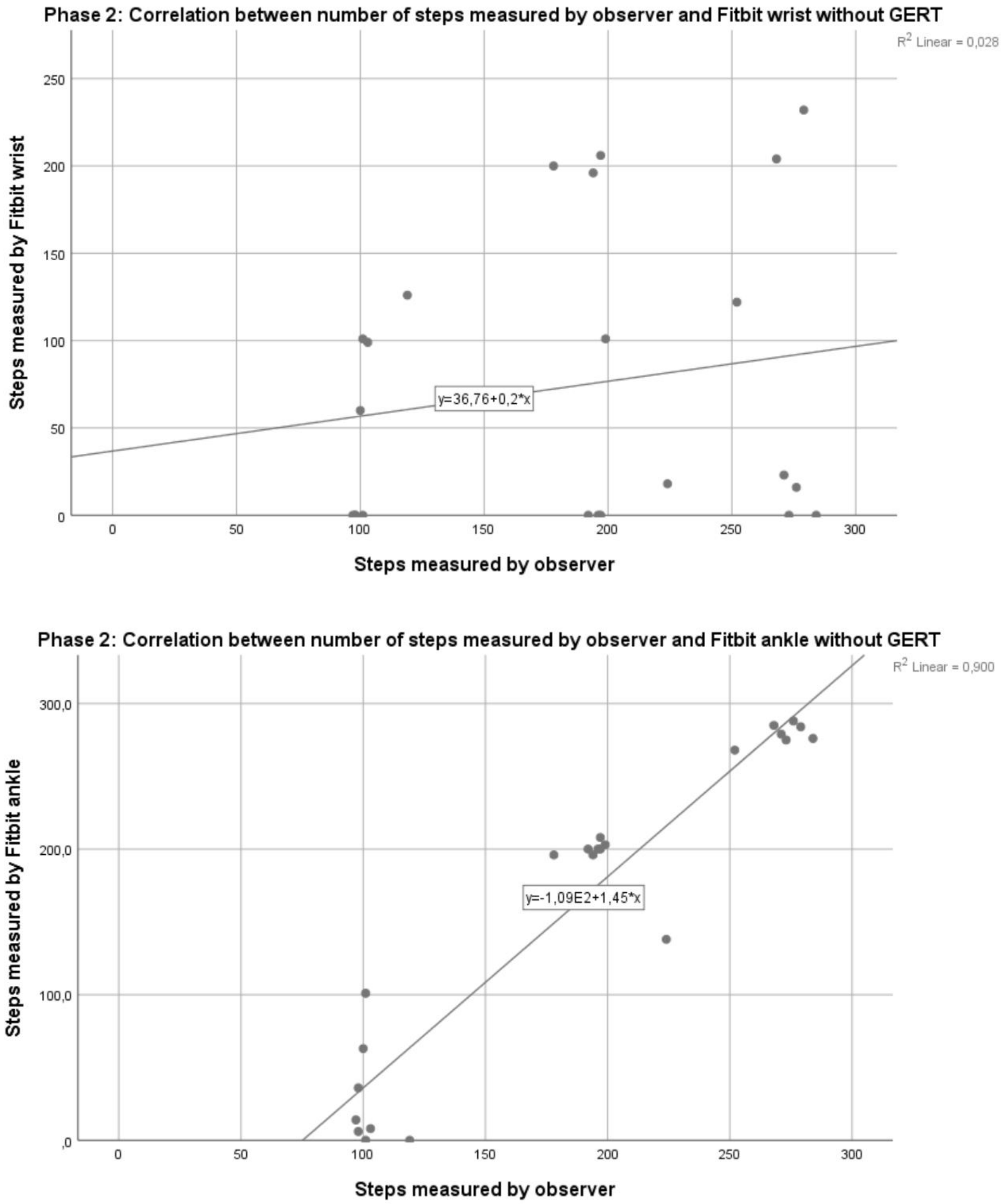


Figure 7: *Correlation between number of steps measured by observer and Fitbit, during phase 2.*

In *Figure 8*, the correlation between the steps measured by Fitbit and the observed steps for phase 3 is shown. The correlation is higher (0.899) for wrist than for ankle (0.627).

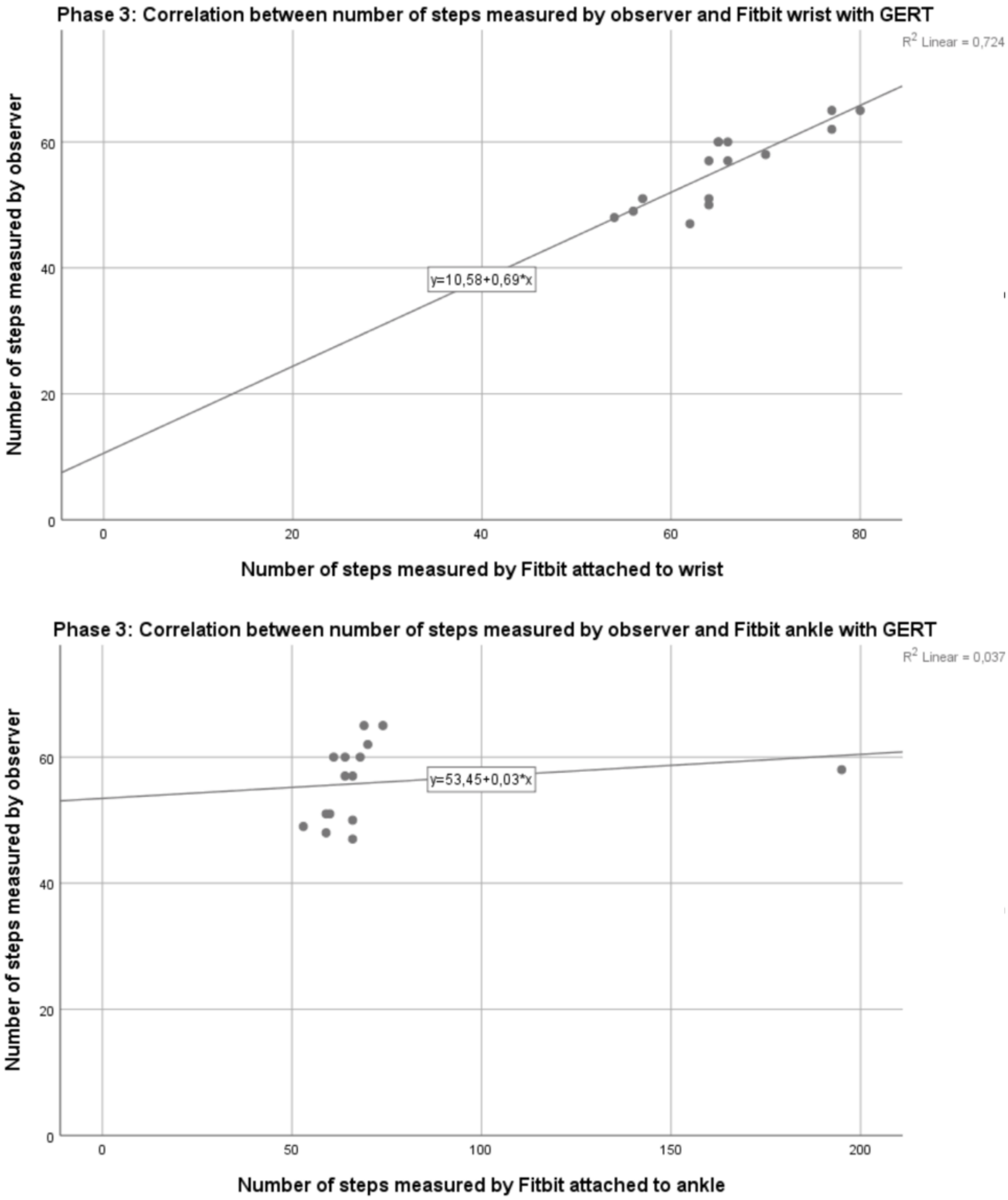
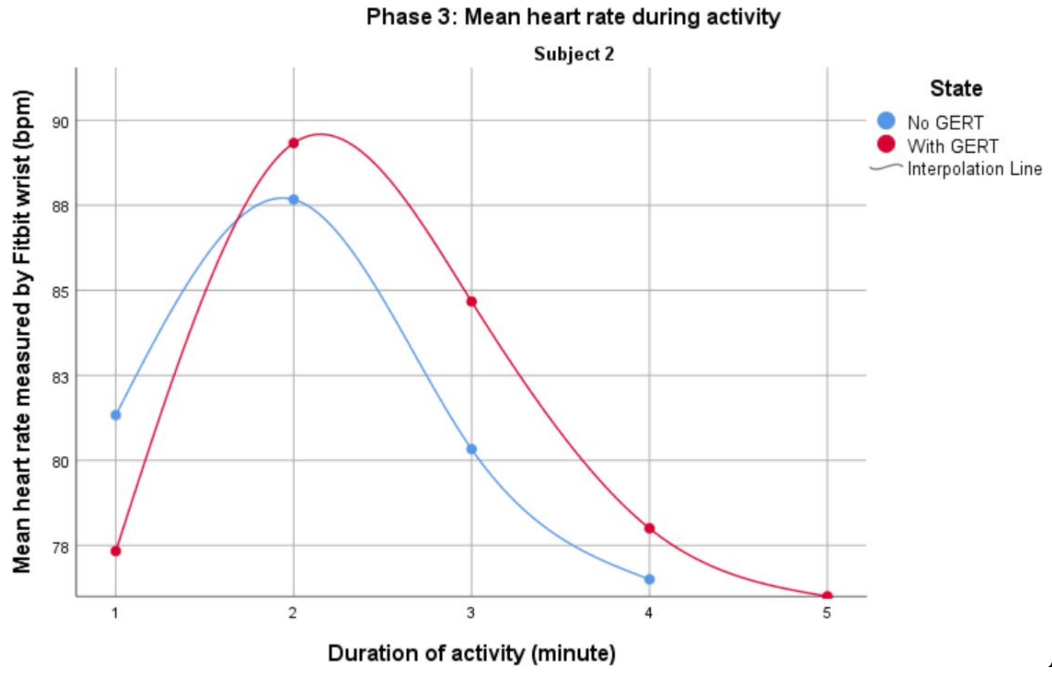


Figure 8: *Correlation between number of steps measured by observer and Fitbit during phase 3.*

Heart rate

Every heart rate measured by the Fitbit attached to the wrist, is assigned to a specific minute, as described in *Section 5.3.4 Data Analysis*. In *Figure 9*, the mean heart rate during phase 3 is shown for both states: 'with GERT' and 'without GERT'.

Figure 9A shows a higher increase in heart rate during the activity 'with GERT' and a slower decrease after activity. *Figure 9B* shows a lower maximum heart rate for the activity 'with GERT', however it is not sure whether the increase in heart rate is also lower in the 'with GERT' group. *Appendix H: Heart rate and intensity over time* consists of the graphs of mean heart rate during activity for subject 6, 7 and 8.



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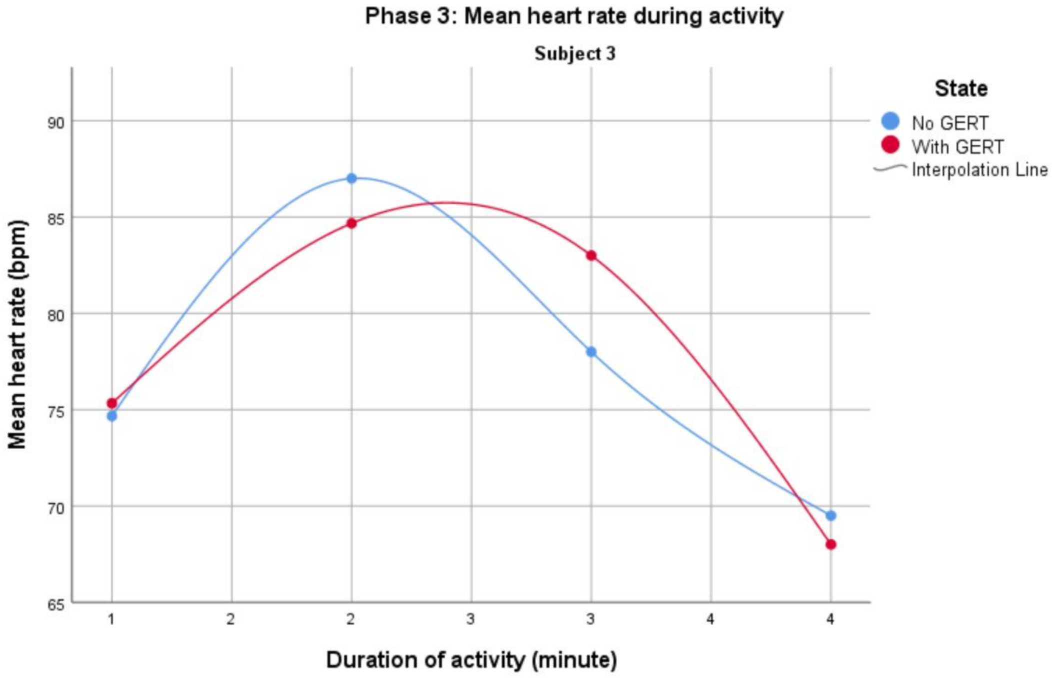
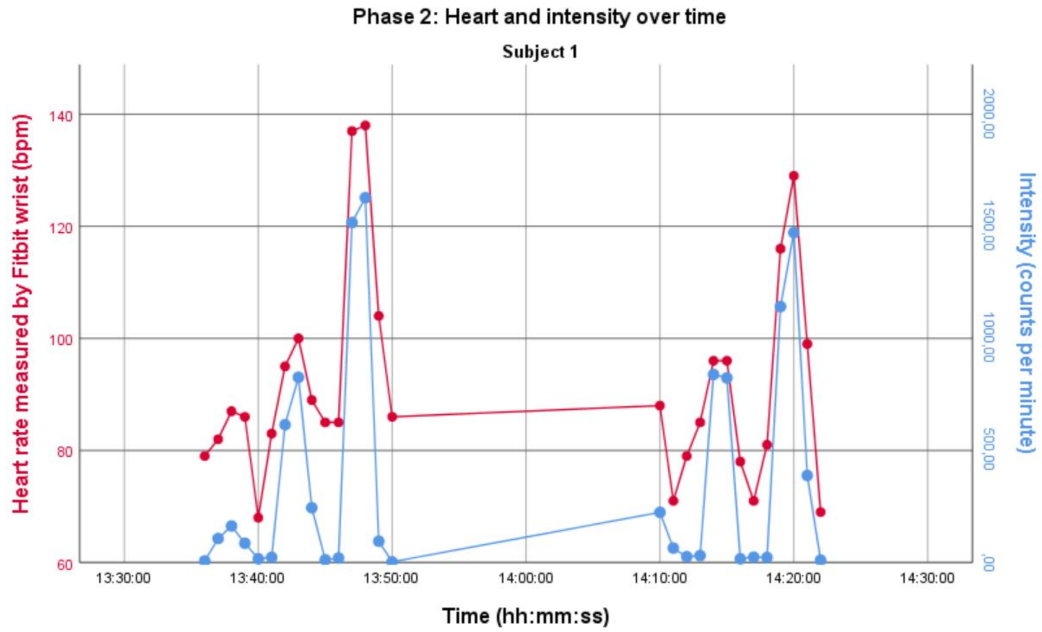


B

Figure 9: *Mean heart rate during activity of phase 3 for 'with GERT' and 'without GERT'.*

A *Wilcoxon test* was used to analyse whether the mean heart rate per classification is different for 'without GERT' and 'with GERT'. There is no significant difference between the heart rate of the two states per classification. The table with the results of this test is shown in *Appendix I: Overview of intensities during different activities*.

Figure 10 shows the intensity (blue line) and heart rate (red line) over time. Figures of the other subjects can be found in *Appendix J: Mean heart rate during activity*. The spikes on the left of the graph are the measurements 'without GERT' and the spikes on the right side of the graph are 'with GERT'. In between these measurements data is filtered to create a clearer overview of the differences between these situations. The intensities do not vary a lot within the two states, however *Figure 10A* shows a clear increase in heart rate. In *Figure 10A* the intensity is also approximately the same for 'without GERT' and 'with GERT'. Unlike *Figure 10A*, *Figure 10B* shows a decrease in heart rate when the subject wears GERT. For subject 1, 2, 6 and 8 a clear increase in heart rate, while comparing the two states with each other, can be seen. The other graphs seem to show a heart rate decrease between the two groups. However $HR_{increase} = HR_{max} - HR_{min}$, could possibly still be higher. Therefore a *Wilcoxon test* is used to determine whether there is a significant difference between these groups.



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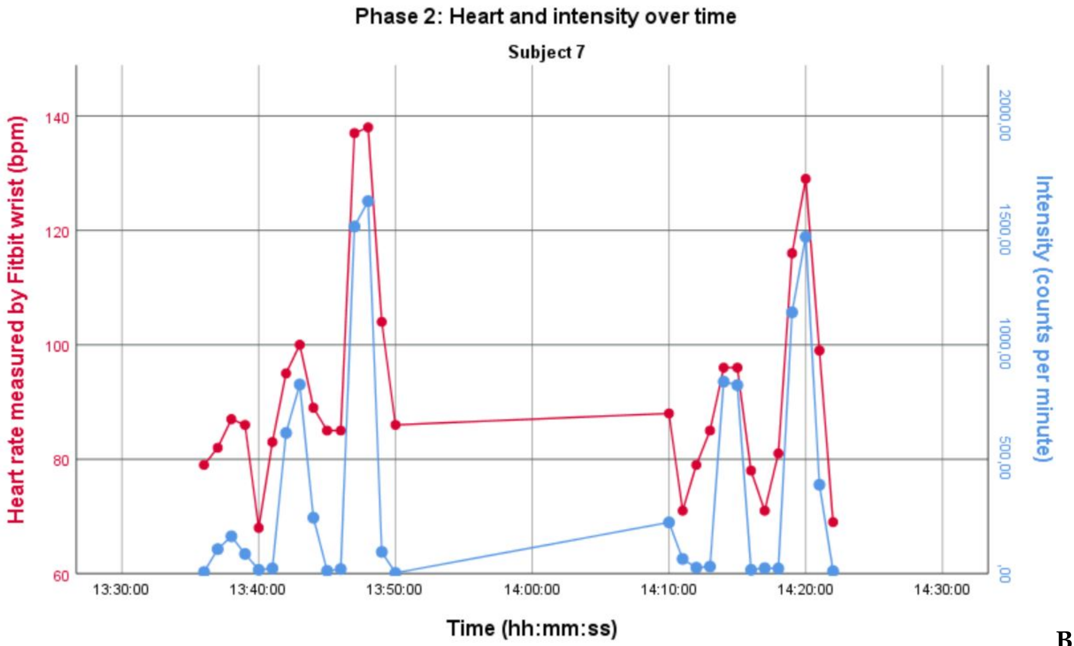


B

Figure 10: *Heart rate and intensity over time during phase 2. The spikes on the left represent the 'without GERT' state, the spikes on the right represent the 'with GERT' state.*

The increased heart rate ($HR_{increase}$) for phase 2, 3 and 4 are not normally distributed. The histograms that prove this, can be found in *Figure 20 in Appendix E: Normal distribution of phase 2* and *Figure 23 in Appendix F: Results normal distribution of phase 3 and 4*.

Wilcoxon test did show a significant (p = 0.021) difference in $HR_{increase}$ between 'without GERT' and 'with GERT' for phase 2. In 15 of the 24 cases the $HR_{increase}$ for 'with GERT' was higher, with a mean rank of 13.17. When a distinction is made between the three walking speeds, only speed 1 shows a significant (p = 0.027) difference in which the $HR_{increase}$ for 'with GERT' is in 6 of the 8 cases higher dan the $HR_{increase}$ for 'without GERT'. The other two cases are equal. There is no significant difference in $HR_{increase}$ between 'without GERT' and 'with GERT' for speed 2 and speed 3.

In *Figure 11*, a graph of heart rate measured by Fitbit and intensity measured by MOX over time is given for phase 3. For subject 3 the intensity fluctuates and the heart rate seems to be higher for ‘without GERT’, than for ‘with GERT’. For subject 6 intensity also fluctuates a bit between the repetitions of ADL, however in this graph a clear increase in heart rate can be seen. During ADL, 2 of the 5 subjects had a clear increase in heart rate while wearing GERT. The other graphs seem to show a decrease or are not clear. These remaining graphs can be found in *Appendix H: Heart rate and intensity over time*.

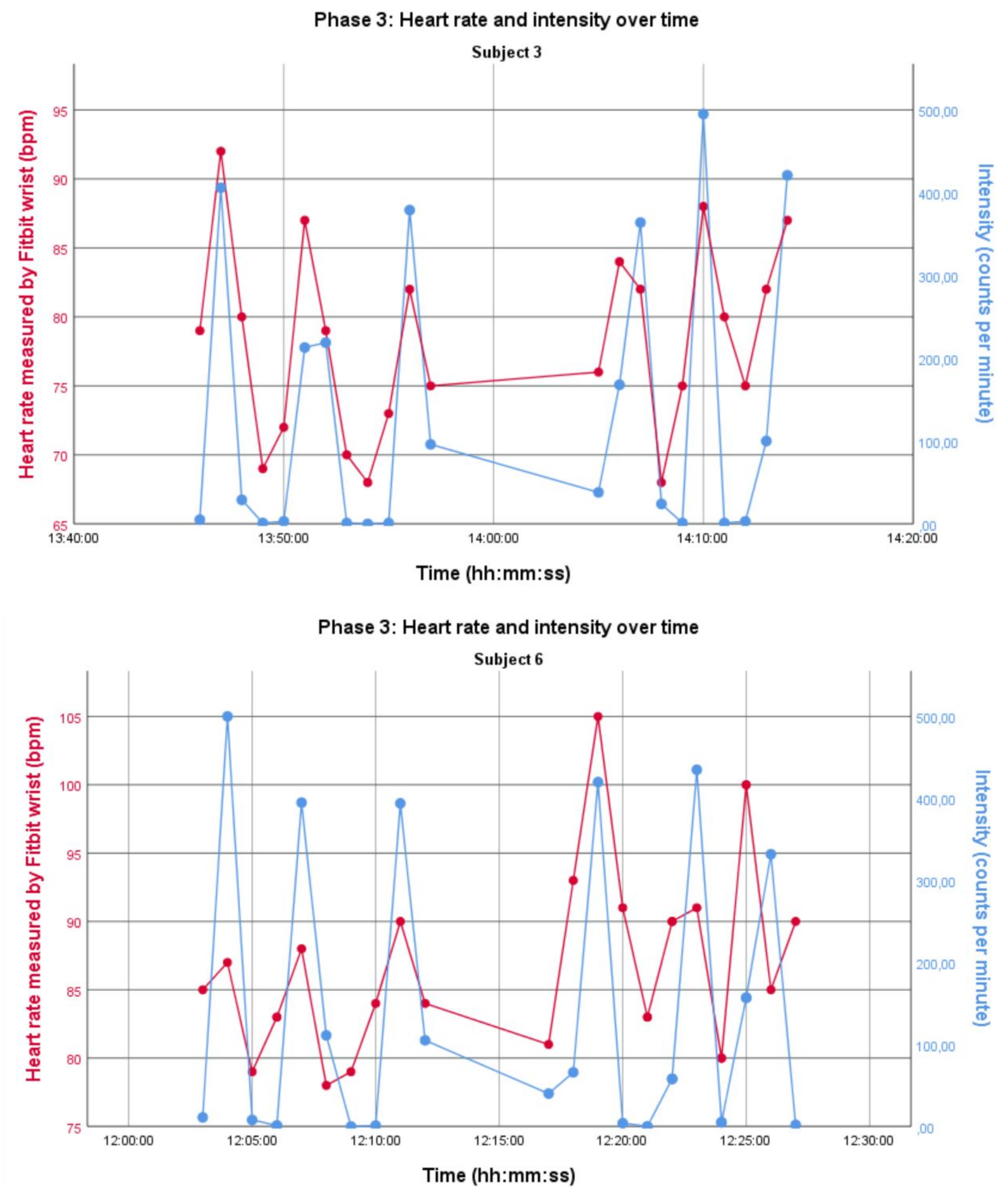


Figure 11: *Heart rate and intensity over time during phase 3. The spikes on the left represent the 'without GERT' state, the spikes on the right represent the 'with GERT' state.*

A *Wilcoxon test* did show a significant (p=0.028) difference between $HR_{increase}$ for ‘without GERT’ and ‘with GERT’. In 11 of the 15 cases the $HR_{increase}$ for ‘with GERT’ was higher than the $HR_{increase}$ for ‘without GERT’. The mean rank of these cases were 7.95.

