THE USE OF CLINIMETRY AND CONTINUOUS MONITORING IN GERIATRIC REHABILITATION AFTER A HIP FRACTURE

MASTER THESIS

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THE USE OF CLINIMETRY AND CONTINUOUS MONITORING IN GERIATRIC REHABILITATION AFTER A HIP FRACTURE

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Abstract

Background: In the Netherlands each year approximately 17.000 elderly people suffer from a hip fracture. Due to the rising average age in the Netherlands, the number of hip fractures will most likely increase. This causes a lot of pressure on the health care system. Organizing processes more efficiently and more effectively by using technology, is expected to both lower this pressure on the health care organizations and to make processes more cost-effective. The overall aim of this pilot study was to get more insight in the value of continuous monitoring in geriatric rehabilitation after a hip fracture. To determine this value, the outcomes of the continuous monitoring were compared with the outcomes of administered clinimetry.

Methods: In this longitudinal study twelve patients were followed during their rehabilitation in a nursing home. This study was carried out in five nursing homes in the vicinity of the ZGT Almelo. The patients were all aged 70+ and had no other severe comorbidity. During their stay, the patients wore a Fitbit continuously. The Fitbit was used to gather data of the patients on four parameters; the number of steps per day, the number of active minutes per day, the longest activity block per day and the resting heart rate.
During the rehabilitation period clinimetry about the progress of the patients was also administered. To determine the value of continuous monitoring, the outcomes of continuous monitoring were compared with information coming from administered clinimetry. The ICF model was used as framework to do so. Within this framework, correlations between the different determinants were investigated. In addition, for the Fitbit parameters the progression per week per individual parameter was also determined to provide an objective insight into the progression of the rehabilitation process. Furthermore, a formula was made to predict the length of stay with as input the gradient of steps per day.

Results: Using the methods described, in the clinimetry on group level a significant improvement was found between admission and discharge on the FAC and the Barthel Index. However, no significant correlations were found between Fitbit data and clinimetry both at admission and at discharge. A strong negative correlation is found at admission between the MMSE and Barthel Index (-0.914 ($p<0.001$)) and at discharge between the SNAQrc and resting heart rate (-0.817 ($p = 0.007$)).
When analyzing the correlation of the tests on the body function, activity and participation determinant, it was found that the activity determinant has the strongest link with the health condition. A correlation was found between the FAC and Barthel (0.877 ($p<0.001$)) at admission. When looking on an individual level, it was shown that two out of the twelve patients show almost no progression during the rehabilitation period. Also, a lot of variability in activity exists between the patients. The progress of the patients on the Fitbit parameters shows a lot of variability as well. The degree of progression on Fitbit parameters varies between 0 and 83%. Furthermore, it was found that the most progression was made by the patients in the first five weeks, the added value of a stay of six weeks or longer is questionable. In literature it is found that the average stay of patients in geriatric rehabilitation is 61.5 days (8.8 weeks).

Discussion: In this study very few correlations were found, some that were found were unexpected. It is hard to define what the reason could be for the low number of correlations but probably the small sample size is related to this. Another factor that might influence the results of the study is a selection bias. Only patients that had a good cognitive functioning at admission were followed. This leads to very small differences on the cognitive test (MMSE), making the influence of outliers large. Also, all patients that were included in this study were going home after rehabilitation, which is not representative for the average rehabilitation process.

Conclusion: By comparing the information coming from the Fitbit with the clinimetry on individual level, it was shown that the Fitbit provides additional information. This form of eHealth could support in providing information about the progression made by a patient and in noticing early in the process that deviations occur in the rehabilitation (high resting heart rate, less activity). The Fitbit can therefore help to make tailored rehabilitation programs, based on the progression the patient makes on the level of activity. However, in this study it could not be proven that the continuous monitoring obtained with a Fitbit is related to administered clinimetry at admission, during and at the end of the rehabilitation process.

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1 Introduction

In the Netherlands each year approximately 17.000 elderly people suffer from a hip fracture (1). In 2013, 68% of the patients with a hip fracture was a woman. Concerning age, there is a peak for patients between the age of 85 and 89 years. The average length of stay for a hip fracture patient in the hospital, is six days (2). The consequences of a hip fracture are serious; on average one in four patients dies within the first year after the fracture and in more than half of the patients the mobility is still limited after one year (3)(4). Furthermore, after geriatric rehabilitation 53% of the patients does not reach the level of functioning from before the hip fracture (5). Due to the rising average age in the Netherlands, the number of hip fractures is most likely to increase. This causes a lot of pressure on the health care system. Organizing processes more efficiently and more effectively by using technology, is expected to lower the pressure on these organizations and make processes more cost-effective.

In 2008 the Center for Geriatric Traumatology (CvGT) was established in Hospital Group Twente (ZGT) to respond to the rising demand of geriatric care. In ZGT about 350 patients with a hip fracture are treated per year. In the CvGT a multidisciplinary treatment concept is applied from the moment a patient is admitted, up to and including the outpatient follow-up (6). After leaving the hospital, about one third of the patients rehabilitates in a nursing home in the vicinity (5).
Because the ultimate goal of geriatric rehabilitation is returning the patient to his or her own living environment, rehabilitation is focused on functional recovery (6)(7). To achieve this, patients receive individual physiotherapy every weekday. However, a full recovery of function is achieved in only 20% of the cases (3). Older adults after hip fracture spend prolonged periods of waking hours sedentary and without much activity; decreasing and breaking up this sedentary time and increasing physical activity is an important target for rehabilitation (8). In 2010, the length of stay of patients in a nursing home in the vicinity of Almelo was on average 8.5 days longer than the national average (5). As such optimization is needed and therefore more insight into the rehabilitation process of hip fracture patients is needed (5).

To get insight in the rehabilitation process, clinimetry administered by physiotherapists, nurses and elderly care physicians is used to acquire information on the functional status and progress of the rehabilitation process of the patient. However, information coming from clinimetry is quite static, and as most tests are administered in a low frequency, insufficient insight in the process is gained to steer the rehabilitation process of individual patients. Information from wearable sensors that enable continuous monitoring can help. They enable recognizing irregularities in the rehabilitation process and can provide information to forecast on in an early stage in the rehabilitation.

One way to achieve this objective, continuous insight, is by using activity trackers. For obtaining continuous data, in the CvGT and the surrounding nursing homes the choice is made to use the Fitbit. Information that can be obtained with the data coming from a Fitbit are the number of steps taken, the number of active minutes per day, the longest activity in minutes per day and the resting heart rate. In literature almost no information is available about the use of wearables like Fitbits in geriatric rehabilitation. Very few studies do have objectified the relationship between ambulatory activity (i.e. number of steps) and disability. One study on physically frail elderly in nursing homes measured with a wearable showed with a cross sectional research, that patients who took more than 1300 steps per day had significantly better clinical outcomes (8).

The overall aim of this pilot study is get more insight in the value of continuous monitoring in geriatric rehabilitation after a hip fracture. To be more specific, the following research question will be answered: “Is the data of the continuously monitored activity parameters using Fitbit related to the outcomes of the clinimetry at the start, end and during the geriatric rehabilitation process after a hip fracture?”

In this thesis the International Classification of Functioning (ICF) model will be used as reference model. With the use of the ICF the clinical outcomes and the information obtained by the Fitbit can be connected in a way that is provides insight into the functional status of the patient. Using this framework, the following sub questions are answered to be able to provide the answer on the research question:

According to the different components of the ICF model:
1. Is the clinimetry related to the continuously monitored activity at baseline?
2. Is the clinimetry related to the continuously monitored activity at discharge from rehabilitation in the nursing home?
3. Is the weekly progress of a patient visible in both the clinimetry and the continuously monitored activity?

Furthermore, the following sub question is answered:
4. Is the gradient of number of steps per day related to the length of stay and the final Barthel score?

2 Theoretical framework

2.1 The ICF model

In this study the ICF model is used as framework to connect the outcomes of the Fitbit parameters to the outcomes of the clinimetry and to interpret these results.

Health is a term which is hard to grasp in objective parameters. Health is defined by World Health Organization (WHO) as "A state of complete physical, mental, and social wellbeing, and not merely the absence of disease or infirmity." There is no clear, specified, definition about what health does contain; therefore, it is also hard to describe what rehabilitation (the process of optimizing) exactly contains (9). In geriatric rehabilitation, the aim is functional recovery. Recovery refers to recapturing the level of functioning and well-being prior to the hip fracture (10)(11). Based on the WHO's integrative model of human functioning and disability, the aim of functional recovery is to enable people which experience disability to achieve and maintain optimal functioning in interaction with the environment (12).

The International Classification of Functioning, Disability and Health (ICF) is a reference classification of the World Health Organization (WHO) Family of International Classifications. In the ICF, health condition is the umbrella term for disease (acute or chronic), disorder, injury or trauma. The model defines three aspects of human functioning: body functions and structures, activities, and participation. Health can therefore be described from a physical, individual and social perspective (13). The interaction between the determinants is dynamic. The interactions of the determinants in the model are in two directions and interventions in one determinant can potentially modify one or more of the other determinants.(14) An individual's functioning or disability in a specific domain represents an interaction between the health condition and the contextual factors (environmental factors and personal factors). Disability due to a hip fracture similarly denotes a decrement in functioning at all those levels. It is an impairment; it limits activity and endures restrictions in participation (15).

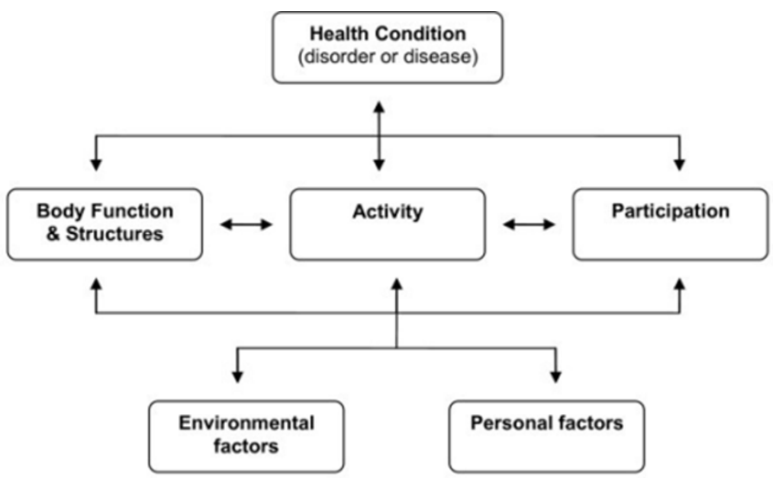

Figure 2-1: ICF Model (16)

The ICF uses an alphanumeric system with the letters b (body function) s (anatomic characteristics), and d (activities and participation). These letters are followed by a numeric code that reflects where the problem can be found in the code book per determinant of the ICF (17). In this study it helps to place the clinimetry on the right place in the framework. The ICF is useful for understanding and measuring health outcomes and can be used in clinical situations, in all kinds of healthcare institutions and in health research at individual and population level (17). In this study the determinants environmental and personal factors were not taken into account.