In *Figure 12*, a graph for intensity and heart rate over time for phase 4 is shown. The intensity fluctuates and the heart rate increases while wearing GERT. For phase 4 the *Wilcoxon test* did not show a significant (p = 1.00) difference between $HR_{increase}$ for 'without GERT' and 'with GERT'.

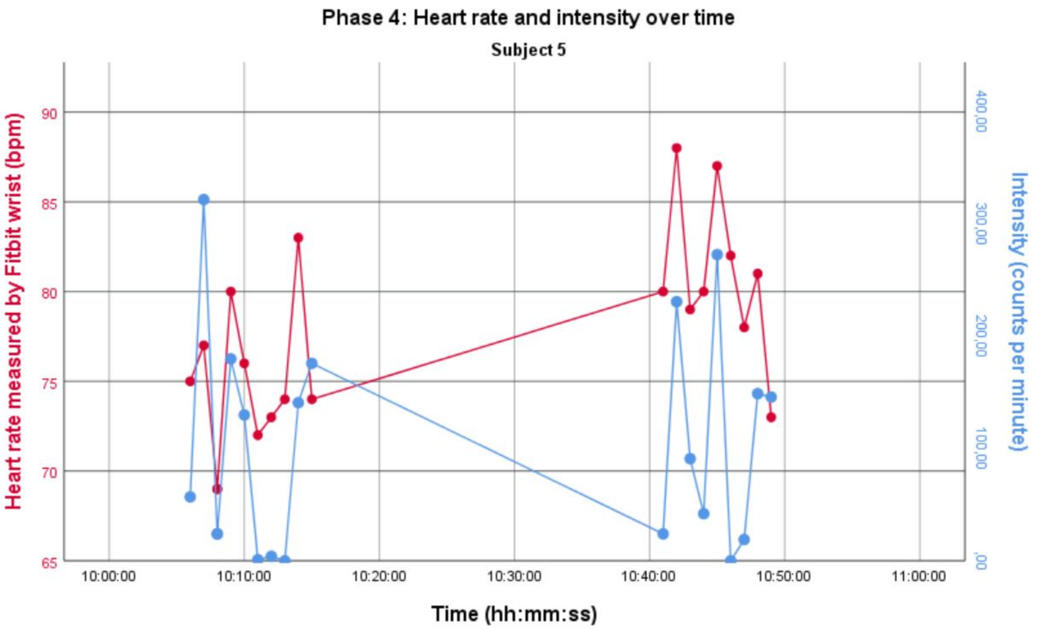


Figure 12: *Heart rate and intensity over time during phase 4. The spikes on the left represent the 'without GERT' state, the spikes on the right represent the 'with GERT' state.*

Intensity

To make sure whether the intensities measured by MOX are correctly corresponding to the performed activities, the intensity is plotted over time for every subject. These graphs are shown in *Figures 13 upto and including 15*. During phase 2 and phase 3, a high overlay between the lines of every subject can be seen. In phase 4 there is a lower overlay between intensities measured by MOX during the activity for the four subjects.

Figure 13: *Intensity during activities of phase 2 at speed 1.*

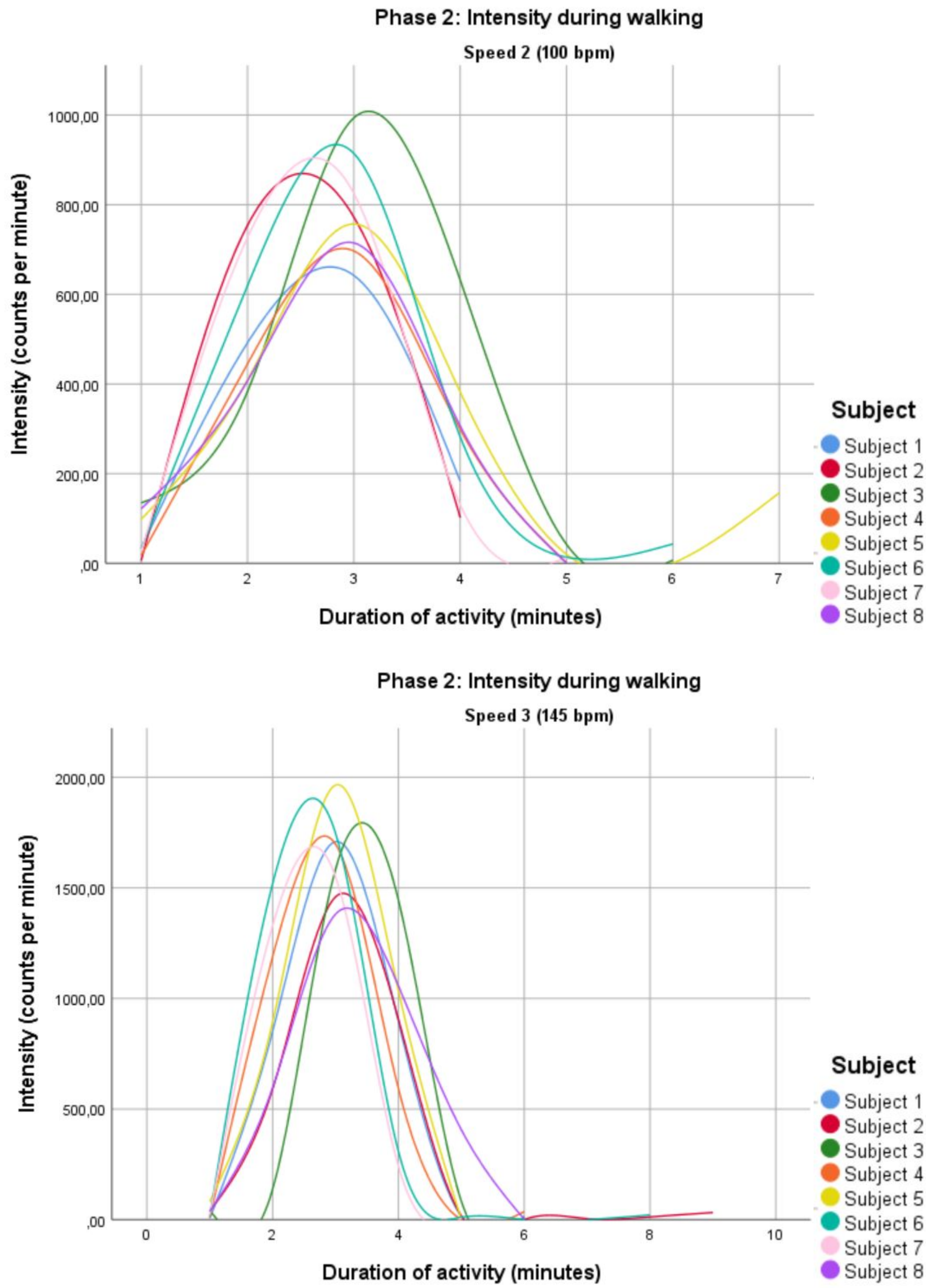


Figure 14: *Intensity during activities of phase 2 at speed 2 and 3.*

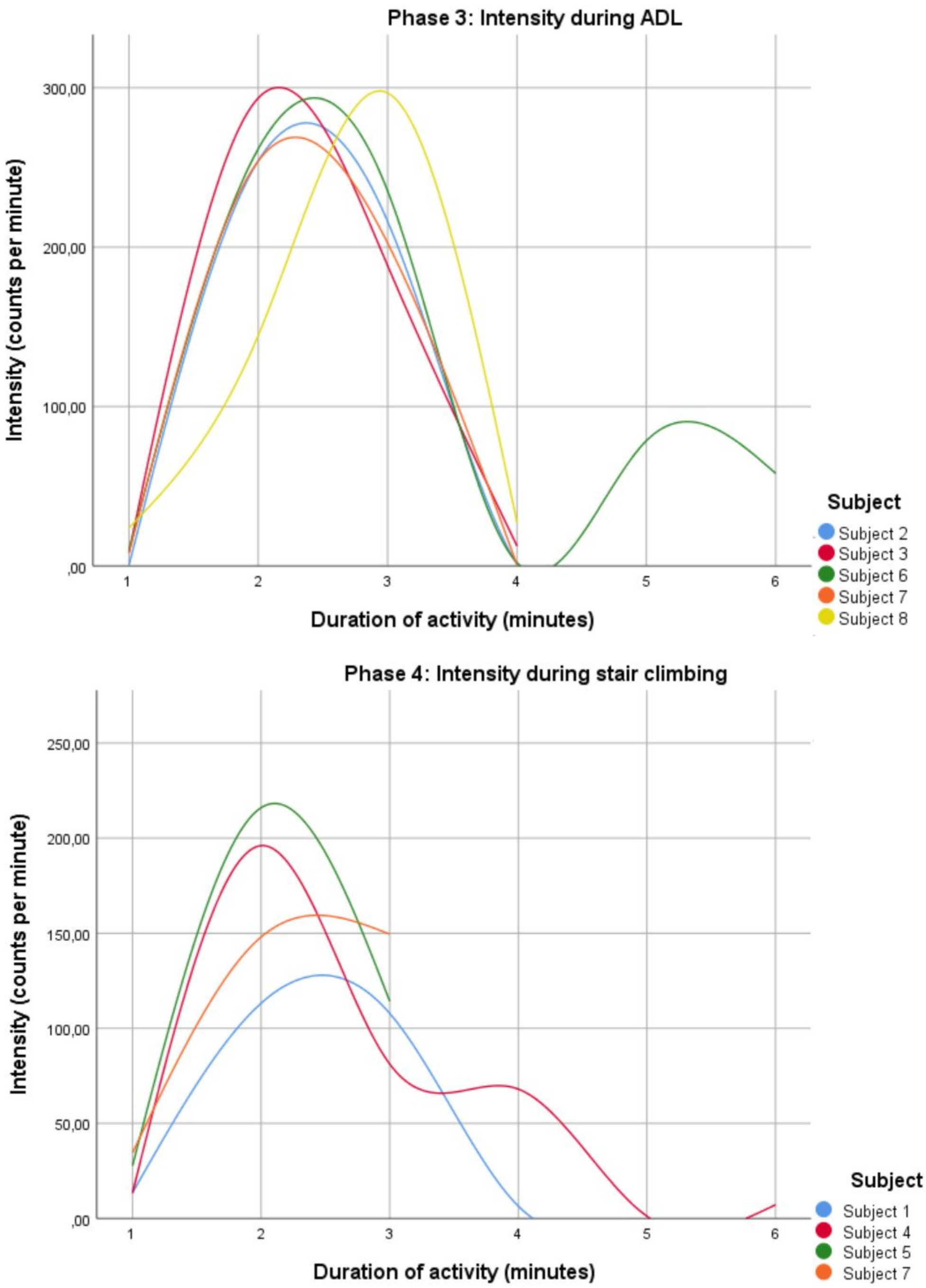


Figure 15: *Intensity during activities of phases 3 and 4.*

To make sure whether the classifications measured by MOX are correctly corresponding to the performed activities, the average classification during phase 2 is calculated (see *Table 5*).

Step frequency	Situation	Average classification
50 bpm	Without GERT	2 (= standing)
	With GERT	2 (= standing)
100 bpm	Without GERT	4 (= MPA)
	With GERT	4 (= MPA)
145 bpm	Without GERT	5 (= VPA)
	With GERT	5 (= VPA)

Table 5: *Average of classification during phase 2.*

An overview of average intensities per activity is made to make the analysis of continuous data easier to interpret (*Appendix I: Overview of intensities during different activities*). Also a graph of heart rate and intensity during two hours of continuous monitoring of a participant, is made (see *Figure 16*). The spikes of the walking phase, phase 2, can be easily distinguished because of the extreme high intensity spike.

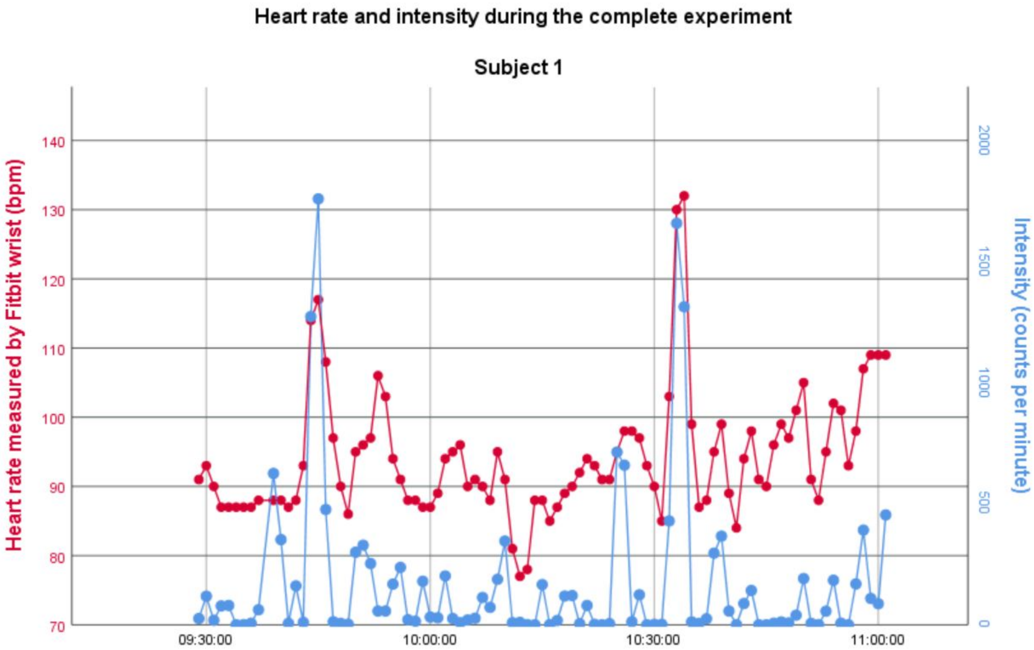


Figure 16: *Heart rate and intensity of subject 1, during all phases.*

6 Discussion

6.1 Discussion of literature research

Little research has been done into terms like perceived exertion and internal and external load for elderly people. As these terms can influence functional recovery for elderly hip fracture patients, it was decided to include studies into these terms regarding to athletes. Athletes are of course not comparable to elderly people. However, the definition of functional recovery which has been formulated by literature research is a more general conclusion. This definition is applicable to elderly people as well as to athletes.

In this study it was decided to only include the factors which contained parameters that could be measured by one of the monitor devices. However, functional recovery can be related to other factors as well, such as safety and independence, mobility, balance and resilience. For this reason the definition of functional recovery formulated in this study, does not cover the entire content.

Safety and independence

As mentioned in the *Section 5.2 Results of interviews*, it is very important that patients are able to perform their daily activities independently and safely again.[61] Nowadays, this can only be quantified and determined by the TUG,[9] which measures duration of sit-to-stand transfers and traveled distance in a certain time span. The Fitbit calculates the traveled distance based on a certain algorithm,[34] using age and length of the user and not the actual covered distance. Hence, safety and independence cannot be continuously monitored by the included monitor devices, due to a lack of technical specifications. Therefore it is not yet possible to measure the ability to independently and safely perform daily activities, for this reason the TUG cannot be replaced by one of the monitor devices.

6.2 Discussion of interviews

Interviews were set up to support and expand the definition of functional recovery, which was initially defined by literature research. The interviews were conducted on five patients and five healthcare specialists. This study population was large enough to make up the definition of functional recovery and get an overview of the most common personal targets of physical functioning during the rehabilitation process. However, the study population was too small to quantify and objectivate the interview results.The definition of functional recovery would have been better substantiated if the frequency of the personal targets could have been quantified, by making use of a bigger study population.

Another thing to take into account is the fact that all stakeholders were involved in the Up&Go project. The results of the interviews can be affected by foreknowledge of the stakeholders.

Interviews were conducted on elderly people in nursing homes and on elderly people in the hospital. Elderly people have a higher probability of suffering from cognitive impairment.[74,75] Therefore some of the patients were not able to completely understand and answer the questions correctly. Especially, elderly people staying in the hospital had some difficulties answering the questions. An explanation for this can be that hip fracture patients have a high chance of getting a delirium in hospital.[76] In addition, it can also be related to the fact that the patients in the hospital have not been in a long rehabilitation process yet. This means that they have not talked very often about their personal targets in order to functionally recover and therefore also do not really know what their targets are.

In the discussion of literature research the importance of performing an activity safely and independently has already been pointed out. However, according to the interviews[59,60] conducted on physiotherapists, the safety of moving can be best evaluated by the specialist, who is involved in the rehabilitation process of a specific patient. According to healthcare specialists, the TUG or another objective monitor device can never replace this subjective judgement of healthcare specialists. Despite this, continuous monitoring of the safety and independence of the performance of an activity may be a useful addition.

6.3 Discussion of experiment

During the experiment, several points of discussion were noticed in the method, analysis and results. These are discussed below.

General

Initially the Fitbit Zip, Fitbit Charge HR and the MOX would be used during the experiment. The Fitbit Zip was not available during execution of the experiment. For this reason, the Fitbit Zip is not included during the experiment and data analysis. During interviews the unreliability of the Fitbit Charge HR attached to the wrist when making use of a walker was mentioned several times. For this reason an extra Fitbit Charge HR was used and attached to the ankle. This Fitbit measured both the number of steps and heart rate.

Subjects were included assuming that the experiment would take a maximum of two hours. Unfortunately, the test phase took at least three hours. Which meant that performing the complete experiment could not be done within two hours. For this reason there is a difference in size of study population between the three phases. Due to the high intensity of activity during phase 2, the hypothesis was that differences in parameters between 'without GERT' and 'with GERT' would be most clear in this phase. Therefore, it was decided to have eight subjects perform phase 2. Due to the lack of time, it was decided to have five subjects perform phase 3 and four subjects perform phase 4. Because of the small study population, results from the statistical tests can be influenced by coincidence and can therefore not be generalised. This has to be kept in mind when analysing the data.

During phase 4, the number of climbed stairs were noted by the observer in order to check the accuracy of the Fitbit Charge HR. It was remarkable that the Fitbits attached to the ankle and wrist measured almost no climbed floors at all. This can be explained due to the fact that the subjects climbed a height of 2.09 meters. Afterwards it turned out that the Fitbit Charge HR only counts a climbed floor when the subject has climbed a minimum height of 3 meters.[10] This has been a mistake in the set-up of the experiment. However, the continuously monitored Fitbit data only consists of number of steps and heart rate per minute. Number of climbed floors is only displayed in the Fitbit App. This is an additional reason why the data of climbed floors could not be analysed.

In this experiment two groups were compared: 'without GERT' and 'with GERT'. This suit adds forces to the torso and limbs, which will lead to an increased feeling of fatigue.[38] For this reason a subject that is not wearing GERT is assumed to be functionally recovered and a subject that is wearing GERT is assumed to be not completely functionally recovered. However, in clinic, functional recovery will take place in much smaller steps than during this experiment. Therefore, the parameters that show a difference between 'without GERT' and 'with GERT' can be potential parameters to continuously monitor functional recovery. However, further research in these parameters is necessary to draw conclusions about monitoring functional recovery during rehabilitation of elderly hip fracture patients. A disadvantage of wearing GERT is that the weight puffs around the wrist and ankle can affect the position of the Fitbit Charge HR around these joints. During the experiment, attention was paid to maintain this position. However, this still may have had an influence on the accuracy of the measurements of the Fitbits.

Keeping a journal and assigning minutes to activities, is obviously the opposite of continuous monitoring. To translate the results of this research into continuous monitoring, a plot of intensity and heart rate during the complete experiment is made for subject 1, see *Figure 16* in *Section 5.3.5 Findings of results*. Unlike the other plots of heart rate and intensity over time, which were made earlier in this research, no data was filtered out. To distinguish different activities in this graph, an overview of the average intensity per activity is made. This overview shows a high standard deviation for all intensities, which makes the intensities less reliable. Also, the time of performance of the activities during phase 3 were noted by the observer per second and might therefore be inaccurate. Hence, the average intensities per activity during ADL may not be able. When a patient is functionally recovering the $HR_{increase}$ will decrease while the intensity will stay the same. This can be caused due to a better physical condition and a decrease of required attention during exercise.[77]

Furthermore, elderly people perform much more activities than those performed during this experiment. A selection of the activities is based on the fact that functional recovery is correlated with perceived exertion. If progression in perceived exertion can be measured by the monitor devices, by making use of heart rate, this monitor devices would also be able to measure progression in perceived exertion during other daily activities as well. Therefore, it does not matter that only these three activities of daily living were evaluated.

Another important aspect is to take into account, to what extent this research is representative of the frail elderly hip fracture patients. The population consisted of 8 healthy subjects from 20 to 25 years old, which is obviously something different than frail elderly patients with a hip fracture. The measured parameters during the experiment can be affected by aging. For example,[78] the mean heart rate[78] and the maximum heart rate[78] decrease with age. Also, the heart rate recovery time[79] in elderly people takes longer. This means that whenever elderly people would have performed this experiment, the conclusions about heart rate may be different. This also applies to the differences in gait between elderly people and the included subjects. To improve security of walking, elderly hip fracture patients adjust their gait,[80] which leads to a decreased stride length and a generally increased step time. As hip fracture patients have a fear of falling,[58] there is a higher probability that these patients will adjust their gait pattern even more than healthy elderly people. Therefore, the conclusion about the correlation of number of steps between observer and Fitbit may be different when elderly hip fracture patients would have performed the experiment. In the *Subsections Heart rate, Number of steps and Intensity and classification*, which can be found below, the results of the parameters will be described while the differences between the subjects and elderly hip fracture patients will be taken into account.

Heart rate

According to research[81] the Concordance Correlation between heart rate measured by an electrocardiogram and the Fitbit Charge HR is 0.84 (95% CI = 0.791-0.871). The reliability of the heart rate measured by the Fitbit attached to the ankle is unknown, therefore this data is disregarded during the data analysis. To draw a conclusion about which monitor device is the most optimal, the addition of a heart rate monitor device which can be used as gold standard would have been useful. For example, the Polar H7[81] which shows a Concordance Correlation of 0.99 (95% CI = 0.987-0.991) with the electrocardiogram. By making use of this 'gold standard' the accuracy of both Fitbits could have been compared. The research of *R. Wang et al.*[81] also shows that the Fitbit Charge HR underestimates heart rate during vigorous exercise. This will not be of great influence in further research, since frail elderly hip fracture patients are not performing vigorous exercise very often.

There are a few aspects that could have affected the heart rate of the subjects while conducting the experiments. First of all, the heart rate is always fluctuating.[82] This makes it hard to draw a consequent conclusion about the heart rate increase during exercise. Secondly, the frequency indicated by the metronome, probably does not resemble the step frequency the subjects are used to walk at. Therefore, the subject should pay more attention in maintaining this step frequency. This may evoke an increase in heart rate.[77] Furthermore, during phase 3 and phase 4 every subject had to perform the activity three times. A repetition of exercises may lead to a reduced attention while performing the same activity. For the same intensity measured by the MOX, this may lead to a smaller increase in heart rate values[77] of 'with GERT' compared to 'without GERT'. This is because 'without GERT' is performed first for almost every subject. Although, this might also be the case during the rehabilitation process, as they also repeatedly perform activities.

At first, the heart rate during phase 3 for the situation 'without GERT' and 'with GERT' were plotted in the same graph. The hypothesis is that the situation 'with GERT' would have led to a higher maximum heart rate and a slower decrease in heart rate after activity, because GERT creates a higher level of fatigue.[38] *Figure 9A*, confirms this hypothesis. However, the other graphs (shown in *Appendix J: Mean heart rate during activity* and *Figure 9B*) do not confirm this hypothesis according to the maximum heart rate and time of decrease. Therefore $HR_{increase} = HR_{max}\text{˘}HR_{rest}$ is measured for every subject and for every phase. For the step frequency of 50 bpm and for phase 3 a significant difference is found in $HR_{increase}$ between 'without GERT' and 'with GERT'. Despite the fact that a significant difference in a small population size can be misleading, $HR_{increase}$ seems to be a useful parameter for further research.

During data analysis, intensity and heart rate are plotted over time for every phase and every subject. These graphs can be found in *Figures 10, 11 and 12* and *Appendix H: Heart rate and intensity over time*. According to the hypothesis, the intensities should be the same during the activity 'without GERT' and 'with GERT' while the heart rate shows an increase when a subject is wearing GERT. In 11 of the 17 graphs a clear increase in heart rate is seen when the subject performs the same activity between 'without GERT' and 'with GERT'. This visual analysis shows that the intensity and heart rate graph over time could give an indication of functional recovery. This plot is more to continuous monitoring, instead of the method in which every heart rate is assigned to a specific minute, as can be seen in *Figure 9*. Although it is important to keep in mind that the visual analysis may be inaccurate and is not supported by statistical tests.

There is no significant difference in average heart rate per classification between 'with GERT' and 'without GERT'. This is not in accordance with the hypothesis that the average heart rate 'with GERT' is higher per classification than 'without GERT'. An explanation can be that the heart rate shows a delayed response[83] to an activity, which makes the heart rate not directly relatable to the classification of an activity.

Number of steps

While analysing the accuracy of the number of steps measured by the Fitbit Charge HR, a distinction is made between 'without GERT' and 'with GERT'. This is for the reason that a subject may walk more shuffling when wearing GERT. This could affect the acceleration that the Fitbit ankle undergoes, and thereby the number of steps. Only for phase 3 all the *Spearman Correlation Coefficients (SCC)* are significant. The SCC is higher (0.707) 'without GERT' than 'with GERT' (0.627), which is possibly caused by shuffling. Elderly hip fracture patients will also walk more shuffling[84] which thus may lead to a lower correlation for the Fitbit attached to the ankle when used by elederly people.

In phase 2, the step frequency of 50 bpm shows a significant SCC of 0.802 for the Fitbit attached to the wrist when a subject is not wearing GERT. This does not meet the expectations, because the hypothesis was that the Fitbit attached to the wrist, when making use of a walker, would be inaccurate. This is because this Fitbit[85] would not undergo acceleration during walking with a walker and the number of steps would, therefore, not be counted. When looking at the correlation graph (see *Figure 7*), it becomes clear that the number of steps on 50 bpm is not measured accurately. The measured number of steps is overestimated as often as underestimated, which probably leads to this high correlation coefficient.

The correlation graph of the number of steps measured by observer and Fitbit ankle 'with GERT', in *Figure 7 and 8* in *Section 5.3.4 Data analysis*, is clearly divided into three groups of steps: 100 steps, 200 steps and 250-300 steps. These groups were created because subjects walked at a step frequency of 50 bpm, 100 bpm and 145 bpm for two minutes. These graphs show the highest correlation for a step frequency of 100 bpm (= 200 steps). Which is confirmed by the highest and significant SCC (=0.707) of all three step frequencies. The differences between the correlation graphs of the Fitbit wrist and the Fitbit ankle show that the Fitbit attached to the ankle measured the number of steps more accurate when using a walker.

In phase 3, the subjects walked on a step frequency of 80 bpm and did not use a walker. This led to significant SCC's for both wrist and ankle. When a subject is wearing GERT the Fitbit attached to the wrist has a higher SCC than the Fitbit attached to the ankle. However, there is no significant difference between the number of steps measured by the Fitbit attached to the wrist and the Fitbit attached to the ankle. There is a significant difference between the Fitbit attached to the wrist and the Fitbit attached to the ankle for phase 2, when the subjects make use of a walker. When a hip fracture patient is walking with a walker, which will often occur during rehabilitation,[58] the Fitbit attached to the ankle is much more accurate for measuring the number of steps.

Intensity and classification

By making use of a journal during the experiment, researchers knew the duration of every specific activity. Subsequently, as described in the data analysis, every specific activity is assigned to a specific minute, which makes it possible to compare data of different subjects. These results are shown in *Figures 13, 14 and 15*. During phase 2 and phase 3 a great overlay between the different subjects is seen, therefore it can be concluded that the MOX measured approximately the same intensities for every subject during the same activity.

After calculating the average classification during phase 2 for every subject, it was found that the lowest step frequency did not display the correct classification. This activity was meant to be 'LPA' (= classification 3), while the average showed that MOX assigned 'Standing' (= classification 2) to this activity. This can be explained by the determination of the step frequencies corresponding to the classifications were based on the test phase. The test phase was performed by one subject, while every person has a slightly different gait pattern.[80] The determination of the step frequencies and corresponding classifications (LPA, MPA and VPA) would have been more reliable when repeating this for other subjects. Therefore, the classifications measured in this experiment are not analysed to draw conclusions about the monitoring of functional recovery. However, if classifications measured by MOX are going to be used in further research, it is recommended to check if the correct classification is assigned to the step frequency of elderly people.

7 Recommendations

As mentioned in the *Section 6 Discussion*, this study population is very different from the population of elderly hip fracture patients. Since this study is still far from being implemented into hip fracture patients, further research is necessary.

It is recommended to do further research to determine if the shown differences within a parameter between 'without GERT' and 'with GERT' also applies to elderly hip fracture patients. Moreover, the population of the experiment of this study is very small and this may occur to misleading results of the statistical tests. Overall, it is recommended to execute a comparable experiment with a small population of hip fracture patients firstly, and thereafter a larger population of hip fracture patients.

This study only included parameters which could be measured by at least one of the monitor devices, in order to continuously monitor functional recovery. Due to restrictions of the technology specifications of the monitor devices, other important parameters, which are also related to the safe and independent way of performing an activity, were not included. Additionally, it is recommended to do further research into the degree of mobility. This is because degree of mobility[39] depends on gait speed, balance, minimum foot clearance and resilience, which is further explained in *Appendix I: Additional parameters*. These parameters are of importance in determining the ability to move safely and independently[39] and should be further investigated, as this was not investigated in this study.

Lastly, instead of using the converted data by algorithms, it is recommended to do further research into the raw data of the MOX. Potential parameters, such as gait speed and step width variability, can possibly be analysed by using raw data of the MOX. In this way it is possible to gain more insight into the activity pattern of elderly people and the independent and safe performance of an activity.

8 Conclusion

According to literature research and conducted interviews, the definition of functional recovery of elderly hip fracture patients is defined as follows:

"Functional recovery of a hip fracture patient is returning to the premorbid living situation by achieving a safe and independent performance of their personal targets of physical functioning, with a low fatigability."

The determined parameters to monitor functional recovery by making use of the Fitbit Charge HR and MOX, are: heart rate, active minutes, intensity and classifications of activities and number of steps. These parameters are examined during an experiment with eight young and healthy subjects who performed activities 'with GERT' and 'without GERT', an age simulation suit. This suit is used to simulate progress in the rehabilitation process caused by functional recovery.

When the subjects made use of a walker, the number of steps measured by the Fitbit attached to the wrist was completely inaccurate while the Fitbit attached to the ankle showed a high correlation with the observed number of steps, the gold standard. When the subjects did not use a walker, the Fitbit attached to the wrist showed a higher correlation coefficient with the observed number of steps in comparison to the Fitbit attached to the ankle. Unlike the correlation coefficients for walking with a walker, the correlation coefficients for walking without a walker are all significant.

Significant differences were found between increase in heart rate for 'without GERT' and 'with GERT'. The increase in heart rate was higher when a subject was wearing GERT. This shows that the parameter heart rate increase is promising in continuously monitoring functional recovery of elderly hip fracture patients, and is therefore a useful parameter for further research.

To continuously monitor functional recovery, the increase in heart rate during two equal intensities could be compared over time. When the increase in heart rate decreases over time for two equal intensities, a patient is probably functionally recovering. Also, the measured number of steps and intensities can give an indication of functional recovery by gaining more insight into the active minutes of a patient. For these reasons, a combination of the Fitbit Charge HR and the MOX is recommended to continuously monitor functional recovery of a hip fracture patient, during the rehabilitation process.

An important aspect to take into account is the representivity of this research for the elderly people with a hip fracture. The small study population consists of healthy and young subjects, which is completely different from the elderly hip fracture patients. Also, the measured parameters may be affected due to aging.

Furthermore, due to restrictions of the technology specifications of the monitor devices, other important parameters, which are related to the safe and independent way of performing an activity, were not included. However, these parameters are of importance in evaluating progress during the rehabilitation process, and therefore functional recovery. For this reason, it is recommended to do further research into these parameters.

References

[1] Margriet C. Pol, Gerben ter Riet, Margo van Hartingsveldt, Ben Kröse, Sophia E. de Rooij, and Bianca M. Buurman. Effectiveness of sensor monitoring in an occupational therapy rehabilitation program for older individuals after hip fracture, the SO-HIP trial: study protocol of a three-arm stepped wedge cluster randomized trial. *BMC Health Services Research*, 17(1):3, dec 2017.

[2] Dario Tedesco, Dino Gibertoni, Paola Rucci, Tina Hernandez-Boussard, Simona Rosa, Luca Bianciardi, Maurizia Rolli, and Maria Pia Fantini. Impact of rehabilitation on mortality and readmissions after surgery for hip fracture. *BMC health services research*, 18(1):701, sep 2018.

[3] Ellis Folbert. *Geriatric Traumatology: The effectiviness of integrated orthogeriatric treatment on 1-year outcome in frail elderly with hip fracture*. PhD thesis, 2017.

[4] Toby Smith, Kelum Pelpola, Martin Ball, Alice Ong, and Phyo Kyaw Myint. Pre-operative indicators for mortality following hip fracture surgery: a systematic review and meta-analysis. *Age and Ageing*, 43(4):464–471, jun 2014.

[5] Landelijke Trauma Registratie. Acute ziekenhuisopnames voor heupfracturen. *Landelijk netwerk acute zorg*, 2014.

[6] Levana G. Amrock and Stacie Deiner. The implication of frailty on preoperative risk assessment. *Current Opinion in Anaesthesiology*, 27(3):330–335, jun 2014.

[7] B. Abrahamsen, T. van Staa, R. Ariely, M. Olson, and C. Cooper. Excess mortality following hip fracture: a systematic epidemiological review. *Osteoporosis International*, 20(10):1633–1650, oct 2009.

[8] Centraal Bureau voor de Statistiek. CBS StatLine - Sterfte na 1e ziekenhuisopname, naar geslacht, leeftijd en VTV-diagnose, 2008.

[9] Zorgpad revalidatie na een heupfractuur. *ZGT*, page 13, 2019.

[10] Fitbit Help. Product Manual Fitbit Charge HR. Technical report, 2019.

[11] Fitbit Help. User Manual Fitbit Zip. Technical report, 2019.

[12] Maastricht Instruments BV. MOX1 - Accelerometry.eu.

[13] Z Arinvon, Z Fidelman, and A. Zuta. Functional recovery after hip fracture in old-old elderly patients. *Archives of Gerontology and Geriatrics*, 40(3):327–336, may 2005.

[14] Agur A. M. R. Moore K. L., Dalley A. F. Hip Joint Anatomy. In *Clinically Oriented Anatomy*, chapter 5, pages 626–634. Lippincott Williams & Wilkins, 7th edition, 2013.

[15] A M R Agur, A F Dalley, and J C B Grant. *Hip Joint Anatomy*. GRANT, JOHN CHARLES BOILEAU//GRANT'S ATLAS OF ANATOMY. Wolters Kluwer Health/Lippincott Williams & Wilkins, 13th edition, 2013.

[16] David A Provenzano and Kailash Chandwani. 71 - Joint Injections. pages 966–980.e4. Mosby, Philadelphia, 2014.

[17] Romée Snijders and Veerle Smit. Hoofdstuk 19: Orthopedie. In *Compendium Geneeskunde 3*, page 187&203. 2016.

[18] Jane A Cauley. Estrogen and bone health in men and women. *Steroids*, 99(Pt A):11–15, jul 2015.

[19] Howard A Fink, Susan K Ewing, Kristine E Ensrud, Elizabeth Barrett-Connor, Brent C Taylor, Jane A Cauley, and Eric S Orwoll. Association of testosterone and estradiol deficiency with osteoporosis and rapid bone loss in older men. *The Journal of clinical endocrinology and metabolism*, 91(10):3908–3915, oct 2006.

[20] Kendall F Moseley and Suzanne M Jan de Beur. Osteoporosis in Men and Women. In Marianne J Legato, editor, *Principles of Gender-Specific Medicine (Second Edition)*, chapter 59, pages 716–736. Academic Press, San Diego, second edi edition, 2010.

[21] Sundeep Khosla, Merry Jo Oursler, and David G Monroe. Estrogen and the skeleton. *Trends in endocrinology and metabolism: TEM*, 23(11):576–581, nov 2012.

[22] J C Rozell, M Hasenauer, D J Donegan, and M Neuman. Recent advances in the treatment of hip fractures in the elderly. *F1000Research*, 5(1953), 2016.

[23] Martyn Parker and Antony Johansen. Hip fracture. *BMJ*, 333(7557):27 LP – 30, jun 2006.

[24] Patiëntenfolder Gebroken Heup, 2019.

[25] Rehabilitation programme after dynamic hip screw (DHS) surgery. Technical report.

[26] DePuy Synthes. PFNA. Proximal Femoral Nail Antirotation Surgical Technique. Technical report.

[27] E C Folbert, · J H Hegeman, · R Gierveld, · J J Van Netten, · D Van Der Velde, · H J Ten Duis, and · J P Slaets. Complications during hospitalization and risk factors in elderly patients with hip fracture following integrated orthogeriatric treatment. *Archives of Orthopaedic and Trauma Surgery*, 137:507–515, 2017.

[28] Ellis Folbert and J.H. Hegeman. Interview met verpleegkundig specialist en traumachirurg, 2019.

[29] Margriet Pol, Sebastiaan Peek, Fenna van Nes, Margo van Hartingsveldt, Bianca Buurman, and Ben Kröse. Everyday life after a hip fracture: what community-living older adults perceive as most beneficial for their recovery. *Age and Ageing*, 48(3):440–447, 2019.

[30] D. Van Dartel and M. Vollenbroek-Hutten. MDO-opdracht: Continue monitoring bij kwetsbare ouderen met een heupfractuur, 2019.

[31] FitBit. Fitbit Help - Charge hr.

[32] FitBit Inc. Fitbit Help - Zip.

[33] Maastricht Instruments BV. Activity Monitor Comparison - Accelerometry.eu.

[34] Help article: How does my Fitbit device calculate my daily activity?

[35] FitBit. Charge HR 101 Guide.

[36] M A Sarzynski, T Rankinen, C P Earnest, A S Leon, D C Rao, J S Skinner, and C Bouchard. Measured maximal heart rates compared to commonly used age-based prediction equations in the Heritage Family Study. *American journal of human biology : the official journal of the Human Biology Council*, 25(5):695–701, 2013.

[37] 'Produkt + Projekt' Wolfgang Moll. Age Simulation Suit GERT.

[38] Simona Vlad, · Nicolae, and Marius Roman. International Conference on Advancements of Medicine and Health Care through Technology;. Technical report, IFMBE Proceedings, 2016.

[39] Aftab E Patla and Anne Shumway-Cook. Dimensions of Mobility: Defining the Complexity and Difficulty Associated with Community Mobility. *Journal of Aging and Physical Activity*, 7(1):7–19, jan 1999.

[40] Konstantinos I Alexiou, Andreas Roushias, Sokratis E Varitimidis, and Konstantinos N Malizos. Quality of life and psychological consequences in elderly patients after a hip fracture: a review. *Clinical interventions in aging*, 13:143–150, 2018.

[41] Anu Salpakoski, Timo Törmäkangas, Johanna Edgren, Mauri Kallinen, Sanna E Sihvonen, Maija Pesola, Jukka Vanhatalo, Marja Arkela, Taina Rantanen, and Sarianna Sipilä. Effects of a Multicomponent Home-Based Physical Rehabilitation Program on Mobility Recovery After Hip Fracture: A Randomized Controlled Trial. *Journal of the American Medical Directors Association*, 15(5):361–368, 2014.

[42] Erja Portegijs, Sarianna Sipilä, Satu Pajala, Sarah E Lamb, Markku Alen, Jaakko Kaprio, Markku Koskenvuo, and Taina Rantanen. Asymmetrical Lower Extremity Power Deficit As A Risk Factor For Injurious Falls In Healthy Older Women. *Journal of the American Geriatrics Society*, 54(3):551–553, 2006.

[43] YI.L. Shyu, MC. Chen, and J. Liang. Predictors of functional recovery for hip fractured elders during 12 months following hospital discharge: a prospective study on a Taiwanese sample. *Osteoporosis International*, 15(6):475–482, 2004.

[44] Benjamin Pageaux. Perception of effort in Exercise Science: Definition, measurement and perspectives. *European Journal of Sport Science*, 16(8):885–894, 2016.

[45] Johannes Scherr, Bernd Wolfarth, Jeffrey W. Christle, Axel Pressler, Stefan Wagenpfeil, and Martin Halle. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *European Journal of Applied Physiology*, 113(1):147–155, jan 2013.

[46] Jose A. Rodríguez-Marroyo and Carlos Antoñan. Validity of the Session Rating of Perceived Exertion for Monitoring Exercise Demands in Youth Soccer Players. *International Journal of Sports Physiology and Performance*, 10(3):404–407, apr 2015.

[47] Durva Vahia, Adam Kelly, Harry Knapman, and Craig A. Williams. Variation in the Correlation Between Heart Rate and Session Rating of Perceived Exertion-Based Estimations of Internal Training Load in Youth Soccer Players. *Pediatric Exercise Science*, 31(1):91–98, feb 2019.

[48] Shona L. Halson. Monitoring Training Load to Understand Fatigue in Athletes. *Sports Medicine*, 44(S2):139–147, nov 2014.

[49] Kent Sahlin. Metabolic Factors in Fatigue. *Sports Medicine*, 13(2):99–107, feb 1992.

[50] R H Edwards. Human muscle function and fatigue. *Ciba Foundation symposium*, 82:1–18, 1981.

[51] Susan E Hardy and Stephanie A Studenski. Fatigue predicts mortality in older adults. *Journal of the American Geriatrics Society*, 56(10):1910–4, oct 2008.

[52] K H Münter, C G Clemmesen, N B Foss, H Palm, and M T Kristensen. Fatigue and pain limit independent mobility and physiotherapy after hip fracture surgery. *Disability and Rehabilitation*, 40(15):1808–1816, 2018.

[53] Romain &NA;, Martine Duclos, Carl Foster, Andrew Fry, Michael Gleeson, David Nieman, John Raglin, Gerard Rietjens, Jürgen Steinacker, Axel Urhausen, European College of Sport Science, and American College of Sports Medicine. Prevention, Diagnosis, and Treatment of the Overtraining Syndrome. *Medicine & Science in Sports & Exercise*, 45(1):186–205, jan 2013.

[54] Catherine A Richardson, Nancy W Glynn, Luigi G Ferrucci, and Dawn C Mackey. Walking energetics, fatigability, and fatigue in older adults: the study of energy and aging pilot. *The journals of gerontology. Series A, Biological sciences and medical sciences*, 70(4):487–94, apr 2015.

[55] Leslie M Julius, Jennifer S Brach, David M Wert, and Jessie M VanSwearingen. Perceived effort of walking: relationship with gait, physical function and activity, fear of falling, and confidence in walking in older adults with mobility limitations. *Physical therapy*, 92(10):1268–77, oct 2012.

[56] Eleanor M Simonsick, Jennifer A Schrack, Nancy W Glynn, and Luigi Ferrucci. Assessing fatigability in mobility-intact older adults. *Journal of the American Geriatrics Society*, 62(2):347–51, feb 2014.

[57] Basil A. Eldadah. Fatigue and Fatigability in Older Adults. *PM&R*, 2(5):406–413, may 2010.

[58] Patiënten. Interviews in het ZGT, 2019.

[59] Alien and Michelle. Interview Carintreggeland, 2019.

[60] Sanne Woudsma. Interviews Krönnenzommer, 2019.

[61] J. Magaziner, W. Hawkes, J. R. Hebel, S. I. Zimmerman, K. M. Fox, M. Dolan, G. Felsenthal, and J. Kenzora. Recovery From Hip Fracture in Eight Areas of Function. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 55(9):M498–M507, sep 2000.

[62] V Pichot, F Roche, J.-M. Gaspoz, F Enjolras, A Antoniadis, P Minini, F Costes, T Busso, J.-R. Lacour, and J C Barthelemy. Relation between heart rate variability and training load in middle-distance runners. *Medicine and Science in Sports and Exercise*, 32(10):1729–1736, 2000.

[63] Jill Borresen and Michael I Lambert. Changes in heart rate recovery in response to acute changes in training load. *European journal of applied physiology*, 101(4):503–511, nov 2007.

[64] G Borg, P Hassmen, and M Lagerstrom. Perceived exertion related to heart rate and blood lactate during arm and leg exercise. *European journal of applied physiology and occupational physiology*, 56(6):679–685, 1987.

[65] David Martin and M B Andersen. *Heart rate-perceived exertion relationship during training and taper*, volume 40. oct 2000.

[66] Mohammad A. Auais, Owis Eilayyan, and Nancy E. Mayo. Extended Exercise Rehabilitation After Hip Fracture Improves Patients' Physical Function: A Systematic Review and Meta-Analysis. *Physical Therapy*, 92(11):1437–1451, nov 2012.

[67] Chiung-ju Liu and Nancy K Latham. Progressive resistance strength training for improving physical function in older adults. *Cochrane Database of Systematic Reviews*, (3), jul 2009.

[68] Tracey E Howe, Lynn Rochester, Fiona Neil, Dawn A Skelton, and Claire Ballinger. Exercise for improving balance in older people. *Cochrane Database of Systematic Reviews*, (11), nov 2011.

[69] Lesley D Gillespie, M Clare Robertson, William J Gillespie, Catherine Sherrington, Simon Gates, Lindy M Clemson, and Sarah E Lamb. Interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews*, (9), sep 2012.

[70] Heike A. Bischoff-Ferrari, Bess Dawson-Hughes, Andreas Platz, Endel J. Orav, Hannes B. Stähelin, Walter C. Willett, Uenal Can, Andreas Egli, Nicolas J. Mueller, Silvan Looser, Beat Bretscher, Elisabeth Minder, Athanasios Vergopoulos, and Robert Theiler. Effect of High-Dosage Cholecalciferol and Extended Physiotherapy on Complications After Hip Fracture. *Archives of Internal Medicine*, 170(9):813, may 2010.

[71] WHO | What is Moderate-intensity and Vigorous-intensity Physical Activity? *WHO*, 2014.

[72] St Antonius Ziekenhuis. Oefeningen na uw heupoperatie Oefeningen na uw heupoperatie. *Fysiotherapie*.

[73] Medisch Spectrum Twente. Een gebroken heup: Orthopedie & Chirurgie. Technical report.

[74] Caroline N Harada, Marissa C Natelson Love, and Kristen L Triebel. Normal cognitive aging. *Clinics in geriatric medicine*, 29(4):737–752, nov 2013.

[75] Christina A Mosk, Marnix Mus, Jos Pam Vroemen, Tjeerd van der Ploeg, Dagmar I Vos, Leon Hgj Elmans, and Lijckle van der Laan. Dementia and delirium, the outcomes in elderly hip fracture patients. *Clinical interventions in aging*, 12:421–430, mar 2017.

[76] Maria Elizabet Furlaneto and Luiz EugÃ\textordfemeninenio Garcez-Leme. Delirium in elderly individuals with hip fracture: causes, incidence, prevalence, and risk factors. *Clinics*, 61:35–40, 2006.