To be more specific about the determinants used in this study (13):

- Body Function and Structures: Body function is defined as the physiological functions of body systems, including psychological functions. Body structures refer to the anatomical parts of the body, such as organs, limbs and their components. Abnormalities of function, as well as abnormalities of structure, are referred to as impairments, which are defined as a significant deviation or loss (e.g. deformity) of structures (e.g. joints) and/or functions such as reduced range of motion, muscle weakness, pain and fatigue.
- Activity: Activity contains the execution of a task or action by an individual and represents the individual perspective of functioning. Difficulties at the activity level are referred to as activity limitation (e.g. limitations in mobility, such as walking). In this study the activity determinant is used to get insight into the capacity of the patient.
- Participation: Refers to the involvement of an individual in a life situation and represents the social perspective of functioning. Activity limitations have their influence on the participation. Problems an individual may experience in his or her involvement in life situations are denoted as participation restriction (e.g. restrictions in community life, but also in walking if walking is an aspect of participation in terms of a life situation). In this study the participation determinant is used as qualifier to describe what an individual does in their current environment (i.e. during rehabilitation) (16).

2.2 Geriatric rehabilitation after a hip fracture

In the Netherlands geriatric rehabilitation is focused on geriatric patients who stayed in the hospital because of an acute illness or an elective surgery. Every year this group contains between 25.000 and 30.000 patients. From this number of patients, 25,1% is rehabilitating from a hip fracture with an average of hospitalization (total number of days in nursing home) of 61.5 days (6)(5). In 2016 in the Netherlands the average stay for a hip fracture in the hospital is six days (2). After the stay in the hospitals 33% of the patients went to a geriatric rehabilitation ward (2).

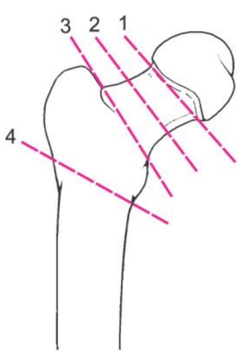

Figure 2-2: The four included types of hip fractures

Patients admitted to the hospital with a hip fracture are mostly already dependent on others for their activities of daily living. In general, they are more limited in the use of their lower limbs than the average population of the same sex and age (4). Furthermore, the age-related aspects such as comorbidity and polypharmacy make the treatment even more complex. Because of this, the risk of getting a serious complication is high and loss of function can occur in these patients. The treatment is often accompanied by high costs (6). When patients with a hip fracture are admitted to the hospital, multiple types of hip fractures are possible. The fracture type is classified using the AO-ASIF (Association for Osteosynthesis/Association for the Study of Internal Fixation) guidelines and can be divided in 1. Medial collum femoris fracture 2. Lateral collum femoris fracture 3. Petrochantairic fracture and 4. Subtrochantairic fracture as shown in Figure 2-2. From surgical perspective, there are certain special considerations in this population including osteoporosis, pre-existing arthritis, age, activity level, and overall health that contribute to the type of surgical fixation performed (9). Goal of the operative treatment is to create a weight baring situation for the patients. Early mobilization is part of the proactive treatment after a hip fracture, to prevent or limit loss of function or complications postoperatively (9). Physiotherapy often starts the day after the surgery. From that moment on, patients are expected to exercise and to improve their activity together with the physiotherapist. Factors like complications (e.g. a delirium or comorbidity) could have a negative influence on the physical activity performed by the patients (11)

After these days in the hospital the patients go to a rehabilitation ward in a nursing home if they are estimated as 'able to rehabilitate'. The indication for short-term geriatric rehabilitation is set in the hospital on day three postoperatively, on the basis of the patient's care needs. The patient is indicated for short-term rehabilitation if it is expected that the patient will be sufficiently recovered within three months to return to the living situation from before the fracture. During rehabilitation the physiotherapist exercises with the patient to build up muscle strengthening, improving balance and reducing fear of falling. The occupational therapist encourages the self-help management and the performance of activities of daily living (15). During rehabilitation, patients are having individual physiotherapy of thirty minutes on a daily base in every nursing home. In one nursing home (TMZ) the patients also have group physiotherapy twice a week (5). Progress of the patients will be monitored by these therapists, but also by nurses and physicians. Patients who are seen as 'not able to rehabilitate' mostly go to a nursing ward with continuous care. Cognitive problems are an important reason to classify patients as 'not able to rehabilitate'. However, the study of Uriz-Otano et al. suggest that previous walking ability and the presence of complications, such as pressure ulcers or delirium, play a greater role in functional recovery than cognitive impairment (19).

2.3 Clinimetry

During the rehabilitation process of a patient, the functional progress is assessed by clinimetry taken at different moments in time. The tests that were used in this study are shown in Table 2-1. A more detailed explanation of the different tests can be found in Appendix I: Administered clinimetry. As can be clearly seen in the table, the letters of the ICF codes reflect that the various tests often measure multiple variables that are in different determinants of the ICF model (12) . To set up a framework for the study, choices are made to place specific tests in the different determinants of the ICF model to be able to analyze the functional status of a patient:

Table 2-1: Overview of administered clinimetry tests

Functional Ambulant Categories (FAC)	Measures the degree of independence of walking (19). ICF codes: d4500 Walking : d465 Moving around using equipment
Barthel Index	Determines the degree of help (physical or verbal) that a person needs to perform general daily actions (20). ICF codes: d510 till d570 ADL : b789 Motion functions, otherwise specified and not specified
Timed up and go (TUG)	Measures balance in elderly people (21). The TUG test is a test of basic mobility and reflects the ability to transfer from sitting to standing and to walk a short distance, two basic functions for home safety. ICF codes: d420 Performing transfers : d4500 Walking : s410 Anatomical functions of the cardiovascular system
10 meter walking test (10 MLT)	Determines functional mobility, gait and vestibular function (22) ICF codes: d4500 Walking : b770 Gait pattern: b235 Vestibular functions
Short Nutritional Assessment Questionnaire for residential care (SNAQrc)	Determines the degree of disease-related malnutrition in patients in nursing homes (23) ICF codes: b510 Intake of food : b539 Functions of digestive system, otherwise specified and unspecified
Mini-Mental State Examination (MMSE)	Screening of cognitive impairment in the elderly (24) ICF codes: b117 Intellectual functions : d175 Solving problems : b144 Memory functions

An overview of the tests administered per week in this study can be found in Table 2-2.

Table 2-2: Overview of administered clinimetry

	Hospital	Rehabilitation				
	Discharge	**At admission**	**Once a week**	**1x per 3 weeks**	**1x per 4 weeks**	**Discharge**
FAC	X	X	X			X
Barthel Index		X		X		X
TUG		X*			X*	X
10 MLT		X*			X*	X
SNAQrc		X				
MMSE		X				

(*when FAC ≥ 3)

ICF: Health condition:

In this research the ultimate goal is functional recovery of the patient. Functional recovery contains independency in performing activities of daily life (25). Therefore, in this study the choice is made to describe the health condition with the Barthel Index. A high score on the Barthel Index means a high level of independency (25). The Barthel index must be a record of what the patient is doing and not a record of what the patient could do (20). The Barthel Index can thus be seen as decisive parameter in deciding if the functional recovery of the patient is sufficient to go home. In multiple researches the Barthel Index is used to determine the functional status of a patient (26) (25) (27).

ICF: Body functions and structures:

The level of functioning of the body of the patient is described with the SNAQrc and the TUG in this study. The SNAQrc (23) gives an indication of the nourishment status of the patient. Malnourishment is a common complication, affecting up to 20% of hip fracture patients. A catabolic state predisposes patients to protein shortage, leading to decreased wound healing and an increases the chance on other postoperative complications (28). The TUG is suitable for assessing walking speed in the context of functional movement. In addition, the TUG helps to determine a possible fall risk (the longer the duration, the greater the chance of an increased fall risk) (21).

ICF: Activity:

Getting mobile again is a stipulation for functional recovery after sustaining a hip fracture. The FAC gives insight into the level of independency in walking. It gives an indication about the progress of physical recovery of the patient with the goal to be independent in walking (29). The 10 MLT walking test is also strongly connected with the activity part, because this test provides insight into the activity levels and physical function of the patient (22). It provides insight about the physical possibilities of walking, gait and physical capacity of the patient. Therefore, the FAC and 10 MLT test are used for the activity determinant in this study. The score of the Barthel Index is also influenced by the scores on these two mobility tests. A certain level of mobility and capacity is required for doing the activities of daily living independent of help.

ICF: Participation:

Participation will be analyzed with the use of the MMSE test, the MMSE is a test that gives an indication of the cognitive function of the patient. In rehabilitation a level of cognitive ability is required to understand and fulfill the rehabilitation program. Patient who are facing cognitive problems have a lower score on functional recovery than patients who are not facing cognitive impairment, furthermore the length of hospitalization is longer for patients with cognitive problem (30). Together with the level of mobility this can give an indication of the level of participation that may be expected from a patient.

2.4 Fitbit measurements

Continuous monitoring will be used alongside the clinimetry, to provide more in-depth insight into the rehabilitation process of a patient. In this study the Fitbit is used for this continuous monitoring. It has the ability to provide continuous, objective, remote monitoring of physical activity and the potential to improve the efficacy of physical activity interventions (13). A Fitbit (shown in Figure 2-3) is a wearable worn like a normal wrist watch. In this study the parameters; resting heart rate, steps per day, active minutes and 'blocks' of active minutes will be determined and analyzed. In this study the Fitbit Charge HR and the Fitbit Charge 2 are used to collect the continuous data. The Charge 2 is similar to a Charge HR, but with some extra add-ons. In the next paragraphs the different parameters measured with the Fitbit will be described.

Figure 2-3: Example of a Fitbit

2.4.1 Measuring resting heart rate

The resting heart rate provides information about the condition and the functional capacity of a patient. When the resting heart rate stays high during the rehabilitation, this may indicate a deviation in the rehabilitating process. Resting heart rate is a familiar and inexpensive-to-measure clinical variable. An overview of the rating of resting heart rate can be found in Table 2-3. Resting heart rate can be modified by a number of factors, such as physical activity, psychologic stress and medications (31). Higher resting heart rate is associated with worse functional status and with higher risk of future functional decline in older adults, independent of cardiovascular disease (26). When by activity the capacity of a patient increases, the resting heart rate will normally decrease. Patients who suffer from a hip fracture can also have a higher resting heart rate due to stress and fear of falling. In a longitudinal study involving 124 patients with a hip fracture rehabilitating in nursing homes, the chance of developing fear of falling is described. Fear of falling is mainly related to the mobility limitation before the fracture, the ADL limitation after the fracture and a high level of anxiety. Fear of falling can increase during rehabilitation, the incidence is found to be between 62.5% and 82.1%. The fear was found to be highest for patients who have a length of stay in rehabilitation between four and eight weeks (32).

Table 2-3: Overview of typical resting heart rates

Gender	**Heartbeats per minute**						
	Athlete	**Excellent**	**Good**	**Above average**	**Average**	**Below average**	**Poor**
Male	50-55	56-61	62-65	66-69	70-73	74-79	80+
Female	54-59	60-64	65-68	69-72	73-76	77-84	84+

To get the most reliable measurement of resting heart rate by manual measurement, the heart rate should be measured directly after waking up in the morning (8). However, in this study the measurements are also available before a patient wakes up. In this study therefore, the resting heart rate is determined by the average over half an hour, 10 minutes before the first tracked activity. This moment is chosen because it is assumed that this is the moment that the patient probably wakes up. This resting heart rate is determined for every day of the patient's stay in the nursing home.

Accuracy measuring heart rate

The described results of the accuracy of Fitbit measuring heart beats per minute in literature vary. In most of the researches a discrepancy is found in the accuracy of the measurements of the heartrate. The accuracy of the Fitbit Charge 2 is described in the research of Benedetto et al. (33) (n=9000, 15 people x 10 min measurements). The mean bias in measuring heart rate was -5.9 beats per minute (bpm) (95% CI: -6.1 to -5.6 bpm), the limits of agreement, between the Fitbit Charge 2 and ECG measurements, were wide (+16.8 to -28.5 bpm) ICC = 0.21. In different researches it is concluded that the Fitbit Charge 2 underestimates the heart rate. The findings of Benedetto at al. are in line with those of several recent publications involving the predecessor of this device (i.e. Fitbit Charge HR) (34),(35),(36),(37).

With taking this information into account, the acquired data in this research can be properly valued. For instance, longer period trends might be discovered, even though single measurements have large tolerances. Also, care should be taken when using the absolute values of these numbers, but assuming that the average bias is relatively constant, longer term differences can give a good indication of improvement or decline.

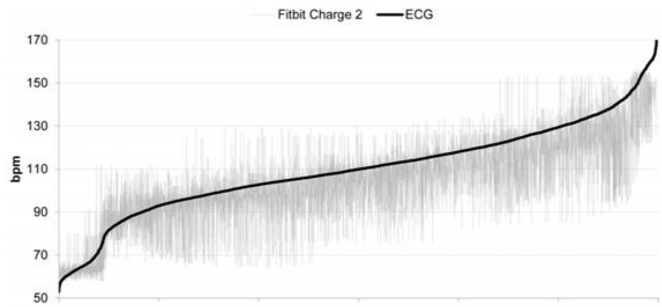

Figure 2-4: Accuracy of heart rate data (Fitbit Charge 2 vs. ECG) (37)

2.4.2 Measuring steps

Step counting is particularly important for the most inactive patients because their entire activity level is reliant on basic ambulatory activities. Step counting devices provide a device of objectively quantifying total daily activity. Also, their counting mechanisms are particularly sensitive to detecting the recommended intensities of walking believed to be associated with a host of healthful outcomes for older adults (38). For instance, very low intensity steps (shuffling) will normally not be registered.

When counting steps, healthy older adults are advised to take 6,000-8,500 steps/day and special populations (patients living with disability and/or chronic illness that may limit mobility and/or physical endurance) are advised to take 3,500-5,500 steps/day (38). In the start of the rehabilitation process it is assumed that this target is too high for the patients. For them it is possible that any increase in daily step relative to individualized baseline values could confer health benefits. The average gait speed of patients rehabilitation of a hip fracture can be determined on 0.54 ± 0.29 meter per second (39). The step length is for patients who have had a surgery for a total hip replacement is 0.43 meter (40). This length of steps is the best fitting number found in the literature, for the subjects in this study.

Decreased mobility after a hip fracture can lead to further muscle weakness and thus an increasing risk of falling. This can lead to a spiral of mobility disability (41). Early mobilization with assistance of physiotherapist may be beneficial (42). Physical therapy after hip fracture is the standard procedure for most elderly patients, the assumption was made that when patients were having physical therapy in a high frequency they are taking more steps per day. More physical therapy immediately after hip fracture surgery was associated with significantly better locomotion two months later (42). Patients who received physical therapy in the hospital, in a skilled nursing facility, or in both locations were more likely to return home on discharge than those who did not receive any physical therapy (42) (43).

Elderly in nursing homes walk, on average, 1678.4 ± 1621 (median = 1300) steps per day (8). Research (n=24) in nursing homes on physically frail elderly people measured with a wearable showed that patients who took more than 1300 steps per day had a significantly higher MMSE score ($p = 0.004$), Katz level ($p = 0.04$), Tinetti score (= evaluation of balance and gait) ($p = 0.0003$), Short Physical Performance Battery score ($p < 0.001$), peak flow ($p = 0.001$) as well as a significantly lower time required to perform the Timed up and Go test (0.0004) than subjects who walked less than 1300 steps per day. As would be expected, subjects more active (i.e. >1300 steps/day) were significantly less frail than less active subjects ($p = 0.0005$) and were requiring nursing or medical care less frequently ($p = 0.03$). Finally, these subjects also had a better nutritional status and less at risk of malnutrition ($p = 0.04$) (4).

In research of Cook et al. (34) on elderly patients who had a major surgery (n=149) a wearable was also used. The data gained with an accelerometer suggests mobility achieved on recovery day two leads to two outcomes: it is demonstrated that remote monitoring of mobility is effective to assess hospital surgical recovery, and secondly that such data has implications for resource utilization and outcomes. Patients with the highest early mobility had the shortest length of stay and were less likely to be discharged to a nursing home or to home with home care. Such data may have powerful predictive value for discharge planning and resource utilization and are additive to conventional predictors.

Accuracy measuring steps

The validity and reliability of the taken steps measured with the Fitbit are described in a systematic review of 22 articles (44). For laboratory-based studies using step counting or accelerometer steps, the correlation with tracker-assessed steps was high for Fitbits (Pearson or Intraclass correlation coefficients (ICC) > =0.80) (44). Walking based Fitbit trials indicated consistently high inter device reliability for steps (Pearson and ICC 0.76–1.00) and distance (ICC 0.90–0.99). Slower walking pace and impaired ambulation, like the limited mobility of the elderly, reduce the levels of agreement (20).

In literature it is described that hip- worn trackers generally outperformed wrist-worn trackers for step accuracy (45). Hip-worn trackers appear to be the most consistently accurate for the assessment of steps because the placement facilitates the detection of ambulatory movement (37) (45) and does not include any arm movement while not taken steps. To mitigate the influence of the measurement accuracy, the difference between the number of steps per week can also be monitored. This way the absolute level is not taken into account, but for instance the gradient of the number of steps per week might be a good indicator for the increase in health of the patient.

2.4.3 Fitbit outcomes in ICF

Number of steps and resting heart rate, but also the clinimetry, all provide insight into the functional status of a patient. In functional status a distinction can be made in in physical activity and in physical capacity. Physical activity is what patients actually do and is defined as any body movement produced by skeletal muscles that require energy expenditure (46). Physical capacity is what people are maximally capable to do, it is defined as ability to be mobile, such as walking and standing up. When measuring the physical capacity of patients, the clinimetry contains tests that are conducting walking, balance, rise and combinations of those functions (47). The connection between physical capacity and physical activity is limited; improving physical capacity does not automatically translate into an increase in physical activity (47).

In this study, just as for the clinimetry data, the Fitbit parameters are also categorized in an ICF determinant:

ICF: Body function and structures:

The resting heart rate can mainly be used as indicator for the body function of the patient. When deviations in the resting heart rate are perceptible, this most likely also has an influence on the other determinants of the ICF model.

ICF: Activity[1]:

Of the available Fitbit data, longest activity block per day fits best into this determinant of the ICF model. The capacity of a patient must have a certain level to participate in the activities of the daily living. The longer a patient is consecutively active per day, the better his capacity and the better the patient’s condition will be. As mentioned before, when a patient is active more than ten minutes in a row, it increases the capacity (16). In previous research is found that patients who were rehabilitating from a hip fracture after two weeks have a capacity to walk six minutes in sequence (48). An increasing longest activity per day might lead to an improved functional capacity in rehabilitation. In short, the ICF activity can be described as: the ability to perform certain tasks, i.e. the physical capacity.

ICF: Participation:

For this determinant number of steps per day and the number of active minutes per day will be used. Those parameters both provide insight into the level of physical activity of a patient. Every minute in which activity

[1] Please note that the ICF Activity is not equal to the Physical Activity (functional movement vs. any muscular movement)

is measured on a patient, is in this research taken as active minute. In this determinant it becomes visible what a patient really performed during a day in rehabilitation. I.e. the actually performed physical activity.

2.5 Composed ICF model

The figure below gives a summary of the chapter:

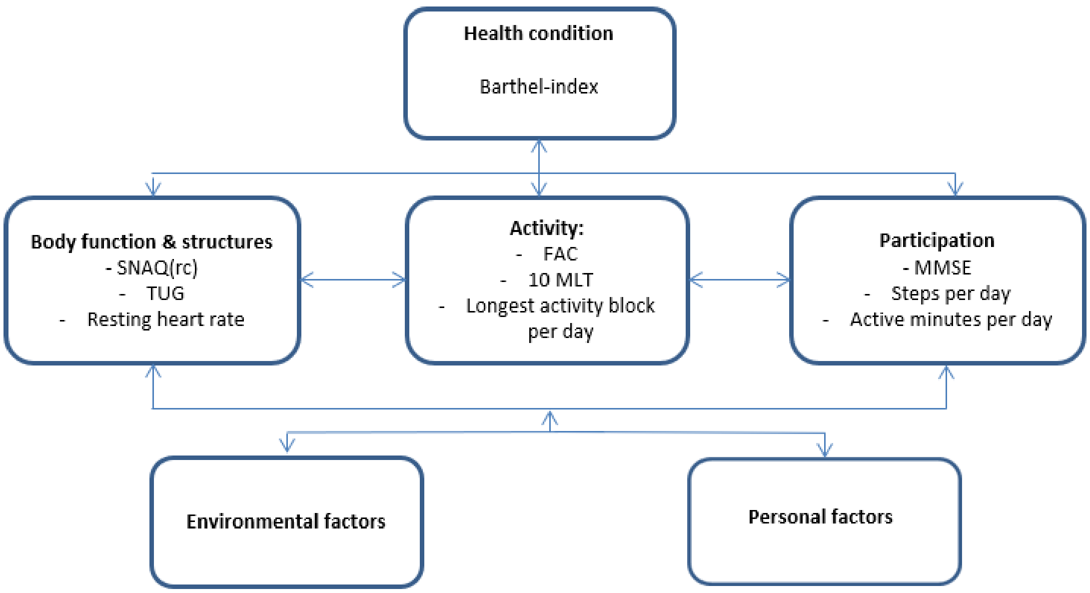

Figure 2-5: Composed ICF model

To further analyze the data, hypotheses are stipulated. At admission it is expected that the scores on the Fitbit parameters are on a low level, because patients have to get used to getting mobile again. The clinimetry data is also expected to be at a low level due to this same reason. One would therefore expect that at admission the clinimetry and Fitbit parameters are correlated. It is expected that the physical activity increases reasonably fast from the start of the rehabilitation. The expectation on the clinimetry is that it increases, however because these exercises require more training relative to the Fitbit parameters it is expected this increase has a lag in time. Therefore, no correlation is expected during the rehabilitation process. At the end it is expected that the level of activity on the Fitbit parameters correlates with the score on the clinimetry.
Furthermore, from baseline, it is expected that patients with a steeper gradient in number of steps per day rehabilitate faster and reach a better functional status faster.
Therefore, the hypotheses in this study are:

1. At baseline a correlation exists between the Fitbit parameters and the clinimetry
2. At the end of the revalidation a correlation exists between the Fitbit parameters and the clinimetry
3. The weekly progress of a patient is only visible in the Fitbit parameters.
4. The gradient of number of steps per day is related to the length of stay and to the final Barthel score.

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3 Methods

This pilot study was executed as part of a bigger project from the Centrum voor Geriatrische Traumatologie (CvGT), the project is called Up&Go after a hip fracture. This pilot study contains a quantitative, explorative, longitudinal research method.