[77] Xin Wang, Ramón A Piñol, Peter Byrne, and David Mendelowitz. Optogenetic stimulation of locus ceruleus neurons augments inhibitory transmission to parasympathetic cardiac vagal neurons via activation of brainstem $\alpha 1$ and $\beta 1$ receptors. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, 34(18):6182–9, apr 2014.

[78] Marcos Antonio Almeida Santos, Antonio Carlos Sobral Sousa, Francisco Prado Reis, Thayná Ramos Santos, Sonia Oliveira Lima, and José Augusto Barreto-Filho. Does the aging process significantly modify the Mean Heart Rate? *Arquivos brasileiros de cardiologia*, 101(5):388–98, nov 2013.

[79] Mercedes R Carnethon, Barbara Sternfeld, Kiang Liu, David R Jacobs, Pamela J Schreiner, O Dale Williams, Cora E Lewis, Stephen Sidney, and Stephen Sidney. Correlates of heart rate recovery over 20 years in a healthy population sample. *Medicine and science in sports and exercise*, 44(2):273–9, feb 2012.

[80] Michael. Whittle. *Gait analysis : an introduction*. Butterworth-Heinemann, 2007.

[81] Robert Wang, Gordon Blackburn, Milind Desai, Dermot Phelan, Lauren Gillinov, Penny Houghtaling, and Marc Gillinov. Accuracy of Wrist-Worn Heart Rate Monitors. *JAMA Cardiology*, 2(1):104–106, jan 2017.

[82] M.D. Howard Lewine. Increase in resting heart rate is a signal worth watching, 2012.

[83] Jussi Peltonen. Running power is here – Does it mean heart rate training is old news? | Polar Blog.

[84] Anke H Snijders, Bart P van de Warrenburg, Nir Giladi, and Bastiaan R Bloem. Neurological gait disorders in elderly people: clinical approach and classification. *The Lancet. Neurology*, 6(1):63–74, jan 2007.

[85] Hoe berekent mijn Fitbit-apparaat mijn dagelijkse activiteit, 2019.

[86] Annika Hellzen Ingemarsson, Kerstin Frandin, Dan Mellstrom, and Margareta Moller. Walking ability and activity level after hip fracture in the elderly–a follow-up. *Journal of rehabilitation medicine*, 35(2):76–83, mar 2003.

[87] Dawn E. Alley, Gregory E. Hicks, Michelle Shardell, William Hawkes, Ram Miller, Rebecca L. Craik, Kathleen K. Mangione, Denise Orwig, Marc Hochberg, Barbara Resnick, and Jay Magaziner. Meaningful Improvement in Gait Speed in Hip Fracture Recovery. *Journal of the American Geriatrics Society*, 59(9):1650–1657, sep 2011.

[88] Hanatsu Nagano, Lisa James, William A Sparrow, and Rezaul K Begg. Effects of walking-induced fatigue on gait function and tripping risks in older adults. *Journal of neuroengineering and rehabilitation*, 11:155, nov 2014.

[89] Rezaul Begg, Russell Best, Lisa Dell'Oro, and Simon Taylor. Minimum foot clearance during walking: Strategies for the minimisation of trip-related falls. *Gait & Posture*, 25(2):191–198, 2007.

[90] P. Garnero, E. Hausherr, M.-C. Chapuy, C. Marcelli, H. Grandjean, C. Muller, C. Cormier, G. Bréart, P.J. Meunier, and Pierre D. Delmas. Markers of bone resorption predict hip fracture in elderly women: The EPIDOS prospective study. *Journal of Bone and Mineral Research*, 11(10):1531–1538, dec 2009.

[91] Kari L Loverro, Nicole M Mueske, and Kate A Hamel. Location of minimum foot clearance on the shoe and with respect to the obstacle changes with locomotor task. *Journal of biomechanics*, 46(11):1842–1850, jul 2013.

[92] L Sciumè, G A A Rebagliati, P Iannello, A Mottini, A Alessandro, A V Caserta, V Gattoronchieri, and L Panella. Rehabilitation after urgent or elective orthopedic surgery: The role of resilience in elderly patients. *Rehabilitation Nursing*, 43(5):267–274, 2018.

[93] B S Felten and J M Hall. Conceptualizing resilience in women older than 85: overcoming adversity from illness or loss. *Journal of gerontological nursing*, 27(11):46–53, nov 2001.

[94] Gregory Hicks and Ram R Miller. Physiological Resilience. In Barbara Resnick, Lisa P Gwyther, and Karen A Roberto, editors, *Resilience in Aging*, pages 89–103. Springer New York, New York, NY, 2011.

[95] K M Connor and J R T Davidson. Development of a new resilience scale: The Connor-Davidson Resilience scale (CD-RISC). *DEPRESSION AND ANXIETY*, 18(2):76–82, 2003.

[96] Amanda J Lamond, Colin A Depp, Matthew Allison, Robert Langer, Jennifer Reichstadt, David J Moore, Shahrokh Golshan, Theodore G Ganiats, and Dilip V Jeste. Measurement and predictors of resilience among community-dwelling older women. *Journal of Psychiatric Research*, 43(2):148–154, 2008.

[97] R A Burns and K J Anstey. The Connor–Davidson Resilience Scale (CD-RISC): Testing the invariance of a uni-dimensional resilience measure that is independent of positive and negative affect. *Personality and Individual Differences*, 48(5):527–531, 2010.

[98] Sabrina Kohler and Sze Ming Loh. Patient resilience in the fracture orthopaedic rehabilitation geriatric environment. *Australasian Journal on Ageing*, 36(1):65–68, 2017.

[99] Darlene Yee-Melichar, Andrea Renwanz Boyle, Linda J Wanek, and Sarah B Pawlowsky. Geriatric rehabilitation and resilience from a cultural perspective. *Geriatric nursing (New York, N.Y.)*, 35(6):451–454.e9, 2014.

Appendices

Appendix A: Clinimetric Tests

Clinimetric tests	Purpose	Parameters
(Pre-)Fracture Mobility Score (FMS)	What is the mobility of the patient? Does the patient need some assistance or an aid to move?	Mobility
Functional Ambulation Categories (FAC)	How well can the patient walk (independently)?	Ambulant status and mobility
Katz-6-ADL	Is the patient able to do ADL independently?	Functional independence
Barthel index	Is the patient able to do ADL (independently)?	Functional independence
Time Up and Go test (TUG)	Determining fall risk and measuring the progress of balancing, sitting to standing, gait and gait speed.	Fall risk (walking, balance) and mobility[?]
10 Meter Walk Test (10MWT)	Measuring gait speed (comfortable) and measuring maximum walking speed over a distance of 10 meter.	Walking ability and mobility[?]
Charison Comorbidity Index (CCI)	Predicting the risk of mortality for a patient who may have a range of comorbid conditions.	Comorbidity
Short Nutritional Assessment Questionnaire (SNAQ)	Detecting malnutrition.	Malnutrition
Short Nutritional Assessment Questionnaire for Residential Care (SNAQrc)	Detecting malnutrition.	Malnutrition
Montreal Cognitive Assessment (MOCA)	Measuring cognitive decline.	Cognition
Living situation	Changing of the living situation	Living situation

Table 6: *List of clinimetric tests*

Appendix B: Composed questions for the interviews

Questions during interviews on specialists

Voorafgaand aan de heupfractuur

1. Wat zijn de oorzaken van het ontstaan van een heupfractuur?
   (a) Wat is de meest voorkomende oorzaak van het ontstaan van een heupfractuur?
2. Wat zijn de verschillende woonsituaties van een patiënt voorafgaand aan de fractuur?
   (a) Wat is de meest voorkomende woonsituatie?

Revalidatieproces

3. Wat zijn de doelen van patiënten voor het revalidatieproces?
   (a) Wat is het meest voorkomende doel van patiënten voor het revalidatieproces?
4. Wordt het revalidatieproces aangepast aan de hand van de doelen/wensen van de patiënt?
   (a) Zo ja, hoe wordt dit gedaan?
   (b) Denkt u dat een gepersonaliseerd revalidatieproces meer motiverend werkt?
   (c) Zo nee, denkt u dat het personaliseren het revalidatieproces wel zou kunnen verbeteren?
   (d) Denkt u dat een gepersonaliseerd revalidatieproces meer motiverend zou kunnen werken?
5. Ziet u (andere) mogelijkheden om het revalidatieproces te verbeteren? Zo ja, hoe?
   (a) Denkt u dat continu monitoren een voordeel is ten opzichte van meten in tijdsopnames?
6. Welke testen worden er uitgevoerd om het herstel in beeld te brengen?
   (a) Wat meet u hier allemaal bij (parameters)?
   (b) Zijn er standaard uitkomsten/richtlijnen die herstel definiëren?
7. Waaraan merkt u dat een patiënt op de goede weg is? Voorbeelden.
8. Welke complicaties kunnen optreden die van invloed zijn op het revalidatieproces? (denk hierbij aan: omgeving, ondersteuning van naasten, thuiszorg, motivatie, woonsituatie, comorbiditeit, gezondheid)
   (a) Wat is de meest voorkomende complicatie die van invloed is op het revalidatieproces?

Functioneel herstel

9. Wat is volgens u de definitie van functioneel herstel?
   (a) Hoe bepalen jullie dat een patiënt naar huis kan?
   (b) Hoe bepalen jullie dat een patiënt hersteld is?
10. Wat is belangrijk voor een goed herstel?
    (a) Is de hoek van de heup van belang?
    (b) Is de stapgrootte van belang?
    (c) Is het stappen aantal van belang?
    (d) Is de loopsnelheid van belang?
    (e) Zijn dagelijkse activiteiten van belang?

Up&Go Project

11. Voert u andere metingen uit sinds het Up & Go Project is opgestart?
    (a) Zo ja, welke?
12. Ziet u al voordelen in het Up & Go Project?

Questions during interviews on patients

1. Hoe zelfstandig was u voordat u uw heup brak?
    (a) Woonsituatie
    (b) Leefomgeving
    (c) Wat deed u op een dag?
    (d) Liep u nog (veel) zelfstandig?
2. Wat denkt u dat het doel is van de revalidatie?
3. Welke doelen heeft u voor ogen om te bereiken na het revalidatieproces?
4. Welke dingen vindt u belangrijk tijdens het herstel?

Appendix B: Questions answered

Interview on specialists at Carintreggeland Delden

Voorafgaand aan de heupfractuur

1. Wat zijn de oorzaken van het ontstaan van een heupfractuur?

   Vallen vanwege onhandigheid is de meestvoorkomende oorzaak, denk hierbij aan fietsen, struikelen, etc.

2. Wat zijn de verschillende woonsituaties van een patiënt voorafgaand aan de fractuur?

   Alleenwonend (met evt. een partner), in een verpleeghuis of bejaardentehuis

Revalidatieproces

3. Wat zijn de doelen van patiënten voor het revalidatieproces?
   Hoofddoel: dat ze zelfstandig weer kunnen leven in de situatie waarin ze leefden, maar daarnaast is het ook van belang dat de patiënten hun eigen doelen bereikt hebben.
   Over het algemeen herstellen naar de oude woonsituatie. Dit is voor elke patiënt anders.
   Voorbeelden:

   - *Fietsen (zelfs een patiënt wilde 40 km op een dag kunnen fietsen);*
   - *Traplopen;*
   - *Bepaalde afstanden lopen;*
   - *Gewoon thuis wonen in het algemeen (bijv. omdat ze ongelukkig zijn in het verpleeghuis).*

   De doelen van de patiënt zijn afhankelijk van de thuissituatie vóór het oplopen van de breuk en het sociale aspect om de patiënt.

   (a) Wat is het meest voorkomende doel van patiënten voor het revalidatieproces?
   Lopen.

4. Zit er verschil in het revalidatieproces bij de verschillende behandelingen?
   In het geval van een prothese is kans op luxatie. Hier moet bij het revalidatieproces rekening mee gehouden worden doordat de patiënt geen kleinere hoek dan 90 graden mag maken. De handelingen van sokken aandoen of bukken bijvoorbeeld mogen dus niet.
   Bij het gebruik van pinnen is het revalidatieproces afhankelijk van de pijn. Zodra de patiënt bijvoorbeeld zelfstandig sokken aan kan doen, mag dit. Komt hier te veel pijn bij kijken, moet deze handeling vermeden worden.
   In het geval van een pertrochantere breuk waarbij het geen nette breuk is, mag de patiënt in de eerste vier weken het been maar 50 procent belasten. Per patiënt verschilt deze percentage aan belasting.

5. Wordt het revalidatieproces aangepast aan de hand van de doelen/wensen van de patiënt?

   Het revalidatieproces wordt aangepast op wat de patiënten willen en kunnen bereiken. Sommige patiënten worden bijvoorbeeld veel eerder ontslagen terwijl ze lang niet alles kunnen, terwijl andere patiënten langer aan het revalideren zijn om een beter resultaat te krijgen.

6. Ziet u (andere) mogelijkheden om het revalidatieproces te verbeteren? Zo ja, hoe?

   Ja! Momenteel is het namelijk erg subjectief wat het heel lastig maakt om te oordelen of patiënten volledig hersteld zijn of niet. De momentopnames kunnen er namelijk ook voor zorgen dat patiënten zich van de beste kant laten zien terwijl ze over het algemeen geen vooruitgang boeken of maar minimaal inzetten.
   Door gebruik te maken van continue monitoring zullen wij meer info verkrijgen over een patiënt wat er voor zorgt dat we meer sturing kunnen geven aan een patiënt en hem/haar ook meer te stimuleren aan de hand van betere feedback.

7. Waaraan merkt u dat een patiënt op de goede weg is? Voorbeelden.

   Elke dag/weken worden dezelfde oefeningen uitgevoerd. Op het moment dat de oefeningen beter gaan ten opzichte van voorgaande oefeningen, ziet de fysiotherapeut dat er verbetering is.

8. Welke complicaties kunnen optreden die van invloed zijn op het revalidatieproces? (denk hierbij aan: omgeving, ondersteuning van naasten, thuiszorg, motivatie, woonsituatie, comorbiditeit, gezondheid)

(a) Wat is de meest voorkomende complicatie die van invloed is op het revalidatieproces?

Een patiënt kan naar huis gestuurd worden terwijl hij/zij nog lang niet klaar is om naar huis te gaan. Maar zo lang er thuis mensen zijn die voor de patiënt kunnen zorgen is er niets aan de hand. Als deze mensen er niet zijn mogen ze absoluut niet naar huis.

Functioneel herstel

9. Wat is volgens u de definitie van functioneel herstel?

   Er is niet echt een beschrijving voor functioneel herstel. Dit komt doordat het bij elke patiënt anders is en er veel meer factoren meespelen in het herstel dan alleen bepaalde handelingen. Functioneel herstel is bij elke patiënt anders. De definitie wordt hier afgestemd op de doelen die gesteld zijn. Over het algemeen hebben deze doelen vaak te maken met de woonsituatie voorafgaand aan de heupfractuur.

   (a) Hoe bepalen jullie dat een patiënt naar huis kan?

   Een patiënt wordt ontslagen op het moment dat hij/zij de doelen bereikt heeft, maar niet aan de hand van klinimetrische testen. Voordat de patiënt daadwerkelijk naar huis mag, worden nog wel klinimetrische testen uitgevoerd om het verschil te bekijken ten opzichte van het begin. Als een patiënt heel graag naar huis wil, maar nog niet genoeg hersteld is, mag deze naar huis, onder de voorwaarde dat de patiënt thuis goed opgevangen kan worden door familie, vrienden of thuiszorg.

   (a) Hoe bepalen jullie dat een patiënt hersteld is?

   Heel belangrijk is dat de patiënten zichzelf weer volledig kunnen redden op zowel praktisch gebied, als veiligheid.

10. Welke testen worden er uitgevoerd om het herstel in beeld te brengen?

    Bij binnenkomst worden klinimetrische testen (hier misschien de testen benoemen) uitgevoerd. 4 weken na de eerste afname van klinimetrische testen worden opnieuw klinimetrische testen uitgevoerd. Maar over het algemeen worden de testen niet als als maatstaf gebruikt, het is meer natte vinger werk door het observeren van de patiënt en ervaring.

    (a) Wat meet u hier allemaal bij (parameters)?

    We meten de:

    - *Zelfstandigheid;*
    - *Snelheid;*
    - *Looppatroon;*
    - *Vooruit;*
    - *Achteruit;*
    - *Draaien;*
    - *Anteversie/abductie etc.*

    (a) Zijn er standaard uitkomsten/richtlijnen die herstel definiëren?

    Nee.

11. Wat is belangrijk voor een goed herstel?

    Het is met name belangrijk dat het revalidatieproces wordt ingezet op wat de patiënten weer moeten en willen kunnen. Daarnaast is het ook heel belangrijk dat patiënten goed aan kunnen geven wat ze voelen en eerlijk zijn. Misschien hebben bepaalde oefeningen veel meer energie gekost dan dat de patiënten aangeven. Lastig te oordelen zonder testen. Ook is nachtrust heel belangrijk. Als een patiënt een slechte nacht gehad heeft, kan deze minder energie hebben en daardoor minder energie overhouden om te revalideren. Hierdoor zal het volledige revalidatieproces vertragen.

    (a) Is de hoek van de heup van belang?

    De hoek van de heup wordt wat minder meegenomen, omdat dit echt afhankelijk is van de stand van het lichaam wat de patiënt al had vóór de fractuur.

    (a) Is de stapgrootte van belang?

    Het is mogelijk dat bij een grotere stapgrootte de patiënt meer pijn ervaart. (dit was een mogelijke verklaring voor de vergrootte pijn bij meneer Schenk)

(a) Is de loopsnelheid van belang?

Het is belangrijker dat de patiënten goed lopen, dan snel .Als een patiënt namelijk snel loopt op de verkeerde manier, zal dit niet bevorderlijk zijn voor het herstel.

(a) Zijn dagelijkse activiteiten van belang?

Dit is erg van belang. Veel patiënten zitten heel erg veel op een dag terwijl lichaamsbeweging het revalidatieproces bevordert.

Up&Go Project

12. Voert u andere metingen uit sinds het Up & Go Project is opgestart?

    Nee. We doen zelf niet echt iets met de metingen.

13. Ziet u al voordelen in het Up & Go Project?

    Sinds het project zit er wel meer structuur in de oefeningen doordat ze op vaste tijden worden uitgevoerd. Echter is het wel lastig om de sensors in te zetten in deze doelgroep, omdat het een hele kwetsbare doelgroep is.
    Het revalidatieproces waarbij de patiënten bij ons zijn, is te kort om echt te oordelen of het daadwerkelijk profijt met zich meebrengt. Om echt inzicht te krijgen in de gegevens van de patiënten moet er namelijk wat langer gemeten worden om te kunnen vergelijken. Wel zou het continue monitoren een goede toevoeging zijn voor de thuissituatie zodat er gekeken kan worden of de patiënt erop vooruit of achteruit gaat.
    We hebben momenteel nog niet gekeken naar de uitkomsten, omdat het nog erg in de kinderschoenen staat. Binnenkort wordt dit voor het eerst gedaan dan kunnen we hier echt wat over zeggen.

Interview on patients at Carintreggeland Delden

Patient 1 | 91 years old

1. Hoe zelfstandig was u voordat u uw heup brak?

   In de woonsituatie was ik nog erg actief. Zo liep ik zonder hulpmiddel, fietste ik veel, werkte ik op de boerderij, ging ik elke dag bij mijn vrouw langs, ochtendgymnastiek en deed ik het huishouden.

2. Wat denkt u dat het doel is van de revalidatie?

3. Welke doelen heeft u voor ogen om te bereiken na het revalidatieproces?

   - *Fietsen;*
   - *Autorijden;*
   - *Traplopen;*
   - *1 km lopen met rollator naar z=mijn vrouw;*
   - *Zelfstandig in en uit bed.*

   Meneer heeft veel doelen, maar doet het rustig aan. Hij beseft heel goed dat hij niet te snel moet willen, omdat het herstellen enige tijd kan duren. Dit zegt hij uit ervaring vanwege zijn bypass operatie op zijn 71e.

4. Welke dingen vindt u belangrijk tijdens het herstel?

   Aangezien ik erg actief was, zou ik alles graag weer willen/kunnen doen na mijn revalidatieproces.

Patient 2 | 86 years old

1. Hoe zelfstandig was u voordat u uw heup brak?

   In de woonsituatie was ik nog erg actief. Zo liep ik zonder hulpmiddel, fietste ik veel, werkte ik op de boerderij, ging ik elke dag bij mijn vrouw langs, ochtendgymnastiek en deed ik het huishouden.

2. Wat denkt u dat het doel is van de revalidatie?

3. Welke doelen heeft u voor ogen om te bereiken na het revalidatieproces?

   - *Fietsen: Soms wel 30 a 40 km op een dag;*
   - *Autorijden: Ook lange afstanden deed hij nog ;*
   - *Zelfstandig in en uit bed.*

   Aangezien ik gelijkvloers woon, is het oefenen van traplopen geen primair doel.

4. Welke dingen vindt u belangrijk tijdens het herstel?

   Ik vind het belangrijk dat het rustig opgebouwd wordt om een optimaal resultaat te kunnen behalen.

Interview on specialists at ZGT

J.H. Hegeman E. Folbert

Voorafgaand aan de heupfractuur

1. Komen patiënten alleen voorafgaand aan de operatie of ook achteraf bij u langs?

   Drie maanden later (postoperatief) op de polikliniek om te kijken of ze goed herstellen.

2. In hoeverre bent u betrokken bij het revalidatieproces?

   Als de patiënten terugkomen op de poli zal de fysio er ook bij zijn. Hier wordt een afname gedaan van de functionele scores waarbij gekeken wordt naar hoe het gaat.
   In 2016 is het kwaliteitsaudeting systeem geïmplementeerd. Zodoende worden functionele aspecten van ouderen van 65 jaar of ouder bijgehouden om inzichtelijk te maken hoe patiënten het in een ziekenhuis doen.

3. Wat zijn de oorzaken van het ontstaan van een heupfractuur?
   Vallen vanuit staande positie:

   - *Struikelen over bijv. kleedjes of met de rollator;*
   - *Slaapmedicatie, antidepressiva;*
   - *Hyponatriëmie;*
   - *Gebrek aan motoriek/coördinatie.*

4. Waarom komt een heupfractuur vaker voor bij vrouwen dan bij mannen?

   Dit komt door osteoporose. Het feit dat vrouwen op middelbare leeftijd een hoger risico hebben op botontkalking. Dit kan komen door ontregeling van hormonen of het niet meer binnenkrijgen van bepaalde voedingsstoffen. Heeft niks te maken met bekkenstand. Veel bewegen voorkomt een hoop!

5. Wat is de meestvoorkomende woonsituaties van een patiënt voorafgaand aan de fractuur?
   In het ZGT vallen ¾ van de mensen bijna uit elkaar waarbij ze een ASA van minimaal 3 of hoger hebben. Dit betekent niet dat ze al volop in de zorg zitten.
   De minimale leeftijd is 80 waarbij de meeste patiënten alleenstaand is of de partner is mantelzorg.
   Comorbiditeiten, zoals:

   - *Cardiaal;*
   - *Pulmonaal;*
   - *Diabetes;*
   - *Overgewicht;*
   - *Slechte levensstijl.*

6. Een klein deel van de patiënten ondergaat geen operatie, waar baseert u dat op?
   In principe wordt elke patiënt zo snel mogelijk geopereerd. Hiervoor wordt gekeken naar:

   - *Mobiliteit;*
   - *Broze gezondheid:*
     - *Als de patiënt te kwetsbaar is, is het niet mogelijk.*
   - *Hoe de patiënt er zelf in staat:*
     - *Kan hij/zij het zelf verwoorden;*
     - *Doelen;*
     - *Kwaliteit van leven.*
   - *Wat vindt de:*
     - *Familie;*
     - *Chirurg;*
     - *Anesthesist:*
       - *Risico's in overweging nemen.*

7. Zijn er ook patiënten waarbij gekozen wordt om niet te opereren omdat het revalidatieproces te zwaar/geen zin meer heeft voor de patiënt?
   In het ZGT wordt 2 tot 3% niet geopereerd. Dit komt vooral doordat het uitsluiten van een operatie ervoor zorgt dat patiënten niet meer uit bed komen (bedleger). Dit resulteert in doorligplekken, urine infectie, etc. en uiteindelijk in overlijden.