3.1 Research population

Participants in this research are older than 70 years, do not have cognitive problems and must have had surgery performed by a trauma surgeon in ZGT Almelo for a type of hip fracture as shown in Figure 2-2. Participants had to be able to mobilize while bearing their full weight on the fractured hip. Patients were included for this research from the 1st of October 2017 until the 15th of April 2018. The selection for including the patients is made by a nurse practitioner or a physician, based on the expected progress in rehabilitation and the available information concerning the patient in the patient's file. Patients who were not included in the study are patients with severe comorbidity and cognitive problems, such as dementia and / or delirium. From the patients that do meet the inclusion criteria before the hip fracture, a notable number was having cognitive problems like a delirium after the surgery. Furthermore, a part of the patients was having other concomitants injuries related to the fall, for instance a humerus fracture. For those reasons the number of patients which could be included was relatively low. In this pilot study 24 patients were visited by a physician/nurse practitioner and a researcher to tell them about the research and if possible to include them. Twelve of these patients were excluded based on various reasons (discussed in the results chapter), leaving a total of twelve studied patients.

After discharge from the hospital, the participants went to one of the following nursing homes: TMZ het Borsthuis (ward Zwaantje), TMZ het Meulenbelt (wards Weleveld and Everloo), CarintReggeland Eugeria, CarintReggeland St. Elisabeth or ZorgAccent Krönnenzommer.

3.2 Informed consent

Patient who were admitted to the hospital with a hip fracture were informed that information (parts of the clinimetry) about their rehabilitating process is obtained and analyzed for the original project Up&Go after a hip fracture. In the original project the patients only were informed that data (clinimetry) is obtained. The patients do not have to sign an informed consent form, because no extra information was obtained about the patient and no additional interventions were performed. Patients that met the inclusion criteria for this pilot study, involving the collection of continuous data, were asked to wear a Fitbit during their rehabilitation in the nursing home. For this part a form of informed consent was needed, because extra information about those patients is gathered. The patients were asked by a physician to participate in this pilot study after they had the surgery in the hospital. Also, an easy to understand information letter was handed over to the patients in which they could find the information concerning the research themselves. When a patient decided to participate, a form of informed consent was signed by the patient and the researcher simultaneously.

3.3 Data collection

When a patient was included in this research and received a Fitbit, the patient received a trial number. This number was to secure the privacy of the patient. From this moment on, only this number was used in collecting the Fitbit data of the patient. Professionals in the nursing home were informed about the trial number of their new patient when the patient was transferred to the nursing home. The Fitbit was worn around the wrist and it was registered whether this was on the dominant wrist or not. The patient had to wear the Fitbit at all times, it was only taken off when the patient was showering or for charging and synchronizing. The Fitbit had to be charged twice a week and synchronized once a week, this was done by physiotherapists in the nursing home. The time the patient was not wearing the Fitbit was registered. For this study, the data gained from day one in the nursing home until the second-last day of stay in the nursing home was used.

The clinimetry was gathered by different stakeholders in this research, like physicians, occupational therapists and physiotherapists during the stay in the hospital and in the nursing home. Data was gathered by these professionals on fixed moments in the care pathway. Each professional was administering the clinimetry which suited their profession and they knew what was expected from them. Each participating organization had a contact person that was well informed on the project and shares the information with his colleagues. For every participating patient a paper file was created in which the outcomes of this clinimetry could be registered. All the outcomes of the clinimetry were processed in Castor to get an overview of the relevant outcomes. Castor is a cloud based electronic platform for capturing data.

3.4 Data analyses

Each Fitbit has an own Fitbit account in which the data was stored. To transform the data coming from the Fitbit into usable information, the data was downloaded from the Fitbit account into an Excel file. From this file the different parameters coming from the Fitbit were processed per parameter into data which could be used in the statistical analyses using SPSS.
In Castor all information on the scores from the patient, from data obtained in the hospital until data obtained in the nursing home was being collected. From Castor the data was also transferred into the same SPSS file.
From both the clinimetry and the Fitbit, data was missing. In the calculations in SPSS, these cells show a zero and these cells were not taken into account when performing calculations.

To gain more insight in the rehabilitation process and the potential added value of continuous monitoring, statistical analyses were performed on this set of data. In the following section the analyses performed to answer each sub question are described.

Sub question 1:

1. Is the clinimetry related to the continuously monitored activity at baseline?

H0: At baseline a correlation exists between the Fitbit parameters and the clinimetry.

For the information at baseline an average for each of the different Fitbit parameters in the first seven days was used for the twelve patients. Previous research with continuous monitoring in the elderly also used a time frame of seven days to determine the average activity and programmes in nursing homes are almost similar every week (8). For each determinant of the ICF model analyses in SPSS (Pearson or Spearman's rho) were performed to determine the degree of correlation between the Fitbit parameters and the clinimetry. The Spearman's rho correlation determines how well a set of data can be described by a single monotonic equation. The Pearson correlation determines the same, but only for a linear relationship between the variables. Due to the large number of analysed correlations, in the first two sub questions a significant correlation was defined only when $p<0.01$, to avoid spurious correlations.

Sub question 2:

2. Is the clinimetry related to the continuously monitored activity at discharge from rehabilitation in the nursing home?

H1: At the end of the revalidation a correlation exists between the Fitbit parameters and the clinimetry

For the information at discharge an average over the last seven days in the nursing home was used for each Fitbit parameter. The length of stay varies between the patients, from 15 till 62 days. Therefore, the seven days for averaging at discharge were not on the same moment after starting the rehabilitation for each patient. For each determinant of the ICF model an analysis (Pearson or Spearman's rho) was performed to determine the degree of correlation between the clinimetry and the Fitbit parameters.

Sub question 3:

3. Is the weekly progress of a patient visible in both the clinimetry and the Fitbit data parameters?

H1: The weekly progress of a patient is only visible in the Fitbit parameters.

This sub question was answered at individual level and at group level.

Group level:

To define if there was a progression on group level on the Fitbit parameters, a mixed model analysis was performed. In this analysis it was tested if there was a significant progression during the weeks of rehabilitation.

To define if there was a progression in clinical outcomes, a longitudinal method was used to define if the progression was significant. Clinimetry of each subject in the group was measured at the same moment in the rehabilitation process, i.e. the first and the last week in rehabilitation. Due to missing data, only an analysis of the measurements at start of the rehabilitation and at discharge from the rehabilitation for the FAC and the Barthel Index could be performed.

Individual level:

To be able to determine if a patient could be classified as clinically progressed (green) on a parameter, thresholds were set. Patients that did not reach this threshold were classified as not clinically progressed (orange). In literature no information could be found which could give an indication of the levels for these thresholds and what could be seen as clinical progression for the Fitbit parameters for these subjects.
In the data of number of steps, a lot of variance was shown. Therefore, when taking an average with such a small group of subjects, the outliers have a large effect. In this case, a high outlier ensures a threshold that is not met by the majority. For this reason, the choice was made to take an increase of 1000 steps during the rehabilitation period as threshold, this is a number just below the median number of steps taken by nursing home residents (8). When the patients meet this threshold, they are more active at the end of the rehabilitation than nursing home residents. When taking the gait speed and length of steps of patients who were rehabilitating from a hip fracture into account (paragraph 2.4.2), 1000 steps is similar to an improvement of ~430 meter or ~13 minutes of walking in the total rehabilitation duration.
The variance in the parameters number of active minutes per day and longest activity block is smaller. Therefore, for these parameters an average of the progression from the included group of patients was taken as a threshold (e.g. $T_{AM} = (\sum_{j=1}^{P}\left(\max_i(AM_{i,j}) - \min_i(AM_{i,j})\right))/P$, with P = total number of patients).
This seems to be a proper choice for the height of the threshold. When making the threshold lower or higher, the majority of the patients will easily reach the threshold or too many patients do not meet the threshold, making a qualitative analysis of the results difficult. In Appendix II the results of a sensitivity analysis show the effects of changing the values of all thresholds.
The clinical progression for the resting heart rate parameter is determined by a threshold of 10% decrease in heart rate based on the heart rate in the week of admission. In resting heart rate, it is hard to determine the moment that must be measured and there is a ceiling effect that could appear (resting heart rate cannot decrease infinitely), so care should be taken in analysing these numbers.

The formulas to determine if a patient makes overall and weekly progression are shown in Table 3-1. The parameters per patient were formulated as vectors (out of the complete matrix for all patients *j=1:P)* containing the data from week 1 to the final week *N*. Note that *N* is different for all patients and represents the length of stay in weeks.

Table 3-1: Used formula's and thresholds for progression analyses (weeks i=1:N), performed per patient j

Parameter	**Formula for overall progression**	**Formula for weekly progression (valid for weeks *i = 2:N*)**	**Threshold (*T*)**
Number of steps per day averaged per week (SW_i)	$\max(SW_{1:N}) - SW_1 \geq T$	$SW_i - SW_1 \geq \frac{T}{N-1} * (i-1)$	1000 steps
Number of active minutes per day averaged per week (AM_i)	$\max(AM_{1:N}) - AM_1 \geq T$	$AM_i - AM_1 \geq \frac{T}{N-1} * (i-1)$	50 minutes

Longest activity block per day averaged per week (AB_i)	$\max(AB_{1:N}) - AB_1 \geq T$	$AB_i - AB_1 \geq \frac{T}{N-1} * (i-1)$	4 minutes
Resting heart rate per day averaged per week (RH_i)	$RH_1 - RH_{discharge} > T$	$RH_1 - RH_i > \frac{T}{N-1} * (i-1)$	10% of week 1 resting heart rate (bpm)

With these formula's, the weekly and overall progress are determined. The overall progress was used to determine if a patient has made progression on the Fitbit parameter, the weekly progress was solely used to get a qualitative insight in the revalidation process of the individual patients.

For the clinimetry no weekly progress could be defined due to missing data and the low frequency of administering. For the Barthel Index and the FAC only a progression over the complete stay could be calculated. To define if there was progress on the Barthel score, the difference between the maximum and the minimum score for the whole rehabilitation period is taken for each patient. The threshold is set on the average of these difference (e.g. the same as for the active minutes and longest activity block). Patients that scored higher or equal to this threshold were classified as good, an improvement between zero and the threshold was classified as moderate and a score of zero or below was classified as poor. For the FAC test, all patients who rose one class were classified as good, because the differences between the different classes are quite big (19).

The final rating was defined as follows: When a patient scored a maximum of one moderate (orange) per ICF determinant and a good (green) on the Barthel Index, the overall score was defined as good. When a person scores moderate more than once on one determinant it will become moderate (orange). The score poor (red) was only defined for the Barthel Index and the FAC. If a patient scored poor on one of these parameters the final score was also poor. This choice was made as both tests are tests for functional independency, which is the aim of geriatric rehabilitation.

Sub question 4:

4. Is the gradient of number of steps per day correlated to the length of stay and the final Barthel score?

H1: The gradient of number of steps per day is related to the length of stay and to the final Barthel score.

The gradient of the number of steps per day defines the progression that the patient makes in physical activity. The gradient in number of steps/day was determined by using the least square regression fit in SPSS, ignoring the zero values. An example of such a fit for a typical patient and the gradient number (red circle, in steps/day) are shown in Figure 3-1.

The gradient correlation with the length of stay and with the Barthel index was calculated using the Spearman's rho method.

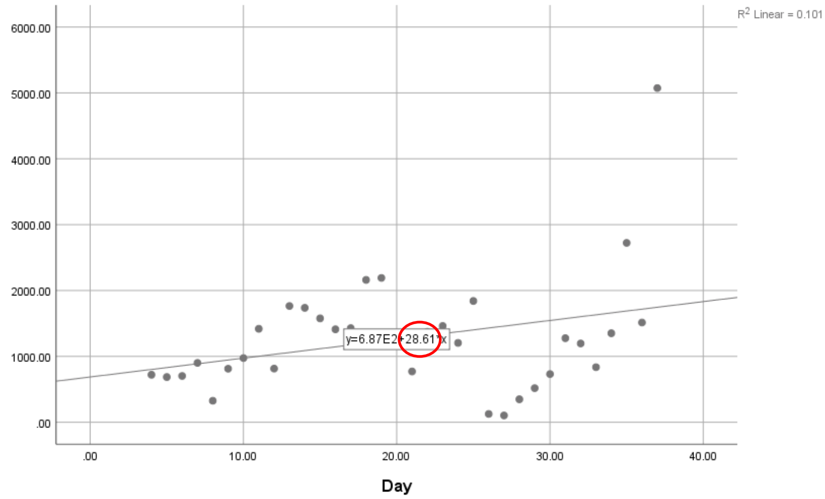

Figure 3-1: Typical result of the steps/day gradient of one patient (least square regression fit in SPSS)

4 Results

4.1 Patient and parameter characteristics

As mentioned in the method part, for this pilot study 24 patients were included. However, twelve of them are lost to follow-up due to different reasons. In the table below an overview of the various reasons is shown:

Table 4-1: Overview of patients lost to follow-up

Total number of patients included = 24 Reason lost to follow-up:	**Patients lost to follow up N = 12** N =
Patient appears not to meet the inclusion criteria	1
Patient decides to stop their participation	1
Problems with (synchronizing) the Fitbit	6
Patients went to a not participating nursing home	2
Patient went home after stay in ZGT	1
Rehabilitation of patient takes too long to take the patient into the analyses	1

The characteristics of the patients who were followed until they were discharged from the rehabilitation ward of the nursing home are described in Table 4-2. In this table, also the outcomes from the clinimetry and the Fitbit parameters are shown on group level.

Table 4-2: Overview of the patient and test characteristics

Patient characteristics n=12					
Gender	Woman		91.6%		
Age	Mean (STD)		80.8 (+/- 7.4)		
	Min		71		
	Max		95		
Length of stay	**Discharge in week**		**N**		
	3		3		
	4		3		
	6		3		
	7		1		
	8		1		
	9		1		
Administered clinimetry	**Admission # patients tested**	**Mean score Admission (STD)**	**Discharge # patients tested**	**Mean score Discharge (STD)**	**Sig. difference:**
MMSE	8	26.9 (1,37)	-	-	-
SNAQrc	9	0.44 (0,73)	-	-	-
TUG	3	42.3 (9,03)	9	27.1 (10,27)	-
10 MLT	3	0.46 (0,09)	9	0.56 (0,18)	-
FAC	12	2.7 (0,89)	12	4.1 (0,39)	p < 0.001*
Barthel Index	12	12 (2,45)	12	16.1 (1,88)	p < 0.001*

Continuously monitored activities	Admission # patients tested	Mean score Admission (STD)	Discharge # patients tested	Mean score Discharge (STD)	Sig. difference
Number of steps	12	978 (553)	12	1996 (976)	p < 0.001*
Number of active minutes	12	55 (31)	12	84 (28)	p = 0.005
Longest activity block (minutes)	12	5 (2)	12	8 (2,5)	p = 0.009
Resting heart rate (BPM)	12	77 (7)	12	68 (3)	p = 0.003

A significance level of p<0.001 is indicated with *.

The table below shows an overview of the administered clinimetry per measuring moment. This gives insight in the availability of results throughout the stay of a patient. As shown in this table, not all tests that should have been administered, were administered in the desired frequency.

Table 4-3: Administered clinimetry tests per measuring moment[2]

Moment	FAC	Barthel	TUG	10 MLT
Admission	12	12	3	3
1	10	3	1	1
2	3	1	0	0
3	2	0	0	0
≥4	0	0	0	0
Discharge	12	12	10	9

4.2 Results of the sub questions

Sub question 1

1. According to the different components of the ICF model, is the clinimetry related to the continuously monitored activity at admission?

In the three determinants (body functions & structures, activity and participation) no significant correlations were found between the clinimetry and the Fitbit parameters. The TUG and the 10 MLT were not analysed, due to the lack of data. The outcomes of all analysis can be found in Appendix III. In this results chapter only the significant results will be described.

The Barthel Index represents the health condition. The correlation analyses between all other parameters and the Barthel Index determines which determinant has the strongest connection with the health condition at admission. This could be an indicator for which determinant to focus on during the first stage of revalidation.
Between the three ICF determinants and the health condition two significant correlations were found. A correlation was found between the FAC and the Barthel Index 0.877 (p<0.001). A certain level of independence in mobility is needed to get a high score in independency on the general activities measured by the Barthel Index.

[2] Desired frequency of different tests varies; an overview can be found in Table 2-2.

Furthermore, a significant negative correlation was found between the MMSE and the Barthel Index -0.914 ($p<0.001$) with $R^2=0.71$. This seems to indicate that cognitive impairment leads to a better score on the Barthel Index. The plot of the MMSE and the Barthel Index is shown in Figure 4-1.

With this result the connection of the participation determinant with the health condition, is hereby deemed to be of less value. At admission therefore, one can conclude that the activity determinant has the strongest connection with the health condition.

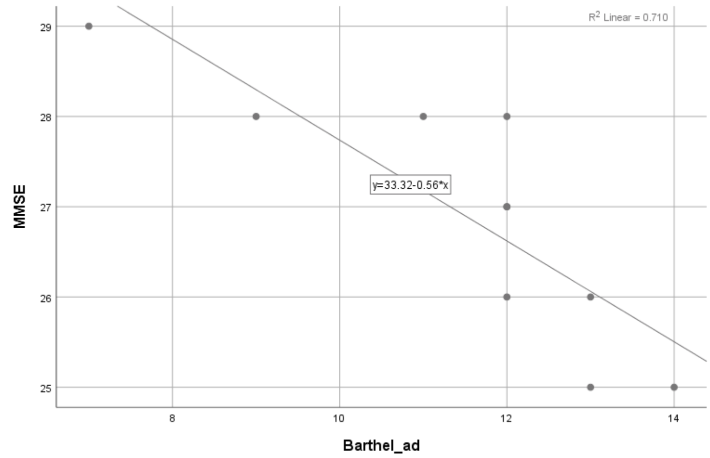

Figure 4-1: Plot of Barthel Index and MMSE at admission

Sub question 2:

In this sub question the same analyses as in sub question one were performed for the values at discharge. An overview of the results can be found in Appendix III. It is important to note that the moment of discharge is not the same for each patient. When analyzing the Fitbit parameters with the clinimetry per determinant one significant correlation was found. In the determinant body functions and structures a significant negative correlation was found between the SNAQrc and the resting heart rate -0.817 ($p=0.007$). When comparing the tests of the different determinants with each other, no correlations were found. It is therefore not possible with this data to define which determinant has the strongest connection with the health condition at discharge.

Sub question 3:

Group level

For answering this sub question a mixed model analysis was performed on the parameters of the Fitbit data. With this test a comparison between the weeks could be made. This test is repeated for each Fitbit parameter. Due to the high number of measuring moments, the low number of participating patients and the missing data, only a mixed model analysis of the first four weeks was performed. Analyses after week 4 were not reliable, therefore these weeks were excluded from the mixed model analysis. In this mixed model analysis this could have an influence on the outcomes of the analysis. For the resting heartrate the improvement for the first four weeks is significant. For number of steps and active minutes per day a significant improvement is found between week 1 and 3 and for longest activity block a significant improvement is found between week 1 and 2. The p-value of all these improvements is $p<0.05$. An overview of the significant outcomes can be found in Appendix IV.

The mixed model was not reliable for the tests of the clinimetry, due to the low amount of data. When analyzing the clinimetry a significant correlation 0.935 ($p<0.001$) was found with the paired sample t-test between admission and week 1. The correlation between week 1 and discharge was not significant. For the other clinimetry tests no pair-wise tests could be performed, due to the lack of gathered data throughout the process.

Individual level

The Fitbit parameters were also analyzed on an individual level, to obtain more insight in the rehabilitation process. As described in the methods chapter the final rating was defined as follows:

When a patient scored a maximum of one moderate (orange) per ICF determinant and a good (green) on the Barthel Index, the overall score was defined as good. When a person scores moderate more than once on one determinant it will become moderate (orange). The score poor (red) was only defined for the Barthel Index and the FAC. If a patient scored poor on one of these parameters the final score was also poor.

For the clinimetry no weekly progression could be defined. Only the progression between the admission and discharge of the FAC and the Barthel Index could be used. Therefore, only the overview of overall progression made by the patients is shown in Table 4-4. An overview of the scores per Fitbit parameter per week can be found in Appendix V. An overview of the known outcomes of the clinimetry can be found in Appendix VI.

Table 4-4: Overall patients progression overview (numbers showing the difference between admission and discharge)

Patient	Resting heart rate	FAC	Longest activity	Number of steps	Active minutes	Barthel	Final rating
1		2				4	
2		1				5	
3		2				6	
4		3				2	
5		0				0	
6		1				3	
7		3				8	
8		2				2	
9		1				3	
10		2				10	
11		0				5	
12		1				4	

As shown in Table 4-4 almost all patients improve on the FAC and all patients have a score of ≥4 at the end of the rehabilitation (as shown in Appendix VI). Therefore, for making a distinction between the patients, the FAC is a less informative parameter. It is also quite a static parameter that gives insight in one specific function, while the patients have to recover on more functions. The Barthel Index and the Fitbit parameters can provide extra information about the functional status. In the Table 4-4 it is shown that, besides the FAC, there is no parameter in which (almost) all patients reach the threshold. When looking at the Barthel Index, in this thesis taken as decisive parameter for going home, it is interesting to see that the progression made on the Index can give another view on the rehabilitation process than the Fitbit parameters do. This difference is most easily seen when looking at patient number 10.

Patient number 10 is an example of the additional information coming from continuous monitoring. In clinimetry the patient seemed to have a good progression. While looking into the Fitbit parameters, the patient showed a decline on longest activity and no progression in number of active minutes. On the other two Fitbit parameters the progression was too small to define it as clinical progression. This could be a patient who already had a sedentary life style at home. For this patient becoming active was not part of the functional recovery. This patient has a functional improvement on the body function part and activity part of the ICF and has less interest in becoming more active (the participation part). Another interesting patient, no. 5, stays on the same level during the whole rehabilitation period in Barthel and FAC score (respectively 17 and 4). This patient starts with the highest score on three of the four Fitbit parameters and high scores on the clinimetry. It can be questioned if the rehabilitation has had added value in the case of this patient. For these patients it could be interesting to tailor the thresholds to the functional status of the patients from before the hip fracture.

In the overall rating, only five of the twelve patients scored a good progression, based on all the different determinants of the ICF model. The individual data per week of the Fitbit parameters does not show clear trends. When further analyzing the weekly progression of the patients, it becomes clear that there is a lot of variability between the patients. The progression of the individual patients, on all four parameters of the Fitbit, varies between 0% and 83%. An overview of the variability between the patients can be found in Appendix VII.

When comparing the scores of weeks of progression for the four parameters the scores of progression are very close to each other. Most progression is made in the parameters steps per minute, active minutes and resting heart rate (all 33 times progression). On the parameters longest activity block the patients make a progression 31 times. When expressing this in percentages, around 60% of the patients scores above the (arbitrarily) chosen thresholds per week. For the overall progression, a sensitivity analysis of the threshold level is shown in Appendix II. This indicates that, for the thresholds, reasonably appropriate values are chosen (between 50 and 60% of the patients classified as progressed).