Geen operatie gebeurt alleen in het geval van patiënten die er dusdanig slecht aan toe zijn (op sterven na al dood). Het is de kunst om zo goed mogelijk in te schatten welke keuze het beste is.
In het ZGT hebben we de Almelo Hip Fracture Score (AHFS) ontwikkeld. Daarbij kijken we ook naar de negen risicofactoren. Als je slecht scoort op al deze factoren, heb je alsnog 35% kans op dat je de operatie binnen dertig dagen overleeft.
Een andere manier is de Nothingham Hip Fracture score (NHFS) die we gemodificeerd hebben naar een doelgroep van patiënten met de leeftijd 70 of hoger. Nu bezig met Machine learning studenten om te kijken of de score beter gemaakt kan worden door in onze database te duiken om te kijken of we daar nog dingen uit kunnen halen waar we nog geen weet van hebben.
Momenteel wordt deze keuze gebaseerd op negen risicofactoren, zoals:

- *Leeftijd;*
- *Geslacht;*
- *Hb: Bloedgehalte bij binnenkomst;*
- *Asa classificatie door anesthesist (dit zegt hoe kwetsbaar je bent);*
- *Neven diagnosen, zoals cardiaal lijden, suikerziekte en/of longlijden.*

Meer behoefte aan een betere maatstaf nodig om te oordelen of je gaat opereren:

- *Patiënt geen plezier;*
- *Ziekenhuis kost het veel geld.*

8. Vindt er ook wel eens een re-interventie plaats?

   Niet zo heel vaak, maar zo wel dan gebeurt het alleen bij:

   - *Een infectie, maar dat komt bijna niet voor;*
   - *Als de kop het begeeft na het plaatsen van een plaat met schroeven;*
     - *Dit heeft als gevolg dat de kop afsterft door het afsterven van de bloedtoevoer;*
     - *Als schroeven breken worden deze incl. plaat vervangen door een prothese.*

9. Welke operatie vindt wanneer plaats?
   Richtlijn proximale femurfractuur wordt gevolgd op basis van de classificatie. Zo wordt gekeken naar welke operatie het beste is voor een patiënt. Daarnaast wordt ook in overweging genomen wat de doelen van de patiënt zijn. Als het doel is om de patiënt verpleegbaar te maken, kan de simpelste operatie uitgevoerd worden waardoor de patiënten alleen kleine handelingen nog uit kunnen voeren.
   Fittere patiënten hebben over het algemeen de lastigere breuken, omdat ze op een hele andere manier vallen.

   (a) Wat is het verschil tussen gamma nails en PFNa?
   In het ZGT wordt geen gebruik gemaakt van gamma nails. PFN is in principe hetzelfde, maar is een ander materiaal.

   (b) Wat houdt luxatie precies in?
   Bij een nieuwe (metalen) kop is er kans op luxatie. Kop draait uit de kom. Het is niet zo dat er een soort verschuiving ontstaat doordat het implantaat met cement vastgezet in het femur wordt dus die zit ram vast. Luxatie komt niet heel vaak voor bij ouderen, want die hebben over het algemeen een grote kop.
   Bepaalde handelingen van patiënten zoals bukken zijn we heel voorzichtig mee om luxatie te voorkomen. Bij een luxatie moeten de patiënten namelijk opnieuw geopereerd worden om dit op te lossen. Na deze operatie is er meer kans op een infectie en vervolgens meer kans op overlijden.

   (c) Waarom kop hals prothese?
   Dit is afhankelijk van het type fractuur. In de meeste gevallen ligt de kop er helemaal af waarbij de breuk in de hals loopt en de kop helemaal gelaxeerd is. Het reponeren van de kop is mogelijk, maar dat levert zoveel schade op dat de doorbloeding niet meer volledig behouden wordt.
   Na een andere operatie heeft 10 tot 15% van de patiënten alsnog een verstoring in de bloedtoevoer waardoor de kop afsterft en alsnog een prothese gedaan moet worden.
   Voorafgaand aan de operatie wordt geen onderzoek gedaan naar de bloedtoevoer. Vanuit ervaring/literatuur is gebleken dat het in de meeste gevallen goed gaat, maar de risico's moeten wel benoemd worden.

   (d) Waarom worden schroeven en DHS gebruikt bij dezelfde breuk?
   Dit is eigenlijk een beetje smaakafhankelijk per chirurg. Over het algemeen wordt een DHS uitgevoerd. Dit is vaker het geval bij fittere patiënten. Schroeven daarentegen worden eigenlijk zelden gebruikt. Aangezien dit een simpelere operatie is, wordt dit bij wat zwakkere patiënten uitgevoerd.

(e) Welke operatie blijkt de meeste complicaties te hebben (tijdens na de operatie)?
Trochantere fracturen doordat de operatie zorgt voor meer wondjes en het aanspannen van de spieren doen heel erg pijn waardoor ze veel slechter op slag komen.
Kophals prothese heeft de minste kans op complicaties. Na dag 2 of 3 al de eerste stappen.

(f) Hebben de complicaties die plaatsvinden na de operatie, invloed op het revalidatieproces?
Angst om nog een keer te vallen, heeft invloed op het revalidatieproces door:

- *Ander looppatroon;*
- *Spieratrofie door:*
- *Minder lopen;*
- *Schade door operatie (door spieren heen);*
- *Minder spierkracht om voeten goed op te tillen;*
- *Schade aan spieren.*

De complicaties zorgen voor:

- *Een flinke deuk in conditie;*
- *Spierverval;*
- *Emotionele tegenslag;*
- *Pneumonie.*

10. Waarom kan het been na sommige operaties wel belast worden (100%) en na sommige niet (50% of lager)?
In principe is het de bedoeling dat iedereen geopereerd wordt waarna ze het been meteen 100% mogen belasten. Sommigen, waarbij de kop volledig kapot is, mogen het been niet maximaal belasten omdat ze de heupkop moeten besparen. Bij jongere patiënten is dit vooral heel belangrijk omdat ze de heup nog wel 30 a 40 jaar moeten gebruiken. Bij ouderen proberen we echt iets te maken wat 100% belastbaar is. Als dit niet het geval is dan is het toch niet helemaal goed gegaan of de breuk is dusdanig 'beroerd'.

11. We hebben begrepen dat patiënten circa 5 dagen in het ziekenhuis blijven. Waarop baseren jullie dat iemand met ontslag mag?
De regel is dat iedereen na 5 dagen zeker naar huis kan mits er geen complicaties zijn. In het ziekenhuis zorgen we ervoor dat de patiënten medisch ontslag klaar zijn waarna het revalidatieproces start.
Voorheen (10 jaar geleden) bleven de patiënten ongeveer 12 dagen in het ziekenhuis. Dit is gehalveerd doordat minder complicaties optreden. Het komt heel vaak voor dat patiënten verward wakker worden (delier). Door ze bewust te maken van tijd/plaats kan dit voorkomen worden. Deze proactieve behandeling zorgt ervoor dat veel complicaties voorkomen worden.
Daarnaast had een heupoperatie vroeger de laagste prioriteit op de OK terwijl dit tegenwoordig veel sneller aan de beurt is. Door het verkorten van e tijd in het ziekenhuis voor de operatie, wordt de tijd verkort. Als je vandaag binnenkomt, op dezelfde dag of dag erna geopereerd. Langer dan 48 laten wachten, meer kans op complicaties. Tenzij de patiënten er zo slecht aan toe zijn dan wachten we nog wat langer.

Revalidatieproces

12. Zien de patiënten het positief in na de operatie of kijken ze heel erg op tegen het revalidatieproces?
Over het algemeen hebben de patiënten niet veel keuze meer. De verantwoordelijkheid over hoe fanatiek ze dit proces ingaan is wel aan hen. Aangezien heel veel ouderen alleen wonen, kunnen ze (tijdelijk) niet terug naar huis. Om deze reden moeten ze wel eerst revalideren om terug te kunnen naar huis.

13. Verminderde activiteit direct na de operatie leidt tot een minder snel herstel, merken jullie dit ook? Wat doen jullie hieraan?
Zo snel mogelijk opereren en zo snel mogelijk weer in beweging laten komen.

14. Wat zijn de doelen van patiënten voor het revalidatieproces?

    - *Naar huis willen;*
    - *Terug naar de woonsituatie;*
    - *Opstaan;*
    - *Zelf uit bed kunnen;*
    - *Zelf naar het toilet kunnen.*

15. Geven jullie specifiek advies aan de fysiotherapeuten?
Eigenlijk niet. De fysiotherapeuten kijken zelf hoe ze het per patiënt aanpakken. Wel vermelden we de belastbaarheid en eventuele bijzonderheden in de ontslagbrief.

16. Wat vindt u van het revalidatieproces?
Wij zien ze circa 7 dagen in het ziekenhuis en dan pas na 3 maanden zien we ze weer terug. In die tussenliggende periode horen/zien we niks. Om dit te verbeteren, zijn hier afspraken over gemaakt met drie verpleeghuizen in de buurt:

- *Alle verpleeghuizen doen verschillende dingen (ligduren etc. zijn anders) Deze procedures zijn nu op elkaar afgestemd;*
- *Kijken of het gestandaardiseerd kan worden;*
- *Eerst onderzoek naar wát er verbeterd kan worden voordat er echt iets verbeterd kan worden;*
  Weinig literatuur, want is nog heel erg zoekende in de verpleeghuizen naar wat wenselijke uitkomsten zijn.

17. Ziet u mogelijkheden in het continue monitoren?

Ja, ik denk dat uiteindelijk iedereen standaard met een monitor de deur uitgaat. Eerst onderzoek naar postoperatieve complicaties. Hartfrequentie, saturatie etc. zouden gemonitord kunnen worden om te kijken of er kans is op complicaties.
Voor het continue monitoren worden patiënten in het GHZ geïncludeerd. Andere patiënten zijn in een te slechte staat waarbij dit niet/minder mogelijk is door bijvoorbeeld dementie of GZ. Daarnaast zijn mensen tijdens het hebben van een denier of andere ziekte tijdens de opname heel lastig.
De grootste potentie in continue monitoring ligt bij het motiveren van de patiënten. De meeste patiënten vertonen een stijgende lijn in de revalidatie waarna dat ook ineens om kan slaan. Het is nu nog niet duidelijk waar dit dal vandaan komt (bijvoorbeeld door complicaties). Dit is zeker iets wat uitgezocht kan worden en wat gemonitord kan worden.
Cognitieve deel van patiënten meten d.m.v. sensoren. Het is moeilijk om de patiënten naast de opdrachten ook in beweging te krijgen.
Zorgpad aanscherpen door feedback voor professionals. Samenvatting van alle data die er is om zodoende de meest belangrijke informatie terug te koppelen.

<u>Functioneel herstel</u>

18. Wat is volgens u de definitie van functioneel herstel?

In de definitie van functioneel herstel zijn de doelen heel erg belangrijk. Op deze manier kunnen patiënten terugkeren naar hun oorspronkelijke woonsituatie mits haalbaar. Voor sommigen is dit gewoon niet meer haalbaar, omdat ze te veel ingeleverd hebben qua functionaliteit.
Bij opname worden patiënten gescoord op:

- *Waar komen ze vandaan?*
- *Wat is de woonsituatie?*
- *Wat is de adl functie?*
- *In hoeverre mobiel binnen- en buitenshuis?*
- *Zelfstandigheid?*

- Welke parameters zijn volgens u belangrijk voor een goed herstel?

Vooruitgang meten In eerste instantie kan een patiënt alleen het bed in en uit terwijl een week later ze zelfstandig een kop koffie kunnen zetten. Het mooiste zou zijn als deze vooruitgang van activiteit in kaart gebracht kan worden. Ook realiseren wat de patiënt daarvoor deed. Sensors daarop in kunnen stellen.
Patiënten vanuit GHZ willen weer naar huis Wat moeten ze thuis weer kunnen? Sensors als hulpmiddel/maatstaf (beter betrouwbaar) gebruiken om te bepalen of patiënten naar huis mogen. Data moet kunnen aangeven dat de handelingen uitgevoerd kunnen worden door de patiënten. Zo zouden de patiënten wellicht eerder naar huis kunnen.

Interview on patients at ZGT

Patient 3 | 70 years old

1. Hoe zelfstandig was u voordat u uw heup brak?

   (a)

   (b) Woonsituatie
   Afhankelijk van het revalidatiecentrum Borsthuis in Hengelo. Ik woonde daar al in verband met een onderbeenfractuur en nu dus ook voor mijn heupfractuur aan de linkerkant.
   Voordat ik naar het revalidatiecentrum ging, woonde ik in een maisonnette die aangepast was voor mijn situatie. Er stond bijvoorbeeld een ziekenhuisbed in de woonkamer. Verder bestond het huis uit drie verdiepingen dus het is niet meer mogelijk om daar weer in te trekken. Nu op zoek naar een nieuw huis waar ik wel zelfstandig kan wonen.

   (c) Leefomgeving
   Afhankelijk van het revalidatiecentrum Borsthuis in Hengelo. Ik woonde daar al in verband met een onderbeenfractuur en nu dus ook voor mijn heupfractuur aan de linkerkant.
   Voordat ik naar het revalidatiecentrum ging, woonde ik in een maisonnette die aangepast was voor mijn situatie. Er stond bijvoorbeeld een ziekenhuisbed in de woonkamer. Verder bestond het huis uit drie verdiepingen dus het is niet meer mogelijk om daar weer in te trekken. Nu op zoek naar een nieuw huis waar ik wel zelfstandig kan wonen.

   (d) Wat deed u op een dag?
   Ik doe nog wel wat dingen in het huishouden zoals stofzuigen, maar verder komt wekelijks een hulp langs. Het lukte me ook niet meer om de boodschappen nog zelf te doen. Koken daarentegen deed ik nog zelf.

   (e) Liep u nog veel zelfstandig?
   Binnenshuis liep ik met een stok en buitenshuis liep ik met een rollator kleine afstanden.

2. Wat denkt u dat het doel is van de revalidatie?

   Het doel zal zijn om mij weer mobiel te maken. Dit houdt in dat ik weer kleine stukjes zelf kan lopen met een rollator.

3. Welke doelen heeft u voor ogen om te bereiken na het revalidatieproces?

   Ik zou heel graag weer diepzee willen duiken, maar dat is een beetje onrealistisch. Wat wel moet kunnen is dat ik weer kan genieten van binnen en buiten. Daarnaast ben ik dus op zoek naar een nieuw huis en ik hoop daar een prettig thuis van te kunnen maken waar ik mezelf kan redden.

4. Welke dingen vindt u belangrijk tijdens het herstel?

   Ik vind het heel belangrijk om te vechten voor mijn herstel. Na alles wat ik meegemaakt heb, heb ik dat wel geleerd. Daarnaast is de communicatie tussen de VU, ZGT en Borsthuis erg belangrijk voor mijn revalidatieproces.

Patient 4 | 86 years old

1. Hoe zelfstandig was u voordat u uw heup brak?

   (a)

   (b) Woonsituatie
   Mijn man is 2,5 jaar geleden overleden. Ik woon nog steeds in hetzelfde huis als waar ik altijd met hem heb gewoond.

   (c) Leefomgeving
   Al mijn kinderen en kleinkinderen wonen bij mij in de buurt. Iedereen probeert mij zo goed mogelijk te helpen en te steunen. Ik ben wel alleen, maar ik ben niet eenzaam.

   (d) Wat deed u op een dag?
   Tegenwoordig krijg ik één keer per week een hulp voor het huishouden en mijn dochter helpt mij met de boodschappen. Koken kan ik niet meer, maar mijn dochter brengt elke dag wat avondeten langs.

   (e) Liep u nog veel zelfstandig?
   Grote afstanden kon ik niet echt lopen, maar kleine afstanden overbrug ik altijd met een rollator.

2. Wat denkt u dat het doel is van de revalidatie?

   Niks. Ik heb geen kracht meer om volledig op de been te komen. Mijn kinderen willen wel heel graag dat ik hier mijn best voor doe, dus dat doe ik dan ook. Maar eigenlijk lukt het mij gewoon niet meer omdat ik geen kracht en energie heb.

   Momenteel loop ik hele kleine stukjes met een rollator, maar dat is echt heel vermoeiend. Doordat ik dan weer moe wordt, ben ik ook banger om weer te vallen.

3. Welke doelen heeft u voor ogen om te bereiken na het revalidatieproces?

   Ik zou wel uitstapjes naar familie willen maken, maar ik weet dat dit toch niet meer gaat lukken.

Patient 5 | 96 years old

1. Hoe zelfstandig was u voordat u uw heup brak?

   (a) Woonsituatie
   Ik ben weduwe en woon momenteel in een soort aanleunwoning met steeds meer toezicht. Ik ben vroeger erg actief geweest in werk en sport. Tegenwoordig fietste ik nog redelijk vaak totdat ik een keer van de fiets ben gevallen en mijn heup brak.

   (b) Wat deed u op een dag?
   Ik ging zelf nog naar de supermarkt.
   Drie keer in de week ging ik biljarten met vrienden in de dagopvang.

   (c) Liep u nog veel zelfstandig?
   In huis hoefde ik geen trap te lopen en liep ik zonder rollator. Buitenshuis daarentegen liep ik de grotere afstanden wel met een rollator.
   Het doel zal zijn om mij weer mobiel te maken. Dit houdt in dat ik weer kleine stukjes zelf kan lopen met een rollator.

2. Welke doelen heeft u voor ogen om te bereiken na het revalidatieproces?

   Ik zou graag weer willen fietsen, maar ik ben ook wel weer bang om te vallen. Niet zo zeer omdat ik denk dat ik niet meer kan fietsen, maar meer door omstandigheden zoals harde wind. Daarnaast zou ik graag weer zelf naar de supermarkt willen lopen.

Interview on specialist at Kronnenzommer Hellendoorn

S. Woudsma

Voorafgaand aan de heupfractuur

1. Wat zijn de verschillende woonsituaties van een patiënt voorafgaand aan de fractuur?
   Meeste patiënten woonden thuis met thuiszorg.

Revalidatieproces

2. Wat zijn de doelen van patiënten voor het revalidatieproces?

   Aan het begin van de opname de doelen formuleren. Dit doet de fysiotherapeut samen met de patiënt. Soms kan patiënt dit niet benoemen en dan formuleren de fysiotherapeuten de doelen. Fysiotherapeuten formuleren aan SamPC:

   - *S: somatisch → meer kracht willen of minder pijn. Dus gaat over lichamelijke beperking;*
   - *A: ADL → lopen, traptropen, in en uit bed gaan, opstaan en gaan zitten. Hogere doelen: boodschappen, eten koken, aan- en uitkleden, toiletgang, fietsen, scootmobiel naar supermarkt;*
   - *M: maatschappelijk → keert iemand terug naar gelijkvloers waar echtgenoot in beeld is of keert iemand terug naar een huis helemaal alleen en zonder aanpassingen;*
   - *P: psyche. Mensen hebben vaak van tevoren al cognitieve problemen, bijvoorbeeld dementie of voorstadium ervan. Andere voorbeelden: een delier, sombere of depressieve gevoelens of een overbelaste mantelzorger;*
   - *C: communicatie. Dit is bij deze doelgroep minder aan de orde. Indien opgenomen met beroerte dan hebben ze daar vaak wel een doel in.*

   (a) Wat is het meest voorkomende doel van patiënten voor het revalidatieproces?
   Lopen is voor iedereen een doel, daarnaast gaan staan en zitten.

3. Zit er verschil in het revalidatieproces bij de verschillende behandelingen?
   Dit is afgestemd op de doelen. Als iemand binnenkomt, worden direct doelen opgesteld en prognose gesteld van de verwachte verblijftijd. Er is wekelijks een MDO over hoe de stand van zaken is en de tijdsplanning nog klopt.Je wil iemand hier zo kort mogelijk houden. De volgende mensen zijn betrokken bij het MDO:

   - *Arts;*
   - *Praktijkverpleegkundige/clientadviseur;*
   - *Maatschappelijk werker;*
   - *Fysio;*
   - *Ergo;*
   - *Dietist;*
   - *Psycholoog;*
   - *Bewegingsagoog.*

4. Wordt het revalidatieproces aangepast aan de hand van de doelen/wensen van de patiënt?

   De therapie wordt zo veel mogelijk op de doelen afgestemd. Als een patiënt voorheen met rollator liep, is het doel niet meer om hem te laten lopen met krukken. We proberen zo functioneel mogelijk te oefenen, dus gericht op vaardigheid (lopen en activiteiten) en het nemen van obstakels en dergelijke. De ergotherapeut gaat een stapje verder hierin. Het is goed dat iemand kan lopen maar diegene moet er ook iets mee kunnen doen. Er zijn een aantal voorwaarden om doelen te kunnen behalen: kracht in benen, balans en uithoudingsvermogen. We proberen een patiënt de eigen regie te geven door ook zelf te oefenen.

5. Denkt u dat continu monitoren een voordeel is ten opzichte van meten in tijdsopnames?

   Ja ik denk dat het kan helpen. 'S ochtends (tijdens de therapiesessies) zie ik wat de patiënten doen, maar de rest van de dag heb ik geen idee. Sommige patiënten kunnen niet vertellen wat ze doen, dus inzicht is fijn. Dan is eventueel pijn te verklaren als de patiënt dat aangeeft. Ook kan ik zeggen dat hij teveel doet of juist te weinig. Hiermee kan je vooral de patiënt dus coachen en eventueel motiveren. Ook kan het de familie helpen. Nu is er vaak alleen een moment opname, dit kan een vertekend beeld geven. Ik probeer de testen zo gestandaardiseerd mogelijk af te nemen maar iedereen doet het weer anders.

6. Waaraan merkt u dat een patiënt op de goede weg is? Voorbeelden.

   Klinimetrische testen zijn ondersteunend. Ik gebruik heel erg de klinische blik. Ook kijk ik naar de doelen en vraag ik me af of iemand iets kan.

7. Welke complicaties kunnen optreden die van invloed zijn op het revalidatieproces?

    - *Delirant;*
    - *Pneumonie;*
    - *Urineweginfectie;*
    - *Vallen;*
    - *Wondinfectie;*
    - *Decubitis.*

    (a) Wat is de meest voorkomende complicatie die van invloed is op het revalidatieproces?
    Pneumonie, de patiënten zijn namelijk kwetsbaarder. De kwetsbaardere patiënten komen hier (GZR) en de goede patiënten gaan rechtstreeks naar huis.

<u>Functioneel herstel</u>

8. Wat is volgens u de definitie van functioneel herstel?

    Hoe kijkt een therapeut er tegenaan en hoe kijkt de patiënt er zelf tegenaan, zijn 2 verschillende dingen. Stukje mobiliteit en stukje ADL is belangrijk (dus echt functieherstel). Dit kan gemeten worden door 10 meter looptest, batel, tug, fac. Hiervoor gelden aantal voorwaarden:

    - *Kracht;*
    - *Balans;*
    - *Uithoudingsvermogen;*

    Gaat ook over functioneren in thuissituatie. Veel factoren van invloed hierop (psychisch, voeding).

    (a) Hoe bepalen jullie dat een patiënt hersteld is?
    Als doelen zijn behaald dan is de patiënt niet hersteld. Ze blijven niet gehele revalidatieperiode hier. Ze komen hier omdat ze zich thuis niet kunnen redden. De meest noodzakelijke doelen die behaal je. Dan ga je naar huis en dan werken ze thuis verder aan de overige doelen. Thuis is dan de beste situatie om verder te revalideren. Omdat de patiënt dan thuis zelfstandig moet functioneren. Fysio wordt dan thuis ook nog betrokken.

    (b) Wat is belangrijk voor een goed herstel?
    Zitten en staan is heel belangrijk en daarnaast is loop snelheid belangrijk. Een patiënt moet zich op zijn niveau goed redden. Aantal stappen maakt niet veel uit. Die zaken zeggen niets over of iemand veilig loopt. Dit is vooral klinische blik. Iemand met rollator loopt niet per se veiliger.

9. Denkt u dat functioneel herstel gemeten kan worden door middel van een Fitbit Zip, Fitbit Charge en/of MOX?

    Zeer waardevol, maar dit alleen is niet genoeg

    (a) Welke parameters zijn hierbij van belang volgens u?
    We meten de:

    - *Van zitten naar staan;*
    - *Loopafstand (x aantal stappen is nooit het doel), aantal stappen kan je gebruiken om x aantal stappen extra te zetten (dus motiveren);*
    - *Loopsnelheid;*
    - *Blok activiteiten zijn ook interessant. Daarmee krijg je meer inzicht in wat de patiént de hele dag doet (zie je dus bij actieve blokken). Wordt iemand actiever gedurende de revalidatie? ;*

    (b) Zijn aanvullende vragenlijsten/klkinimetrische testen dan nog nodig?
    Ja, namelijk:

    - *Pychologische test;*
    - *Voedingstoestand test;*
    - *Fac score is veiligheid van lopen (die kan je niet vervangen want dit is inschatting);*
    - *Fracture mobility score.*

    Sensoren kunnen wel de 10 MLT vervangen.

Up&Go Project

10. Ziet u al voordelen in het Up & Go Project?

    Ja, we deden al veel klinimetrie maar nu is meer vastgelegd en heb je vaste meetmomenten (dus meer gestandaardiseerd). Inzet van sensoren. Nu kijkt ze al naar gegevens van fitbit.

Appendix D: Schedules of the experiment

Personal information

Personal information	
Name	
Gender	
Length (cm)	
Weight (kg)	
Birth date	
Wrist	Dominant / Non-dominant
Ankle	Dominant / Non-dominant

Phase 1

Phase 1: Resting heart rate				
	Before activity		**Heart rate in rest**	
	Begin time	Heart rate	End time	Heart rate
Wrist				
Ankle				

Phase 2

Phase 2: Walking back and forth from A to B						
	Speed	**Fitbit**	**Before activity**			
			Begin time	Heart rate	Number of steps	Floors
Without GERT	**1**	**Wrist**				
		Ankle				
	2	**Wrist**				
		Ankle				
	3	**Wrist**				
		Ankle				
With GERT	**1**	**Wrist**				
		Ankle				
	2	**Wrist**				
		Ankle				
	3	**Wrist**				
		Ankle				

Phase 2: Walking back and forth from A to B							
	Speed	**Fitbit**	**Number of steps per round**				
			Round 1	Round 2	Round 3	Round 4	Round 5
Without GERT	**1**	**Wrist**					
		Ankle					
	2	**Wrist**					
		Ankle					
	3	**Wrist**					
		Ankle					
With GERT	**1**	**Wrist**					
		Ankle					
	2	**Wrist**					
		Ankle					
	3	**Wrist**					
		Ankle					

Phase 2: Walking back and forth from A to B							
	Speed	Fitbit	Right after activity				
			Local time	Heart rate	Number of steps	Floors	Distance (m)
Without GERT	**1**	**Wrist**					
		Ankle					
	2	**Wrist**					
		Ankle					
	3	**Wrist**					
		Ankle					
With GERT	**1**	**Wrist**					
		Ankle					
	2	**Wrist**					
		Ankle					
	3	**Wrist**					
		Ankle					

Phase 2: Walking back and forth from A to B				
	Speed	Fitbit	After recovery	
			End local time	Heart rate
Without GERT	**1**	**Wrist**		
		Ankle		
	2	**Wrist**		
		Ankle		
	3	**Wrist**		
		Ankle		
With GERT	**1**	**Wrist**		
		Ankle		
	2	**Wrist**		
		Ankle		
	3	**Wrist**		
		Ankle		

Phase 3

Phase 3: Activities of Daily Living						
		Fitbit	**Before activity**			
			Begin time	Heart rate	Number of steps	Floors
Without GERT	**1**	**Wrist**				
		Ankle				
	2	**Wrist**				
		Ankle				
	3	**Wrist**				
		Ankle				
With GERT	**1**	**Wrist**				
		Ankle				
	2	**Wrist**				
		Ankle				
	3	**Wrist**				
		Ankle				

Phase 3: Activities of Daily Living											
	Local time of every activity										
	Out of bed	Walking	Pants off	Stand to sit	Sitting	Sit to stand	Pants on	Walking	In bed	Steps forward	Steps backward
Without GERT											
With GERT											

Phase 3: Activities of Daily Living						
	Right after activity				**After recovery**	
	End local time	Heart rate	Number of steps	Floors	End local time	Heart rate
Without GERT						
With GERT						

Phase 4

Phase 4: Climbing stairs										
		Fitbit	Before activity				Time			
			Begin time	Heart rate	Number of steps	Floors	End going up	Start going down	End going down
Without GERT	1	Wrist							
		Ankle							
	2	Wrist							
		Ankle							
	3	Wrist							
		Ankle							
With GERT	1	Wrist							
		Ankle							
	2	Wrist							
		Ankle							
	3	Wrist							
		Ankle							

Phase 4: Climbing stairs								
		Fitbit	Right after activity				After recovery	
			Local time	Heart rate	Number of steps	Floors	End local time	Heart rate
Without GERT	1	Wrist						
		Ankle						
	2	Wrist						
		Ankle						
	3	Wrist						
		Ankle						
With GERT	1	Wrist						
		Ankle						
	2	Wrist						
		Ankle						
	3	Wrist						
		Ankle						

Appendix E: Results of normal distribution of phase 2

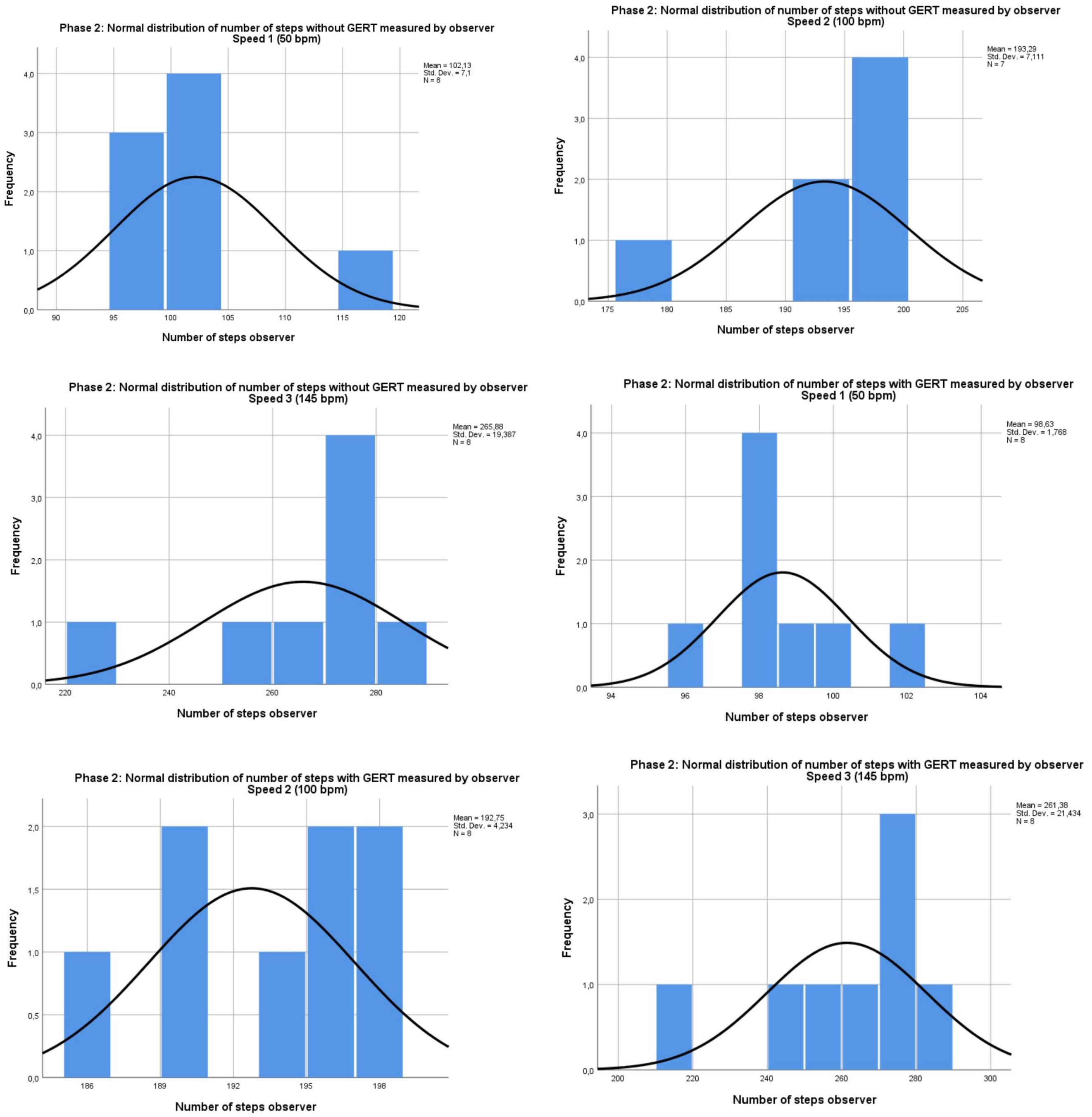


Figure 17: *Normal distribution of number of steps of subjects with and without GERT counted by observer, during phase 2*

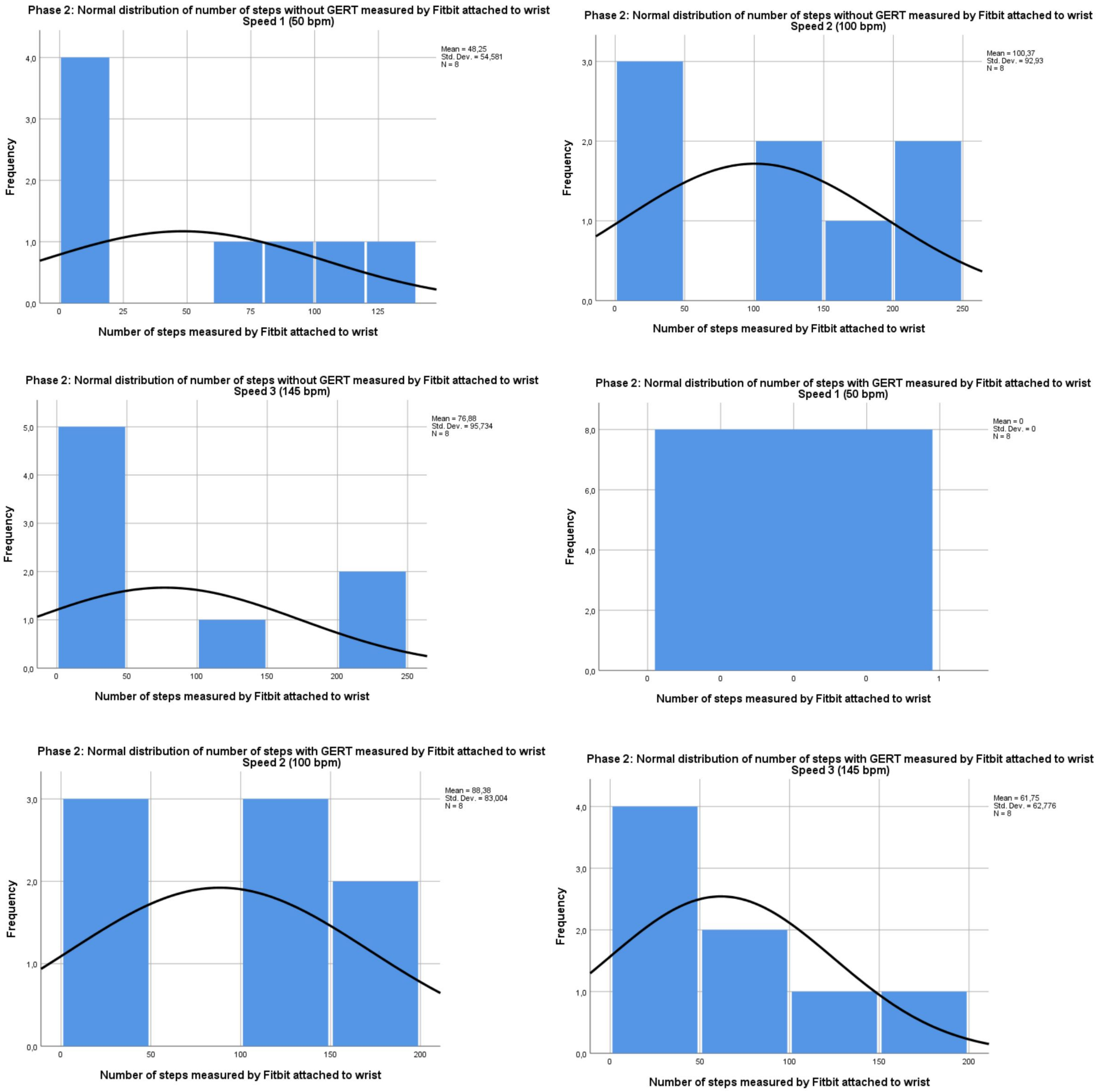


Figure 18: *Normal distribution of number of steps of subjects with and without GERT counted by Fitbit wrist, during phase 2*

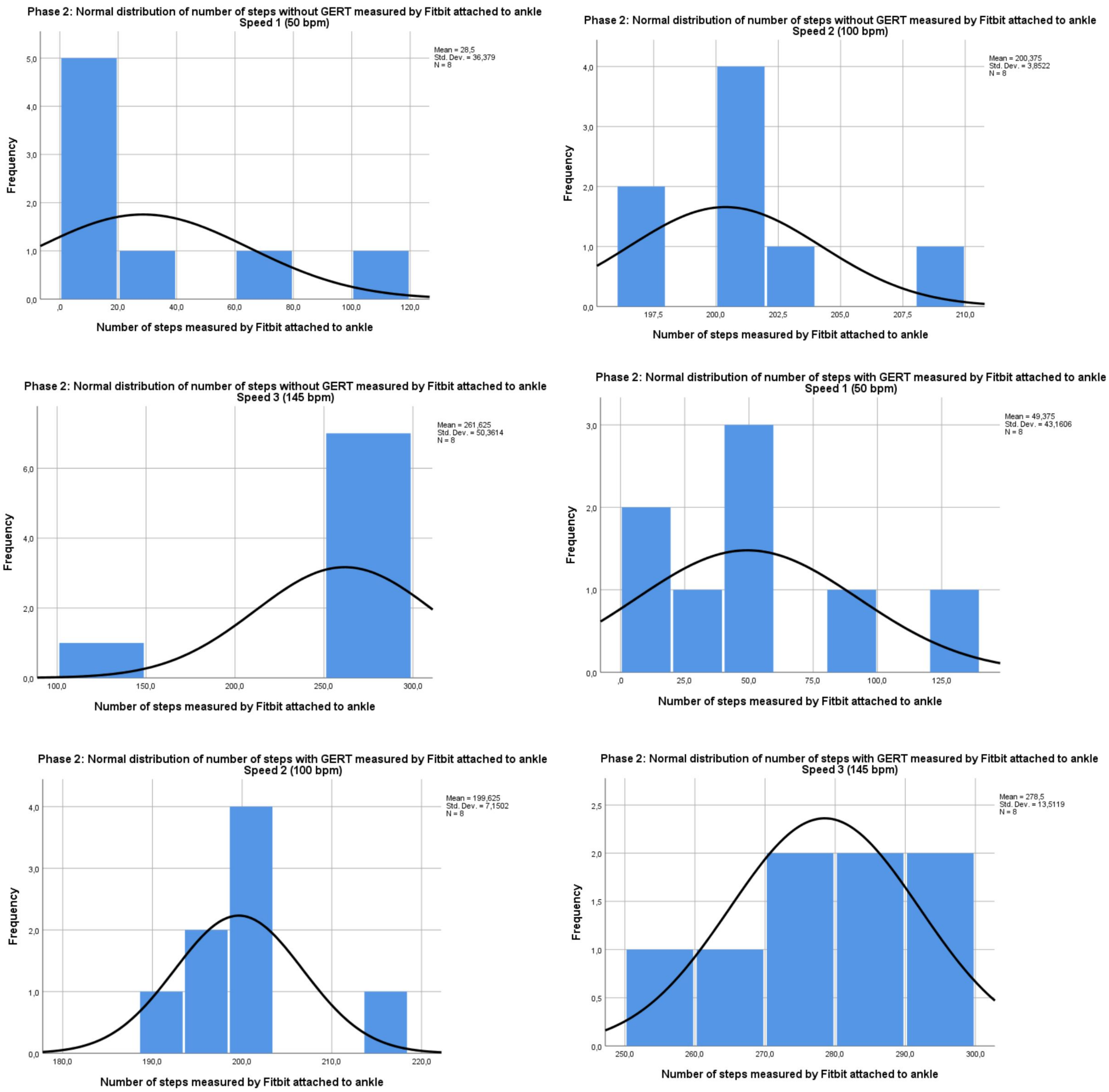


Figure 19: *Normal distribution of number of steps of subjects with and without GERT counted by Fitbit ankle, during phase 2*

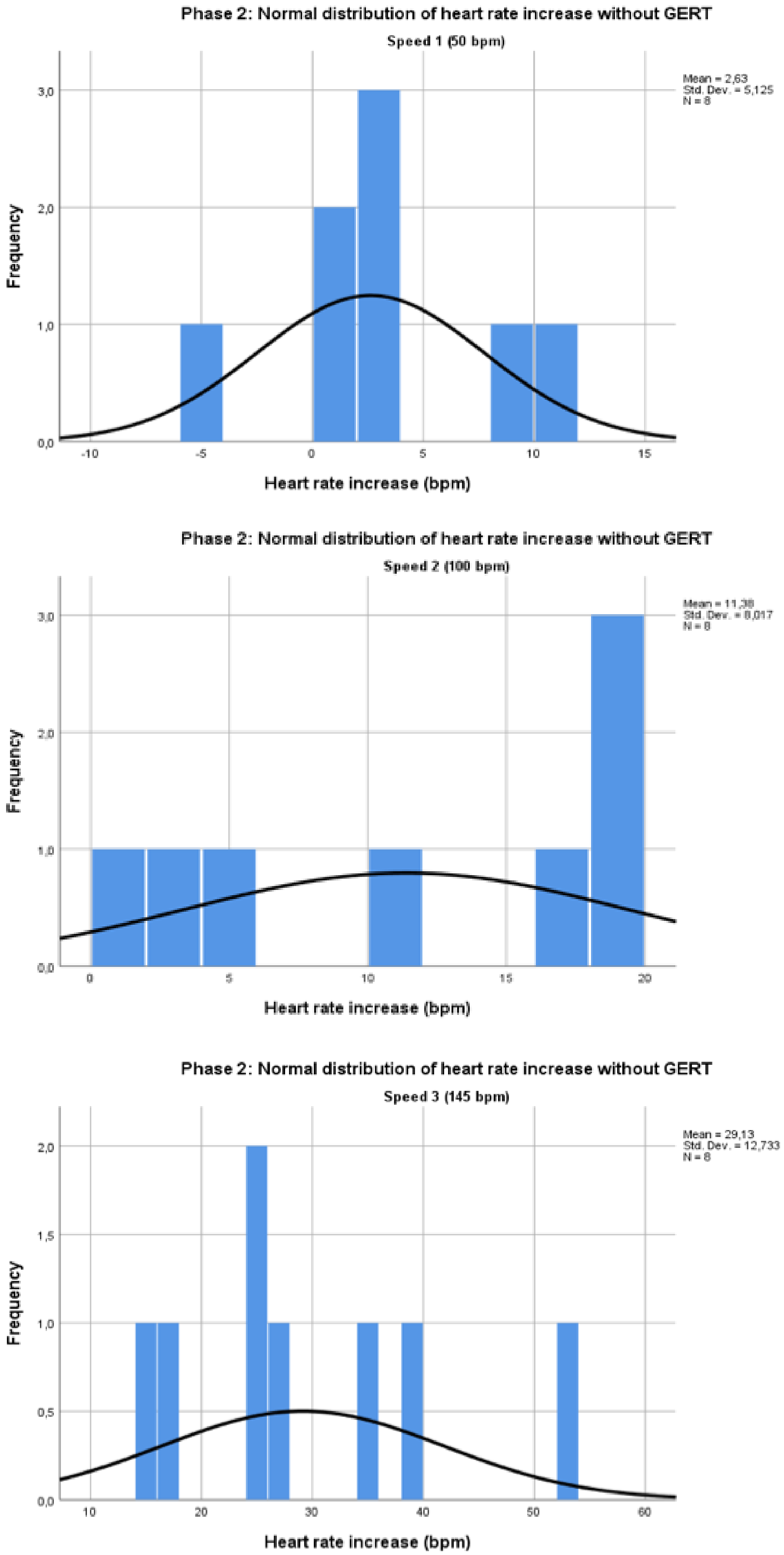
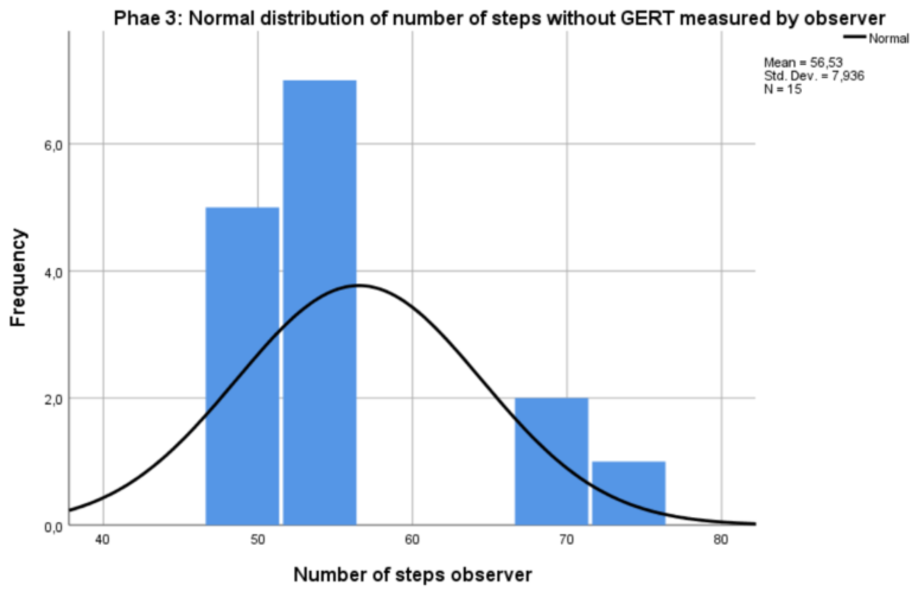
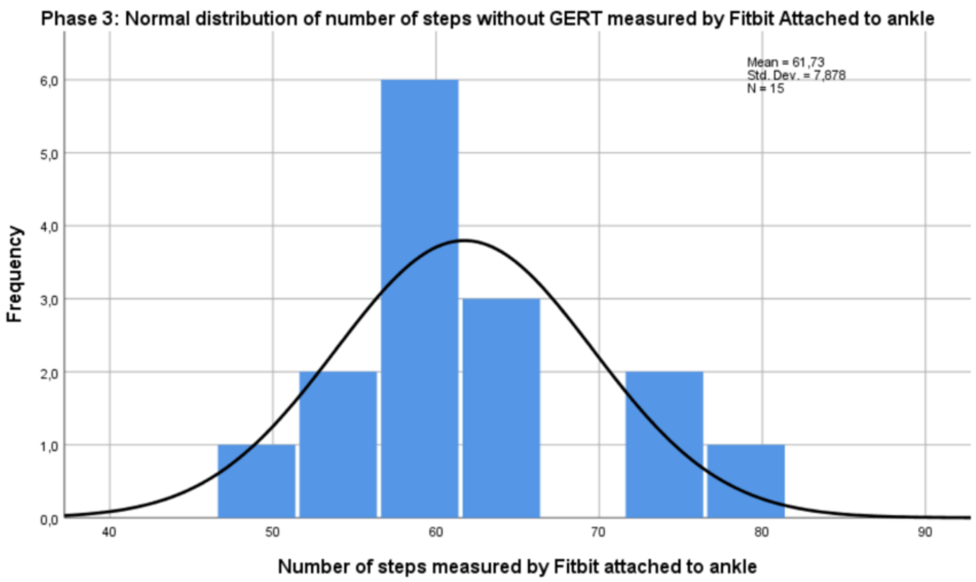