From the results it also becomes clear that the progression which is made is not on the same moment for each patient. Up until week 5 most progression is made by the patients, as visualized in Figure 4-2. After week six less progression seems to be made by the patients. The percentage of progression decreases from week six from approximately 65% to 25%. An overview of the progression per week can be found in Appendix VIII. In the figures below the progress of the patients during weeks 1 to 7 is visualized per Fitbit parameter. The last two weeks are not taken into account, because of the low number of patients is those weeks (n=2). The decreasing scores in this week can be due to the fact that a high value on the number of steps, active minutes and longest activity block can normally not be made without FAC ≥4. From this score on, the patients can be active on their own. However, when patients having a score of FAC ≥4, they received less physical therapy and they had to manage the activities of daily living more on their own. This could lead to a decrease of activity at the end of the rehabilitation period.

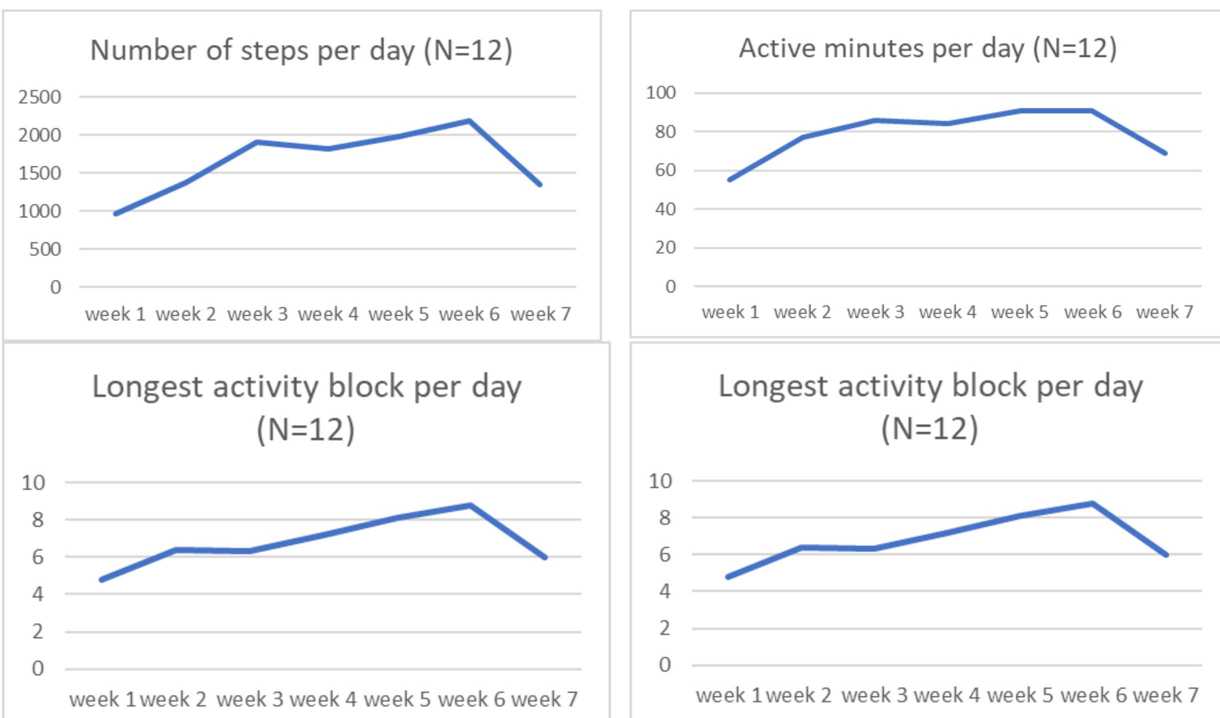

Figure 4-2: Average value per Fitbit parameter

Sub question 4:

In this sub question first the gradient of number of steps per day was correlated with the length of stay and with the score of the Barthel Index at discharge. Both using the Spearman’s rho test. No significant correlations were found when all twelve patients were taken into account:

Table 4-5: Correlation analysis gradient number of steps

	Gradient number of steps per day
	Spearman's rho correlation
Length of stay	-0.497 (p=0.126)
Barthel score at discharge	-0.467 (p=0.101)

When plotting the gradient of number of steps per day versus the Barthel Index no trends appeared. A higher gradient in steps per day seems to lead to a shorter length of stay. While plotting the gradient of the steps per day with the length of stay (LOS) a pattern did appear. However, one outliers seemed to have a large influence.

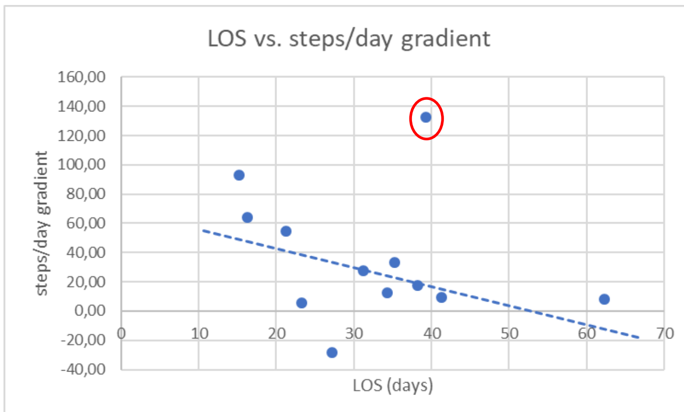

Figure 4-3: Length of stay vs. gradient number of steps showing the fit and the removed outlier (red circle)

This biggest outlier is the dot with the red circle. When looking into the individual data of these patients it became clear that this patient had the highest score on number of steps, the highest score on active minutes per day and the highest longest activity block. No complications during the rehabilitation were noted. His/her relatively long stay raises suspicion, but a definite reason could not be indicated in the available data. When repeating the correlation analysis without this outlier, a significant relation between the length of stay and the steps per day gradient was found (p=0.016). Also, the correlation with the Barthel Index was more significant in this analysis.

Table 4-6: Correlation analysis gradient number of steps (removed outlier)

	Gradient number of steps per day
	Spearman's rho correlation
Length of stay	-0.700 (p=0.016)
Barthel score at discharge	-0.523 (p=0.099)

The formula for the trend line which correlates the length of stay with the gradient of steps per day is as follows: $LOS = 52.8 - 0.77 * Gradient\ steps/day$

5 Discussion

Four sub questions

1. “According to the different components of the ICF model, is the clinimetry related to the continuously monitored activity at admission?”

Between the Fitbit parameters and the clinimetry on group level at admission no correlations were found. It was expected that a lower score on the Fitbit parameters would be correlated to a lower score on the clinimetry. Within the clinimetry data at admission a correlation based on the determinants of the ICF model was found between the FAC and the Barthel Index. Also, a negative correlation between the MMSE and the Barthel Index was found. The Barthel Index and the FAC are both tests for measuring independence. It is possible that the limitations in mobility (measured by the FAC) are also visible in the score of the Barthel Index, where a level of mobility is also required to reach a good score (49). The correlation of 0.877 indicates a very strong connection between these two tests.

The very high negative correlation (-0.914) between the MMSE and the Barthel Index is highly questionable. Other research shows a positive correlation between the two tests (24). The negative correlation found in this study might be due to a selection bias. The patients that were included in this research all have a good cognitive function; otherwise the indication for geriatric rehabilitation could not be given. This leads to a very small bandwidth in outcomes (scores 25 to 29) of the MMSE test and therefore a small difference in test outcome can have a large influence on this correlation.

When looking at the individual level, a trend between the Fitbit parameters and the clinimetry could also not be shown. That no trends and correlations were found could be due to the fact that wrong choices were made when placing the different tests into the ICF model. To check this, all clinimetry tests and Fitbit parameters were compared, with this check no new significant correlations were found. It is hard to determine if this lack of correlation is due to the small sample size or simply due to the fact that no correlation exists.

When linking the information of the correlation of the FAC and the Barthel Index to the ICF model, the activity part of the ICF model is most strongly connected to the health condition. This indicates that at admission the level of capacity of the patients has the largest influence on the health condition of the patient. For the Fitbit parameters, this indicates that being active for a longer consecutive period of time has more influence on functional recovery than taking more steps or being active more minutes per day. At admission the participation part had a limited influence on the activity part, most patients needed supervision and help for being mobile (FAC ≤ 3) (42). Therefore, the level of physical activity a patient could perform by practicing on its own (i.e. participation) was limited. However, a big difference between the values of the patients on the Fitbit parameters in the week of admission exist.

2. “According to the different components of the ICF model, is the clinimetry related to the continuously monitored activity at discharge from rehabilitation in the nursing home?”

At discharge no significant correlations were found when comparing the clinimetry with the Fitbit parameters, except for a negative correlation between the SNAQrc and the resting heart rate. On well-nourished patients, one would expect a positive correlation (i.e. better health status → lower resting heart rate) (50). A possible explanation for the negative correlation could be that when a patient is malnourished, there is a higher risk of bradycardia (51). However, in this study the resting hate rate of the clients with a classification of malnourishment or risk of malnourishment are not low enough to suspect bradycardia (resting heartrate <60 BPM) (51). Therefore, the most likely explanation for this result is the low amount of data.

When comparing the outcomes of the clinimetry at discharge with the values at admission on group level, a significant improvement is made on the FAC and the Barthel Index (both $p<0.001$). Most of the patients (10/12) go from a score of dependence to a score that independence of help indicates (shown in Appendix VI). The outcomes on the TUG and 10MLT could not be compared, due to a lack of data at admission. On group level a significant improvement is found for all four Fitbit parameters. When placing this information into the ICF model, the patients improve during the rehabilitation on each determinant of the model.

The resting heart rate significantly decreases in the first four weeks, which could be due to lowered stress levels and more confidence in walking. This might also be visible in lower a score on the TUG test (=less risk of falling) and could also be due to the influence of the level of capacity and activity. However, these expected correlations could not be found in this study. In the research of Mooijaart et al. (26) it was found that a higher resting heart rate also is associated with a worse functional status (lower score on the Barthel Index). Therefore, also a correlation between the resting heart rate and the Barthel Index was expected (i.e. between the body function determinant and the health condition).
In a systematic review for patients with neurological conditions, mobility tests are linked with step activity (52). Therefore, a correlation for both the FAC and 10MLT with the number of steps was also expected for these patients with mobility problems due to a hip fracture. These expected correlations assume that a link between the activity and the participation determinant is also there.
A correlation between the Barthel Index and the FAC was found at admission, while a correlation at discharge was not found. This is in contrast with other research (20). From previous studies one would expect that at admission a low score on the Barthel would be due to limitations in mobility (measured with the FAC), therefore it was expected that an improvement in mobility would be linked to a higher score on the Barthel Index (i.e. activity determinant and the health condition).

When comparing the data of the different determinants with each other, no correlations were found. Therefore, in this study it was not possible to define which determinant has the strongest correlation with the health condition. Based on literature and when speaking with geriatric physical therapists, the activity determinant was deemed as most influencing determinant on the health condition.