Figure 20: *Normal distribution of heart rate of subjects without GERT counted by Fitbit ankle, during phase 2*

Appendix F: Results of normal distribution of phase 3 and 4





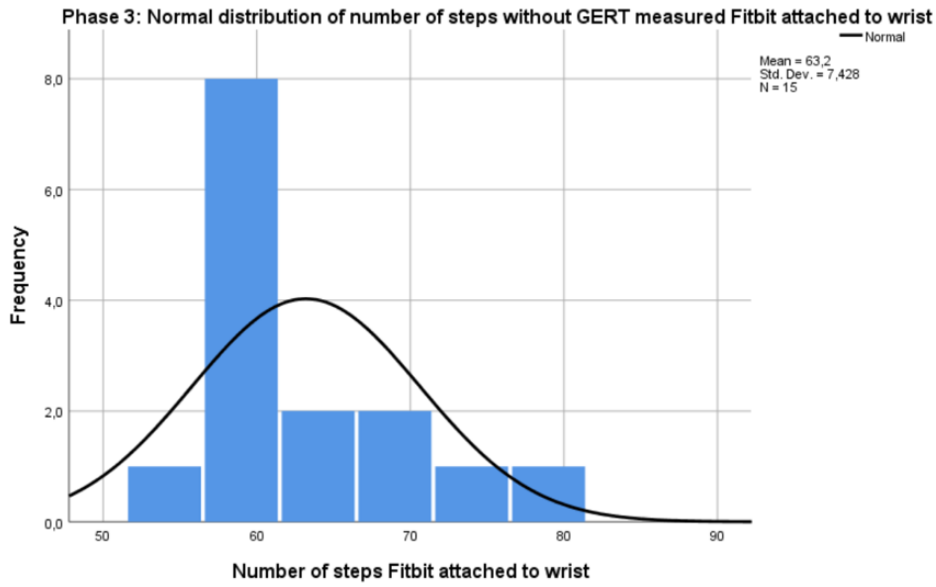


Figure 21: *Normal distribution of number of steps counted of subjects without GERT, during phase 3*

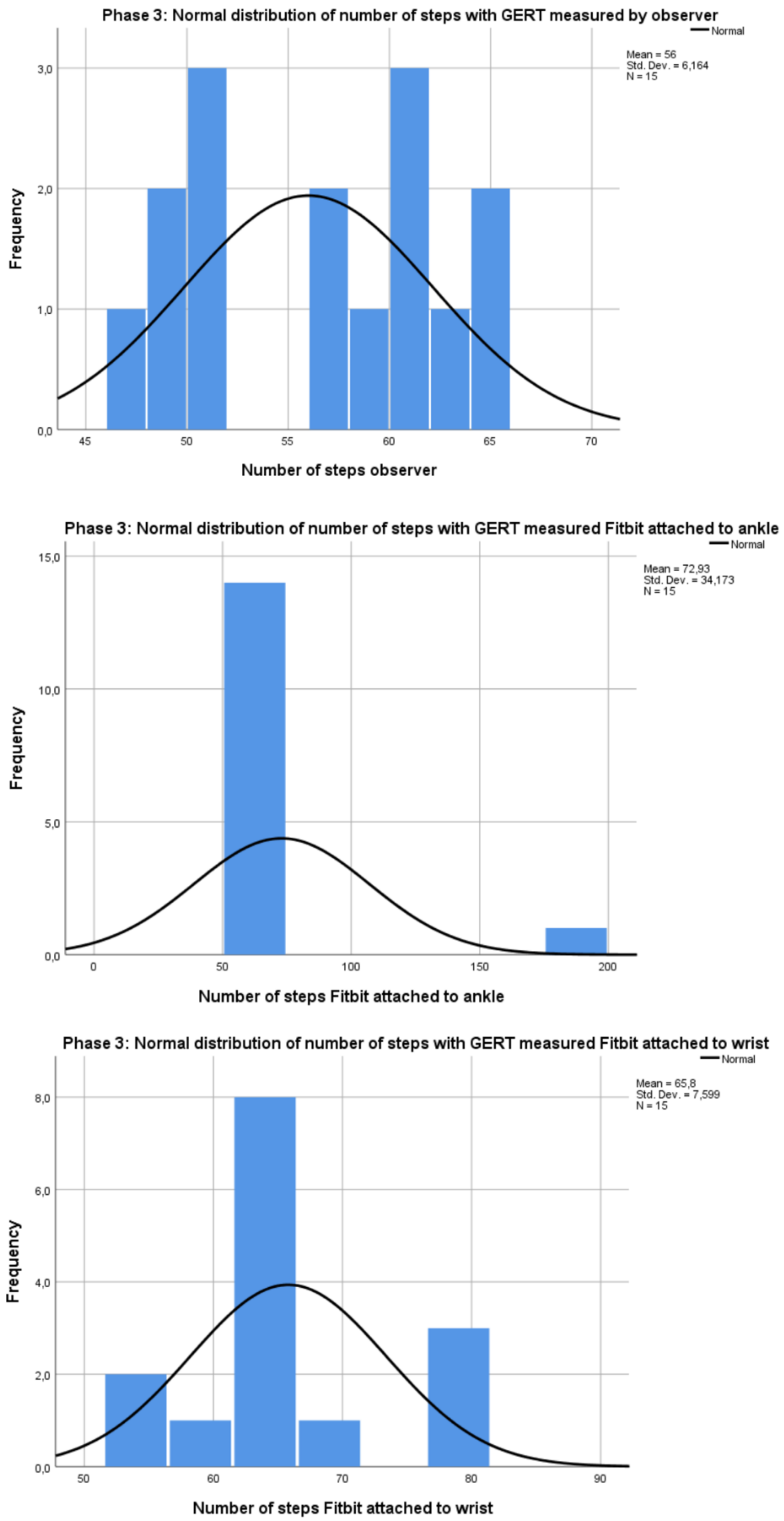
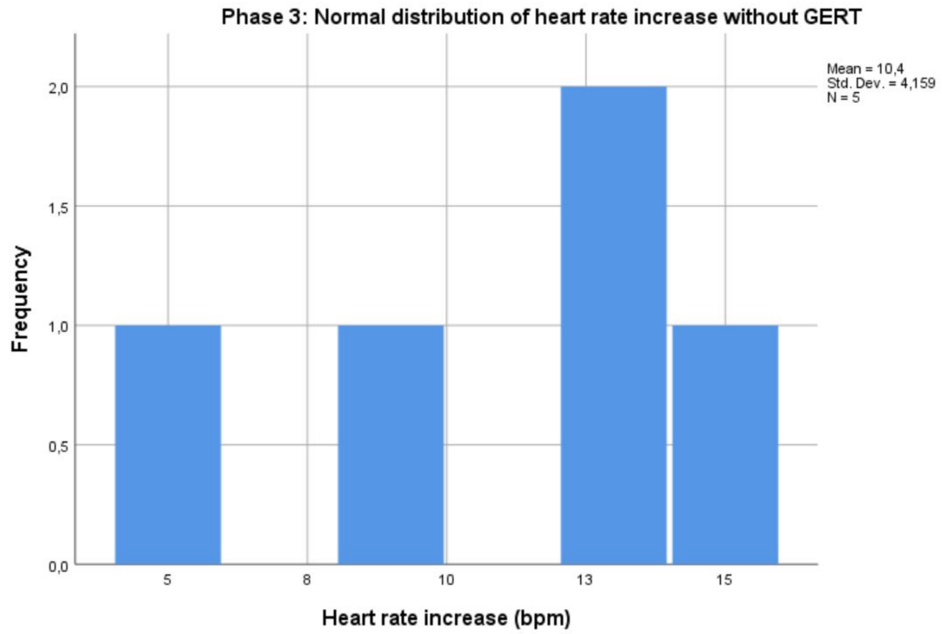


Figure 22: *Normal distribution of number of steps counted of subjects 'with GERT', during phase 3*



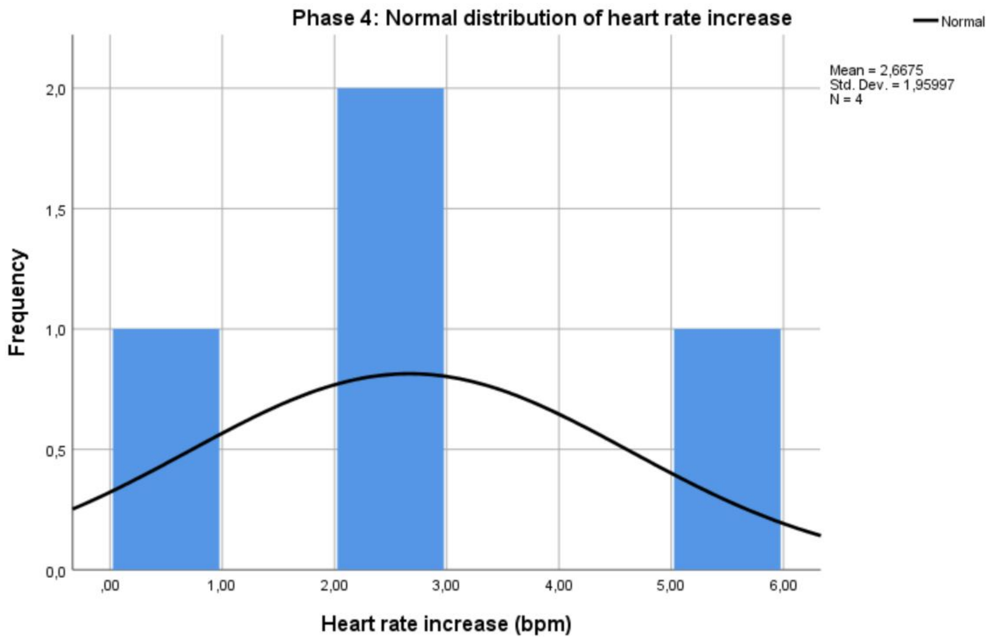


Figure 23: *Normal distribution of heart rate of subjects 'with GERT', during phase 3 and 4*

Appendix G: Results of correlation

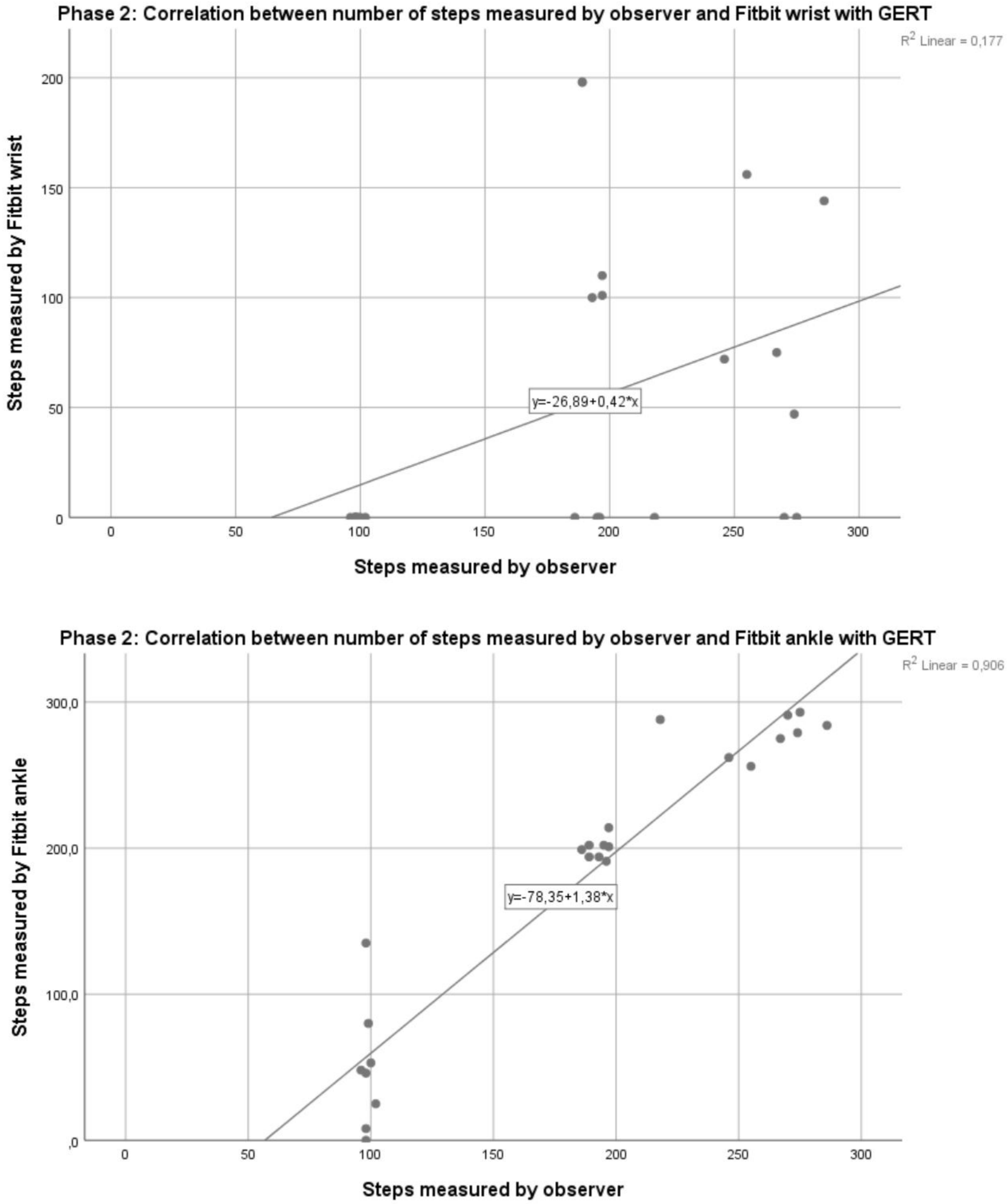


Figure 24: *Correlation of number of steps, during phase 2*

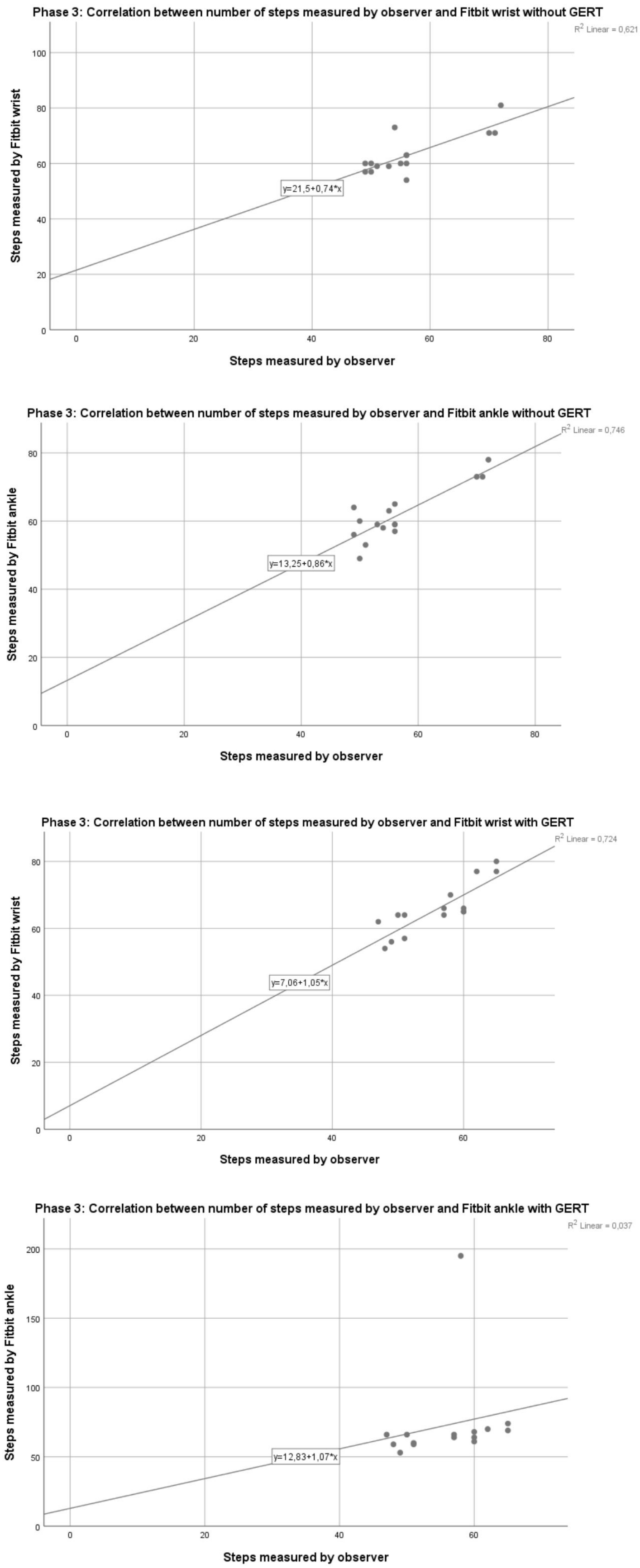


Figure 25: *Correlation of number of steps, during phase 3*

Appendix H: Heart rate and intensity over time

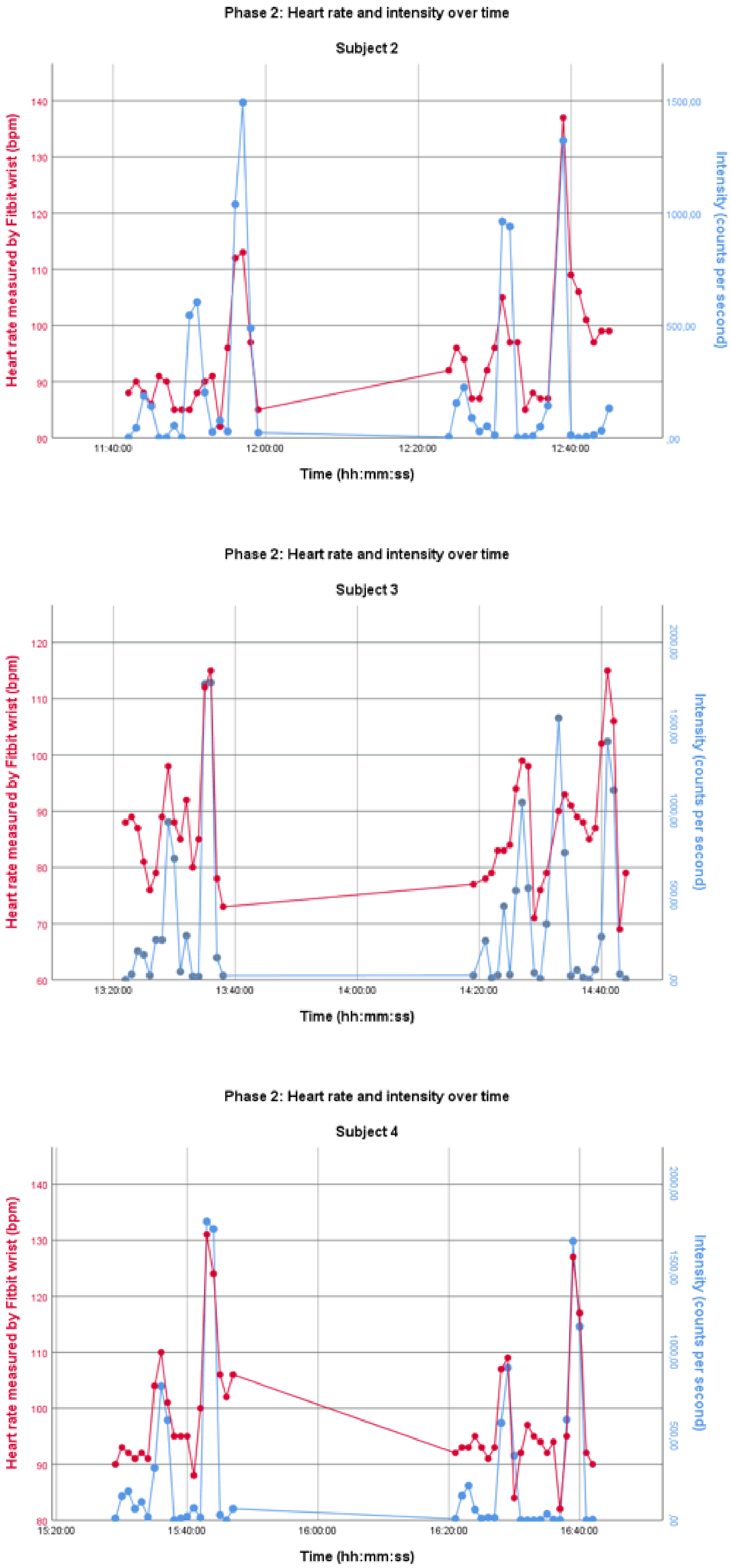


Figure 26: *Heart rate and intensity over time during phase 2 of subjects 2, 3 and 4. The spikes on the left represent the 'without GERT' state, the spikes on the right represent the 'with GERT' state.*

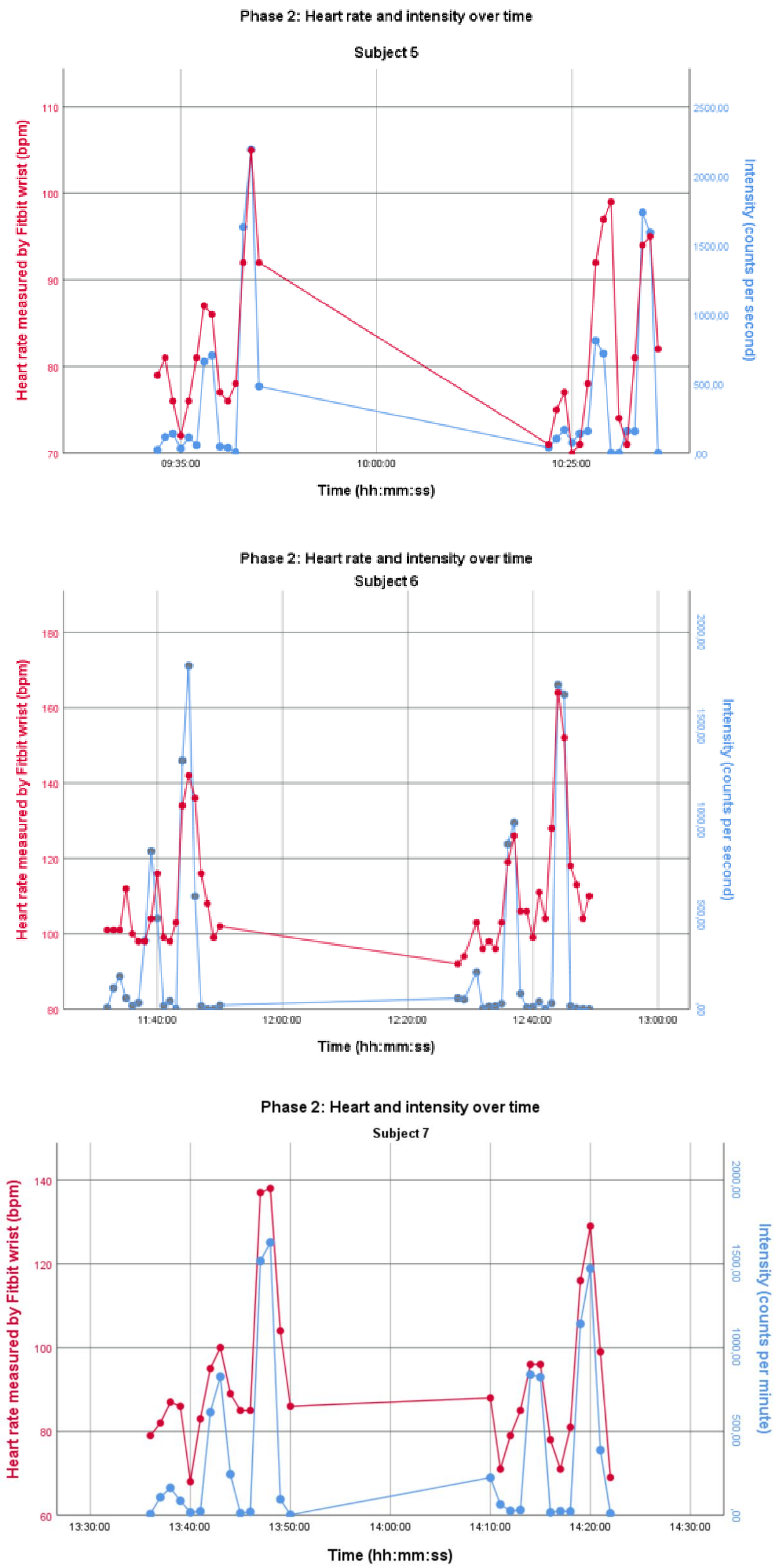


Figure 27: *Heart rate and intensity over time during phase 2 of subjects 5, 6 and 7. The spikes on the left represent the 'without GERT' state, the spikes on the right represent the 'with GERT' state.*

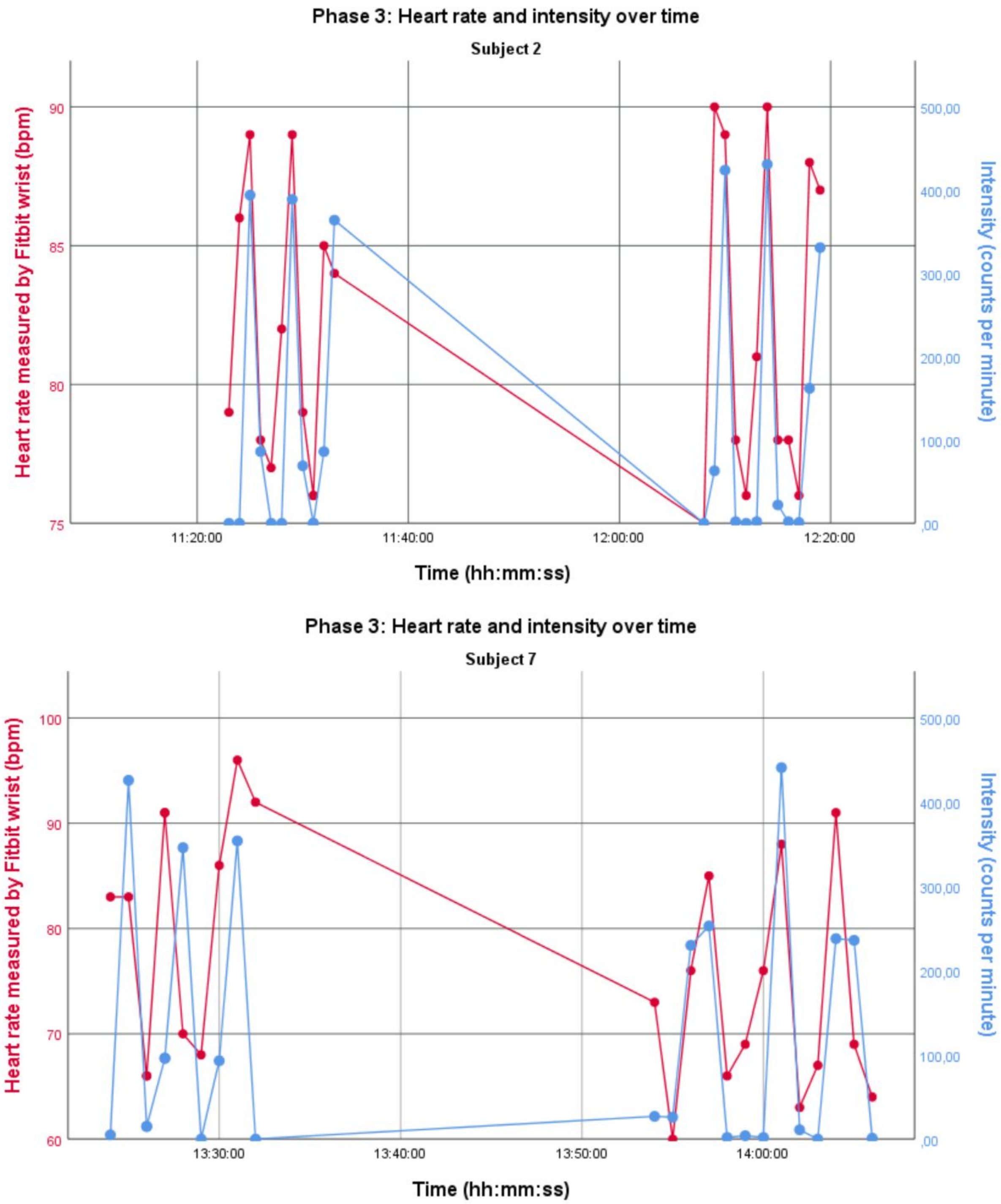


Figure 28: *Heart rate and intensity over time during phase 3 of subjects 2 and 7. The spikes on the left represent the 'without GERT' state, the spikes on the right represent the 'with GERT' state.*

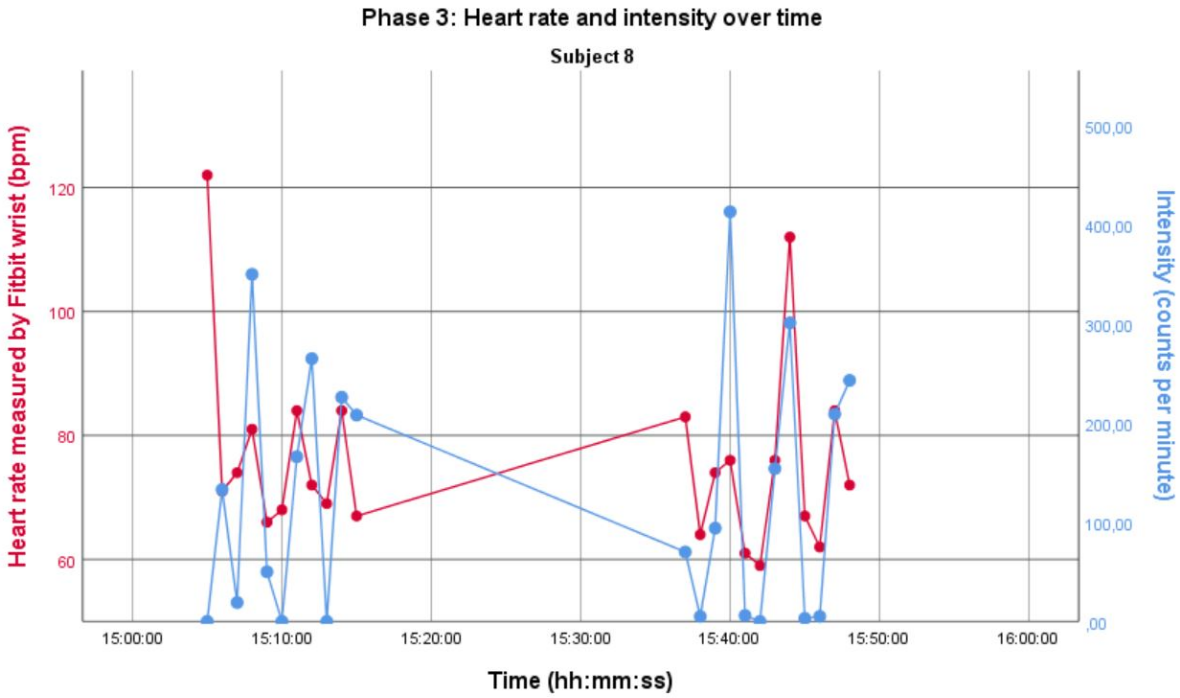


Figure 29: *Heart rate and intensity over time during phase 3 of subject 8. The spikes on the left represent the 'without GERT' state, the spikes on the righ represent the 'with GERT' state.*

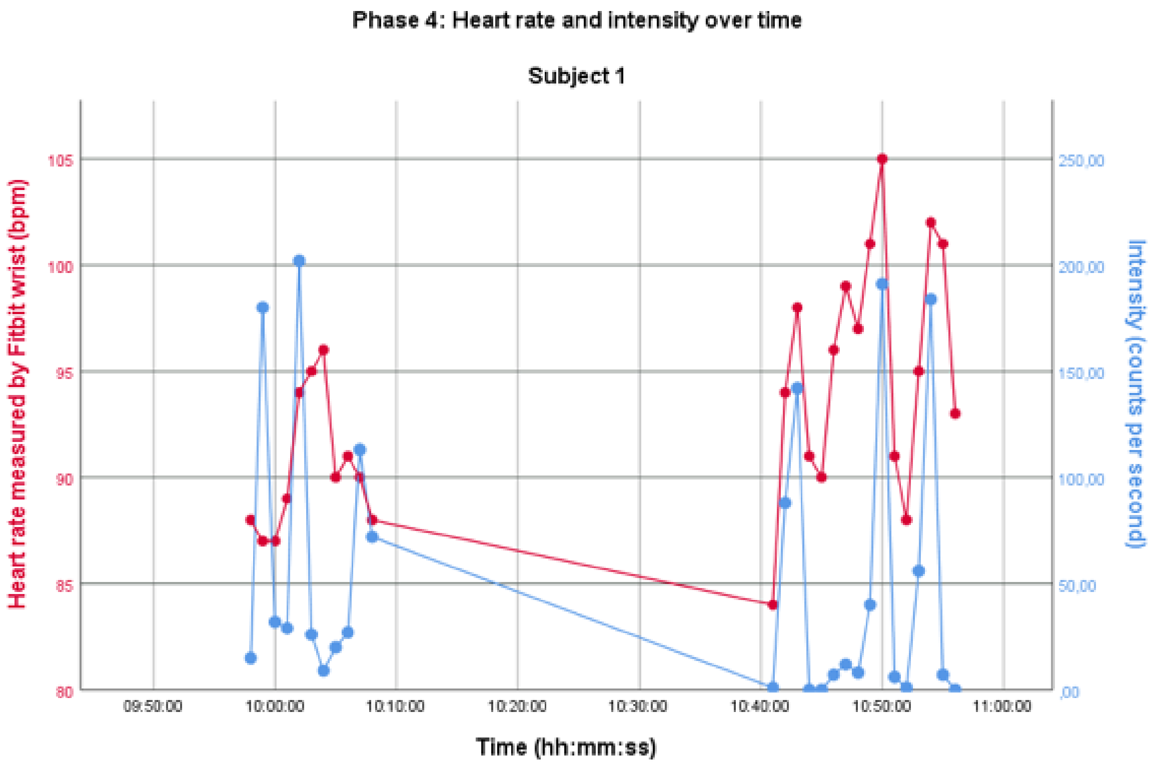
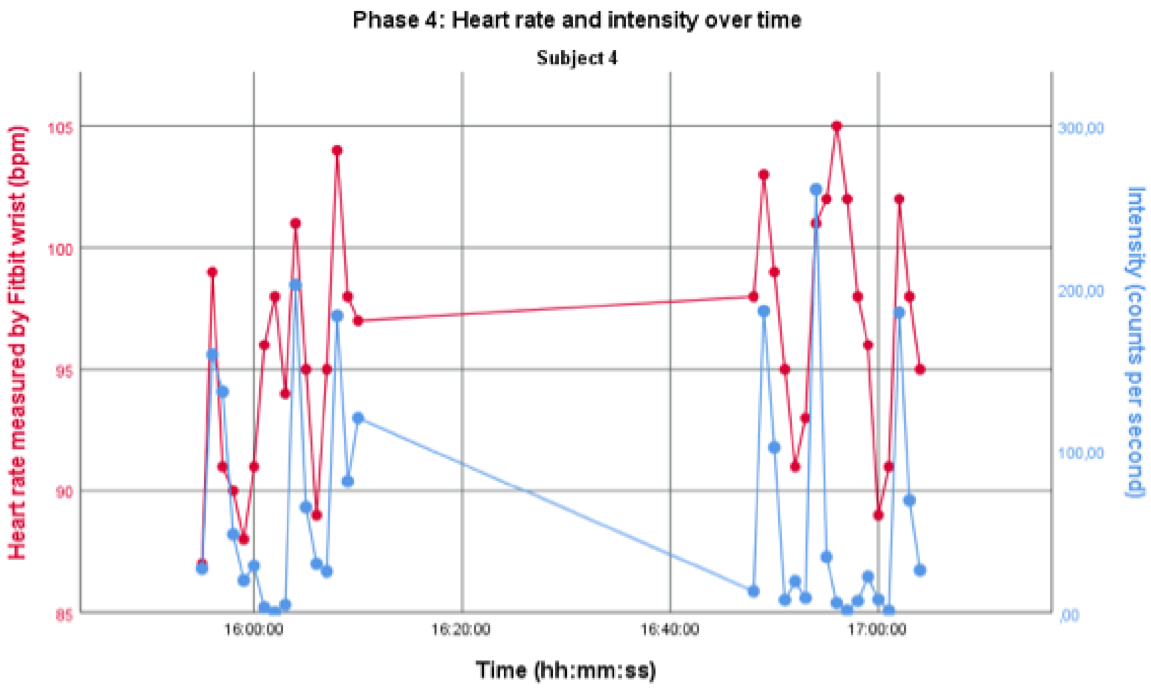


Figure 30: *Heart rate and intensity over time during phase 4 of subject 1. The spikes on the left represent the 'without GERT' state, the spikes on the righ represent the 'with GERT' state.*



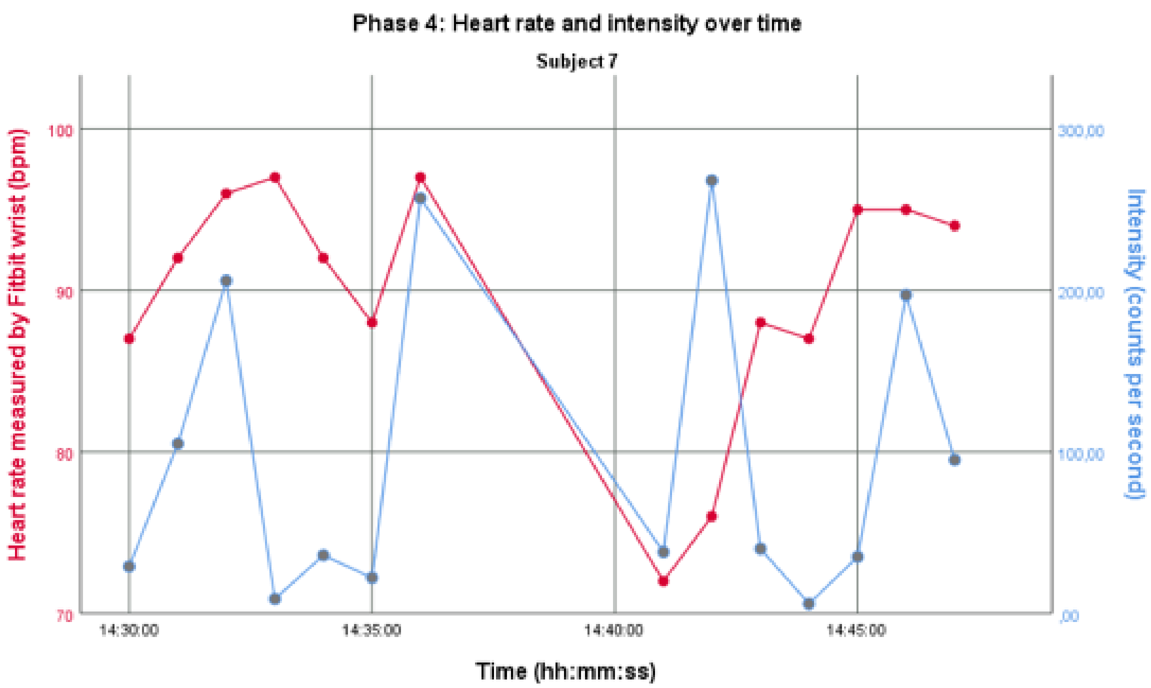


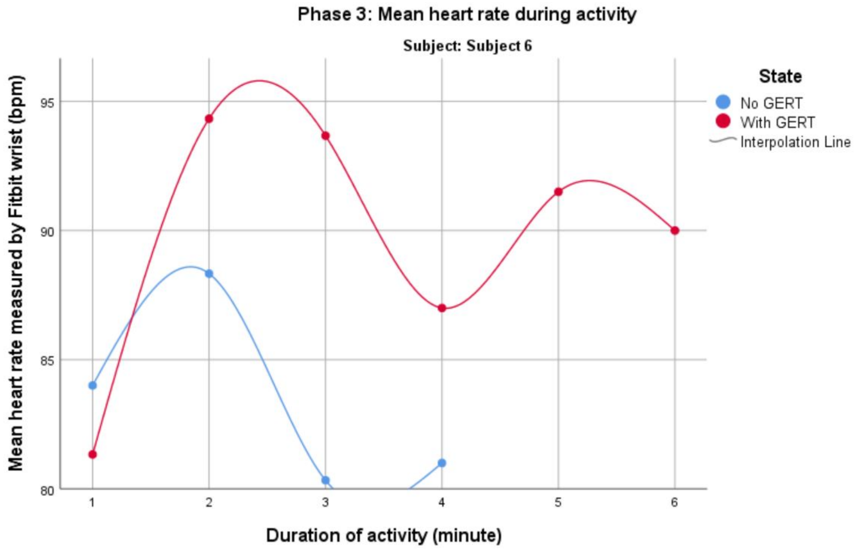
Figure 31: *Heart rate and intensity over time during phase 4 of subjects 4 and 7. The spikes on the left represent the 'without GERT' state, the spikes on the righ represent the 'with GERT' state.*

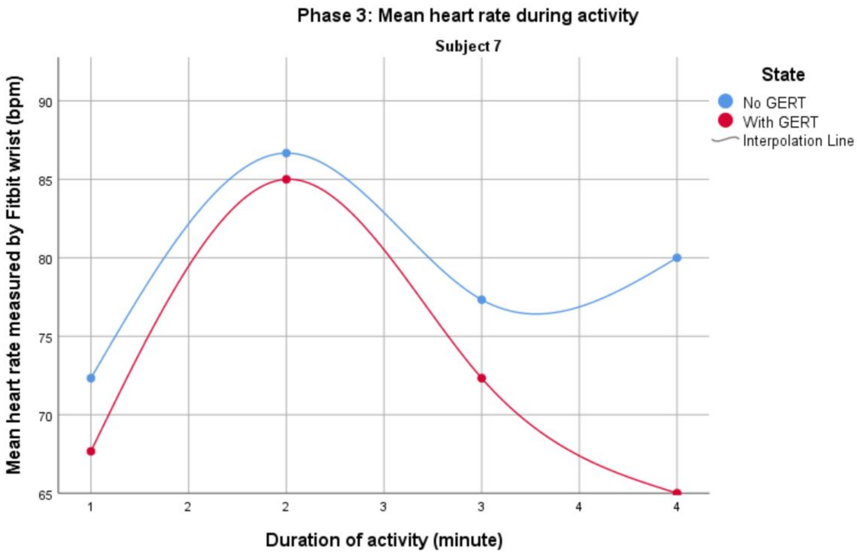
Appendix I: Overview of intensities during different activities

Activity	Mean intensity	SD
Walking (50 bpm)	92.26	81.13
Walking (100 bpm)	348.32	340.45
Walking (145 bpm)	572.91	703.37
Getting out of bed	4.88	3.32
Walking (80 bpm)	8.98	2.77
Pants off	3.97	3.14
Stand to sit	2.20	1.69
Sitting	1.22	2.13
Sit to stand + pants on	3.53	4.32
In bed	3.89	3.04
Sit to stand	3.54	3.44
Pants on	4.13	3.78
Stair climbing	91.52	85.15

Table 7: *Overview of intensities during different activities*

Appendix J: Mean heart rate during activity





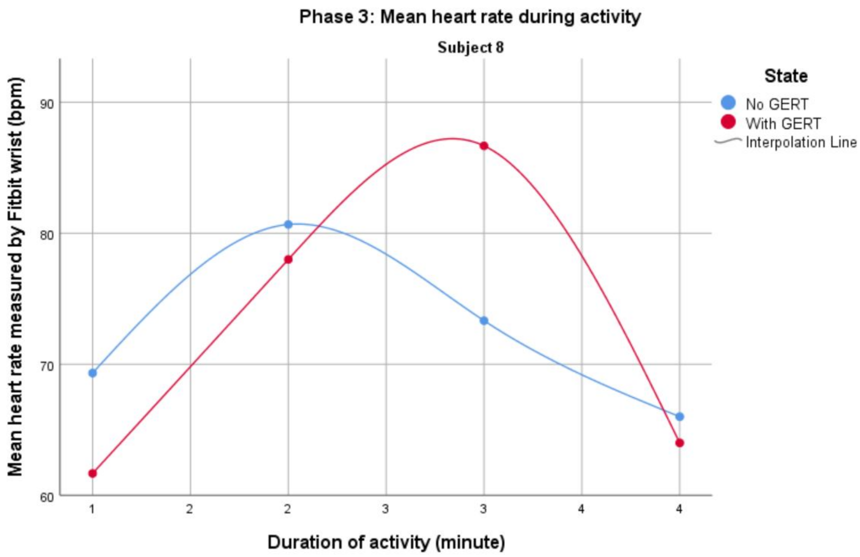


Figure 32: *Mean heart rate during activity of phase 3 for 'with GERT' and 'without GERT'.*

Appendix K: Additional parameters

As mentioned in the *Section 7 Recommendations*, the parameters gait speed, balance, minimum foot clearance and resilience, which are related to mobility,[39] are of importance in determining the ability to move safely and independently.[39] In this appendix it is explained why it is important to further investigate these parameters.

Mobility

Mobility,[39] defined as the ability to move safely and independently, is a fundamental part of many basic and instrumental activities of daily living. Mobility is associated[42,43] with gait speed and balance. Regarding hip fracture patients, research[86] has shown that balance increased one year after hip fracture treatment. Therefore, the continuous monitoring of mobility could give an indication of functional recovery.

Balance

Balance is related to gait speed,[87] step width[88] and minimum foot clearance[89] (MFC). Hip fracture patients have a lower gait speed[90] in comparison to people of the same age without a hip fracture. Declining gait speed[87] can be related to poor functional performance. Furthermore, an increased variability in step width[88] is a sign of impaired balance and may be caused by fatigue. Due to fatigue, elderly people are identified with decreases in walking efficiency[88] and increased tripping risk. Tripping risk[89] can be minimised by increasing MFC, which is the foot-ground clearance. Another way to minimise tripping risk,[89] is reducing MFC variability to attain a more consistent swing foot control. In addition, a decreased MFC[91] is associated with fatigue. To conclude, gait speed, step width and MFC are related to balance. Therefore these parameters have a major impact on the risk of falling for elderly. Fear of falling has a negative influence on functional recovery of hip fracture patients.[58] For this reason it is of importance to include the above mentioned parameters when deciding whether a patient is able to perform an activity safe and independent.

Resilience

Resilience[92,93] is described as “the ability of a patient to retain, achieve or regain a level of physical health after stressors such as illness”. Regarding recovering from moderate stressors, a patient may have adequate physiologic reserves, yet lack sufficient resilience[94] to recover from severe stressors. Currently, resilience is quantifiable by the Connor-Davidson Resilience Scale.[95–97] Treatment,[95] which includes rehabilitation, makes it possible to improve resilience. Yet, no significant relationship[98] is found between resilience and outcomes in geriatric rehabilitation. However, resilience shows future research prospects[98] in promoting healthy aging.[92,99] Improving resilience may enhance functional recovery during the rehabilitation process of hip fracture patients.

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