Since there is no matching reference data available to which the patients in this study could be compared, it is interesting to compare the results at admission and at discharge of this study with research in other fields. The research of Buckinx on residents in nursing homes (7) is compared with the results of this study. The average number of steps in this study is, for the most of the patients, lower in the beginning of the rehabilitation (978 ± 553 (median = 881)) than found in the research of Buckinx (1678.4 ± 1621 (median = 1300)). At the end of the rehabilitation the patients in this study perform better (1996 ± 976 (median = 1654)). In this study the mean score of TUG at admission was (42.3 ± 9.03) and at discharge (27.1 ± 10,27) seconds. The score of the TUG in the study of Buckinx was considerably lower; (16.3 ± 8.3 seconds). This could be due to the fact that people rehabilitating from a hip fracture have more problems with functional mobility as standing up and sitting down, despite the fact that these patients were taking more steps. The research of Buckinx used the Katz-ADL test to define the functioning of the ADL. In this study the Barthel-Index is used. These tests are not comparable, the Barthel Index measures more aspects of daily living than the Katz-ADL and the Katz is normally used with chronic diseases (37). Also, it is not known what the details of the score on the Katz-ADL were in the research of Buckinx, so for the general activities of daily living no comparison could be made. The patients in this study score approximately equal on the MMSE (26.9 ± 1.37) as the patients who scored ≥1300 steps per day in the research of Buckinx (24.8 ± 4.4). As described, the two studies are not comparable on all components. However, the improvement of the TUG and the potential of taking more steps per day, gives rise to the assumption that patients with a hip fracture have a better functional status at discharge than the residents in a nursing home have.

3. “Is the weekly progress of a patient visible in both the clinimetry and the Fitbit data (number of steps per day, active minutes per day, longest activity per day and resting heart rate)?”
The weekly progress on individual level could be shown with the use of the four Fitbit parameters. To determine if there was progress, thresholds were used. These are determined primarily based on results from this same group due to a lack of information available in literature. The thresholds used in this study were chosen arbitrarily to be able to analyze the data in a systematic way and it is not clear if the values of these thresholds are actually relevant in rehabilitation. It is possible that the values of the thresholds were too high/low and therefore the level progression of the patients is not reviewed based on realistic values. Also, when looking at the average of all Fitbit data per week in Figure 4-2 one might argue that a linear function for change in thresholds for the weekly progress is not the most suitable choice.
When looking at the longest activity block in this study, half of the patients improve more (average of the

total group on longest activity 6.4 minutes in week 2) than found in previous research (6 active minutes in week 2) (48). When taking the progression made by patients per week (Appendix VIII) into account, the added value of a stay of six weeks or longer is questionable. In literature it is found that the average stay of patients in geriatric rehabilitation is 61.5 days (8.8 weeks) (6)(18). There is an interesting discrepancy between these numbers. When taking the costs of the geriatric rehabilitation into account, a discrepancy of 2.8 weeks can make a considerable difference. Based on the estimated costs of a day in rehabilitation costs of 250 euro (53), this can save approximately 5000 euros per patient. These large potential savings make it a very interesting topic for more in depth research. If only 10% of the 17.000 patients will undergo this revalidation process, it will already have a potential saving of more than 8 million euros. Therefore, it is recommended to expand the current research with more patients to get more reliable results on the progression that patients make per week in rehabilitation. The current study shows that more insight in the variability between patients and therewith possible shortening of rehabilitation processes based on personalized and early feedback by continuous monitoring is a promising technique.

For the clinimetry no analyses on weekly level could be determined. The FAC, 10 MLT, TUG and also the Barthel Index are tests that could be used to provide insight into the weekly progression of the patients on the clinimetry. However, for most patients these tests were not administered on the desired frequencies in the nursing homes. Herewith it is not possible to make a significant statement about whether an improvement on the Fitbit data is linked to an improvement on the clinimetry data.

4. “Is the gradient of number of steps per day correlated to the length of stay and the final Barthel score?”
In the fourth sub question it is shown that the gradient of steps per day is a relatively reliable predictor for the length of stay. However, with this low amount of data points outliers have a big influence on the reliability. In the results of this sub question one outlier is removed. Doing this is debatable, because it is uncertain if this is really an outlier in the rehabilitation process. With the availability of more data a more accurate formula might be determined to be able to estimate the expected length of stay of the patient early in the rehabilitation process. Possibly, the same can be done for the expected independence (Barthel Index) at discharge. For the patient this means a shorter and more effective stay on the rehabilitation ward. On organization level this might lead to better planning and more effective use of available resources, herewith extra patients could be treated or the pressure on the health care system could be decreased.

Influencing variables

Other influences that were not taken into account in this study that could have an effect on the outcomes of the rehabilitation, are fear of falling and depression. While rehabilitating, roughly 60% till 80% of the patients suffers from the fear of falling (32). The incidence of patients who suffer from a depression after a hip fracture was reported over the wide range of 9% to 47% (54). Those factors can have a profound effect on capacity to rehabilitate. Depression symptoms are associated with poorer participation in rehabilitation (54). In this study no tests are performed that give an indication concerning the fear of falling or a depression that the patient might experience. Therefore, the influence of fear and depressions, which could be confounders, is not taken into account in the analyses. If this was taken into account in this study, it is expected that patients with a relatively bad score on the TUG, 10 MLT and the Fitbit parameters suffer from fear of falling. For detecting depression, it would be interesting to screen the patients who make less progression during the weeks in rehabilitation. In some nursing homes, the TUG is used as an indicative test for fear of falling. The TUG is a validated test for indicating the risk of falling, but it is not (yet) validated for measuring the fear of falling. The Falls Efficacy Scale-International (FES-I) could be used to measure the fear for falling (1).
Another influence is the noise added to the data by the problems with the accuracy of the Fitbit. In general, the Fitbit underestimates the heartrate and the Fitbit is not that accurate in recognizing the walking pattern of the elderly. Therefore, the measured values could differ with results gathered with, for example an ECG. The method of determining when the resting heartrate should be determined and the time period for averaging, is also debatable. Therefore, to determine the resting heart rate, it is recommended to use another more accurate (separate) device for measuring this parameter.

From literature it is known that after rehabilitation 53% of the patients do not receive the level of functioning from before the hip fracture. In this study all twelve patients were going home after the rehabilitation and only two of twelve patients were classified as having no progression. The discrepancy between these numbers makes rises the suspicion of a selection bias. In the hospital only the patients with a good prognosis for recovery were included. However, going home after rehabilitation is no stipulation for reaching the level of functioning from before the hip fracture.

Organization of the implementation

An interesting fact in the data collection is that the half of the patients who were included to wear the Fitbit are lost to follow-up. The main reason for this, as shown in Table 4-1, is problems with synchronizing the Fitbit. Synchronizing and charging the Fitbit in the start of the project Up&Go was a task of the researchers of ZGT and through time became a task of the physiotherapists in the nursing homes. From that moment on, more data was lost due to not charging the Fitbits and forgotten/not knowing how to synchronize the Fitbit. During the transferal of this task, presumably the importance of good data collection was not emphasized sufficiently. The same goes for the clinimetry, the desired frequency of tests was not met for a single patient.

When implementing a care pathway; communication and coordination are crucial points (55). In this study the following aspects are points that need improvement: organizing educational meetings, clinical reminders and more practical guidelines of low complexity (56). In this project educational meetings were frequently organized. However, most of the time only the coordinators of the nursing homes were present in these meetings. A possible explanation of the missing data is that knowledge is not always transferred further into the nursing homes. In the nursing home professionals were reminded in a low frequency that they had to fill in the clinimetry. The clinimetry has to be filled in on paper, while the normal patient dossier is electronic. Therefore, it was extra administration for the professionals and the paper files were not within sight of the professionals. Also, in the nursing home no guideline was available which could be read by new colleagues, information was transferred verbally. An advice is to have a better focus on the theory concerning the organization of implementation when setting up a clinical pathway. The consolidated framework for implementation research (CFIR) is a model that fits the method that is used in the Up&Go project. It is recommended to critically review the steps taken in the current project using the CFIR framework (57).

It is also recommended to be available on short term for questions and to visit the participating locations more frequently to stay connected with the professionals in the nursing homes as this most likely will improve their compliance. What also might help to improve the compliance, is to provide useful information to the professionals in the nursing homes about the progress their patients make. When this information can be adopted in their own procedure, they will begin to rely on this information. Therefore, the urge to gather this data will also rise.

6 Conclusion

The main research question in this study was as follows: "Is the data of the continuously monitored activities using Fitbit related to the outcomes of the clinimetry at the start, end and during the geriatric rehabilitation process after a hip fracture?"

At the admission none and at discharge one significant correlation was found between the clinimetry and the Fitbit parameters. The hypothesis about sub question three is proven, the Fitbit parameters help to get a continuous insight into the progression which a patient makes. With the use of Fitbit data it can be determined in an easy manner if a patient makes a clinical progression every week. For the clinimetry in this study it is hard to determine a weekly progress, due to the lack of data. The last hypothesis is partially proven. The gradient of number of steps is correlated with the length of stay and the Barthel Index. The correlation with the Barthel Index is not very strong and no linear effect could be found.

The ICF model has been useful in this study as connecting framework between the outcomes on clinimetry and the Fitbit parameters. With the use of the ICF model the gathered information could be linked to the rehabilitation process of the patients. Using the information found in literature and the correlations found in

this study, it becomes clear that the focus in the rehabilitation should be on the parameters in the activity determinant, as these seem to have the strongest connection with the health condition. The Fitbit parameters of the participation determinant can be seen as training to score better on the activity determinant. These results are consistent with the thought that the rehabilitation is focused on functional recovery.
In this study the information coming from the Fitbit is determined as valuable:

- The Fitbit provides extra information into the rehabilitation process. In some cases, the Fitbit information even provides a different insight into the rehabilitation process than the clinimetry does.
- The Fitbit parameter 'longest activity block' is the parameter with the strongest influence on the functional status. It is therefore recommended to focus in rehabilitation on this parameter.
- The Fitbit can be used for tailoring the rehabilitation process. Based on the Fitbit information from the first one/two weeks and the rehabilitation goal, the thresholds to define progression can be adjusted per patient.

This form of eHealth could support in providing information about the progression made by a patient and in noticing early in the process that deviations occur in the rehabilitation (high resting heart rate, less activity).

In this study continuous insight is obtained in the rehabilitation process of twelve patients together with the classification of the progress by administered clinimetry. The results found in this study have to be interpreted with caution as no sufficient evidence was found to support that the clinical outcomes measured with the clinimetry are related to the Fitbit parameters. However, the minimal impact for the patient and the additional information acquired by continuous monitoring using wearables is a promising step in making more tailored rehabilitation pathways and interesting results were found that stress the need for more research.

7 Recommendations

Given this study is a pilot study on a relatively new field of research using continuous monitoring in geriatric rehabilitation, the following recommendations are made for follow-up research:

- Stimulate good engagement and involvement of all parties that participate in the research by providing sufficient and clear information and provide incentives to obtain good quality data.
- Increase the number of participants to gather more data to be able to do tests that could not be performed in this study (e.g. correlations with clinimetry during the rehabilitation) and to check the reliability and the significance of the results already found (e.g. unexpected negative correlations)
- It should be considered to use a more valid wearable for continuous monitoring; however this might be more intrusive in the patient's comfort of living (e.g. steps might not have been registered properly due to "shuffling", a thigh or hip worn alternative might give more reliable results).
- Further research on determining if the method with thresholds for determining clinical progress can be justified and if the values of these thresholds can be improved.

8 Bibliography

1. Pol MC, Ter Riet G, Van Hartingsveldt M, Kröse B, De Rooij SE, Buurman BM. 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 [Internet]. 2017;17(1):1–13. Available from: http://dx.doi.org/10.1186/s12913-016-1934-0

2. Dutch Institute for Clinical Auditing. Jaarrapportage. Heupfracturen. 2017;95–6. Available from: https://dica.nl/media/993/DICA-2016-jaarverslag.pdf

3. Folbert EC, Hegeman JH, Gierveld R, van Netten JJ, Velde D van der, Ten Duis HJ, et al. Complications during hospitalization and risk factors in elderly patients with hip fracture following integrated orthogeriatric treatment. Archives of Orthopaedic and Trauma Surgery. 2017;137(4):507–15.

4. Koso RE, Sheets C, Richardson WJ, Galanos AN. Hip Fracture in the Elderly Patients: A Sentinel Event. The American journal of hospice & palliative care [Internet]. 2017;35(4):1049909117725057. Available from: http://journals.sagepub.com/doi/10.1177/1049909117725057%0Ahttp://www.ncbi.nlm.nih.gov/pubmed/28823174

5. Folbert EC, Hegeman JH, Haas RJ De, Broersma B, Velde D Van Der, Heelkunde A, et al. Kortdurende geriatrische revalidatie Resultaten na behandeling van een heupfractuur. 2012;304–9.

6. Folbert E, Smit R, Van Der Velde D, Regtuijt M, Klaren H, Hegeman H. Multidisciplinair zorgpad voor oudere patiënten met een heupfractuur: resultaten van implementatie in het Centrum voor Geriatrische Traumatologie, Almelo. Ned Tijdschrift Geneeskunde [Internet]. 2011;155:1–7. Available from: https://www.zgt.nl/media/6097/multidisciplinair-zorgpad-voor-oudere-patienten-met.pdf

7. Tang VL, Sudore R, Cenzer IS, Boscardin WJ, Smith A, Ritchie C, et al. Rates of Recovery to Pre-Fracture Function in Older Persons with Hip Fracture: an Observational Study. Journal of General Internal Medicine [Internet]. 2017;32(2):153–8. Available from: http://dx.doi.org/10.1007/s11606-016-3848-2

8. Buckinx F, Mouton A, Reginster JY, Croisier JL, Dardenne N, Beaudart C, et al. Relationship between ambulatory physical activity assessed by activity trackers and physical frailty among nursing home residents. Gait and Posture [Internet]. 2017;54:56–61. Available from: http://dx.doi.org/10.1016/j.gaitpost.2017.02.010

9. Rozell JC, Hasenauer M, Donegan DJ, Neuman M. Recent advances in the treatment of hip fractures in the elderly. F1000Research [Internet]. 2016;5(0):1953. Available from: http://f1000research.com/articles/5-1953/v1

10. Matta A, Chahed S, Sahin E, Dallery Y. Modelling home care organisations from an operations management perspective. Flexible Services and Manufacturing Journal. 2014;26(3):295–319.

11. Carpintero P. Complications of hip fractures: A review. World Journal of Orthopedics [Internet]. 2014;5(4):402. Available from: http://www.wjgnet.com/2218-5836/full/v5/i4/402.htm

12. Kohler F, Connolly C, Sakaria A, Stendara K, Buhagiar M, Mojaddidi M. Can the ICF be used as a rehabilitation outcome measure? A study looking at the inter- and intra-rater reliability of ICF categories derived from an ADL assessment tool. Journal of Rehabilitation Medicine. 2013;45(9):881–7.

13. Stucki G, Cieza A, Melvin J. The international classification of functioning, disability and health: A unifying model for the conceptual description of the rehabilitation strategy. Journal of Rehabilitation Medicine. 2007;39(4):279–85.

14. Steiner W, Ryser L, Huber E, Uebelhart D. Use of the ICF model as a clinical problem-solving tool in physical therapy and rehabilitation medicine. Physical [Internet]. 2002;82(11):1098–107. Available from: http://ptjournal.apta.org/content/82/11/1098.short

15. Ziden L. Life after hip fracture-Impact of home rehabilitation versus conventional care and patients' experiences of the recovery process in a short-and long-term perspective. University of Gothenburg;

16. Ustün TB, Chatterji S, Kostansjek N, Bickenbach J. WHO's ICF and functional status information in health records. Health care financing review. 2003;24(3):77–88.

17. RIVM. Nederlandse vertaling van de International Classification of Functioning, Disability and Health. WHO FIC Collaborating Centre in the Netherlands, RIVM [Internet]. 2002;45. Available from: http://www.who-fic.nl/dsresource?type=pdf&disposition=inline&objectid=rivmp:230329&versionid=&subobjectname=%0Ahttp://www.who-fic.nl/dsresource?type=pdf&disposition=inline&objectid=rivmp:230329&versionid=&subobjectname=%5Cnhttp://scholar.google.com/schola

18. Verenso. Behandelkaders Geriatrische Revalidatie. 2010;(030):42. Available from: http://www.vumc.nl/afdelingen-themas/69713/27797/Verenso-Behandelkaders_geri1.pdf

19. Uriz-Otano F, Uriz-Otano JI, Malafarina V. Factors associated with short-term functional recovery in elderly people with a hip fracture. Influence of cognitive impairment. Journal of the American Medical Directors Association [Internet]. 2015;16(3):215–20. Available from: http://dx.doi.org/10.1016/j.jamda.2014.09.009

20. Sainsbury A, Seebass G, Bansal A, Young JB. Reliability of the Barthel Index when used with older people. Age and Ageing. 2005;34(3):228–32.

21. Podsiadlo D, Richardson S. The Timed "Up & Go": A Test of Basic Functional Mobility for Frail Elderly Persons. Journal of the American Geriatrics Society. 1991;39(2):142–8.

22. de Jong, K. Sanderink THI. 10 Meter Timed Walking Test.

23. Kruizenga HM, Seidell JC, de Vet HCW, Wierdsma NJ, van Bokhorst-de van der Schueren MAE. Development and validation of a hospital screening tool for malnutrition: The short nutritional assessment questionnaire (SNAQ©). Clinical Nutrition. 2005;24(1):75–82.

24. Beuken, L van den, Huijskens J, Nicolaes L, Engelen, E van. Uitgebreide toelichting van het meetinstrument: Mini-Mental State Examination (MMSE). 2011;2002(april):15–20.

25. de Haan R, Limburg M, Schuling J, Broeshart J, Jonkers L, van Zuylen P. Klinimetrische evaluatie van de Barthel-index, een maat voor beperkingen in het dagelijks functioneren. Vol. 137, Nederlands tijdschrift voor geneeskunde. 1993. p. 917–21.

26. Mooijaart SP, Macfarlane PW, Ma ENC, Kearney PM, Westendorp RGJ, Craen AJM De, et al. Resting heart rate, heart rate variability and functional decline in old age. Cmaj. 2015;187(15).

27. Wallace M. Katz Index of Independence in Activities of Daily Living (ADL) Katz Index of Independence in Activities of Daily Living INDEPENDENCE : DEPENDENCE : American journal of nursing. 2008;108(2):67–71.

28. Jefferson T. Hip fracture in old older patients: Tips and tools to speed recovery. The Journal of Family Practice.

29. de Jong K, Sanderink T, Heesbeen I. Functional Ambulation Category. Neuro-Klinimetrie de Hoogstraat [Internet]. 2011;4. Available from: https://meetinstrumentenzorg.blob.core.windows.net/test-documents/Instrument10/FAC handl HOOGSTRAAT.pdf

30. Kruijne R, Hartingsveldt MJ Van, Visser B. Behandelprotocol revalidatie na een heup fractuur RAAK-

Publiek onderzoek HIPPER.

31. Zhang D, Shen X, Qi X. Resting heart rate and all-cause and cardiovascular mortality in the general population: a meta-analysis. The Canadian Medical Association Journal. 2015;188(3):1–11.

32. Visschedijk J, van Balen R, Hertogh C, Achterberg W. Fear of Falling in Patients With Hip Fractures: Prevalence and Related Psychological Factors. Journal of the American Medical Directors Association. 2013;14(3):218–20.

33. Benedetto S, Caldato C, Bazzan E, Greenwood DC, Pensabene V, Actis P. Assessment of the Fitbit Charge 2 for monitoring heart rate. Plos One [Internet]. 2018;13(2):e0192691. Available from: http://dx.plos.org/10.1371/journal.pone.0192691

34. Croll R, Boyd J, Maslove D. Accuracy of a Wrist-Worn Wearable Device for Monitoring Heart Rates in Hospital Inpatients: A Prospective Observational Studyle. Journal of Medical Internet Research. 2016;18(9).

35. Wallen MP, Gomersall SR, Keating SE, Wisløff U, Coombes JS. Accuracy of heart rate watches: Implications for weight management. PLoS ONE. 2016;11(5):1–9.

36. Stahl SE, An H-S, Dinkel DM, Noble JM, Lee J-M. How accurate are the wrist-based heart rate monitors during walking and running activities? Are they accurate enough? BMJ Open Sport & Exercise Medicine [Internet]. 2016;2(1):e000106. Available from: http://bmjopensem.bmj.com/lookup/doi/10.1136/bmjsem-2015-000106

37. Jo E, Lewis K, Directo D, Kim MJY, Dolezal BA. Validation of biofeedback wearables for photoplethysmographic heart rate tracking. Journal of Sports Science and Medicine. 2016;15(3):540–7.

38. Tudor-Locke C, Craig CL, Aoyagi Y, Bell RC, Croteau KA, De Bourdeaudhuij I, et al. How many steps/day are enough? For older adults and special populations. International Journal of Behavioral Nutrition and Physical Activity [Internet]. 2011;8(1):80. Available from: http://www.ijbnpa.org/content/8/1/80

39. Kline Mangione K, Craik RL, Lopopolo R, Tomlinson JD, Brenneman SK. Predictors of Gait Speed in Patients after Hip Fracture. Physiotherapy Canada [Internet]. 2008;60(1):10–8. Available from: http://utpjournals.press/doi/10.3138/physio/60/1/10

40. Lugade V, Klausmeier V, Jewett B, Collis D, Chou LS. Short-term recovery of balance control after total hip arthroplasty. Clinical Orthopaedics and Related Research. 2008;466(12):3051–8.

41. ACTIVITY IN OLDER ADULTS AFTER HIP FRACTURE : RESULTS FROM A. 2016;(October).

42. Penrod JD, Boockvar KS, Litke A, Magaziner J, Hannan EL, Halm EA, et al. Physical therapy and mobility 2 and 6 months after hip fracture. Journal of the American Geriatrics Society. 2004;52(7):1114–20.

43. Chudyk AM, Jutai JW, Petrella RJ, Speechley M. Systematic Review of Hip Fracture Rehabilitation Practices in the Elderly. Archives of Physical Medicine and Rehabilitation [Internet]. 2009;90(2):246–62. Available from: http://dx.doi.org/10.1016/j.apmr.2008.06.036

44. Evenson KR, Goto MM, Furberg RD. Systematic review of the validity and reliability of consumer-wearable activity trackers. International Journal of Behavioral Nutrition and Physical Activity [Internet]. 2015;12(1). Available from: http://dx.doi.org/10.1186/s12966-015-0314-1

45. Cadmus-Bertram L. Using Fitness Trackers in Clinical Research: What Nurse Practitioners Need to Know. Journal for Nurse Practitioners [Internet]. 2017;13(1):34–40. Available from: http://dx.doi.org/10.1016/j.nurpra.2016.10.012

46. Zusman EZ, Dawes MG, Edwards N, Ashe MC. A systematic review of evidence for older adults' sedentary behavior and physical activity after hip fracture. Clinical Rehabilitation. 2017;

47. Cvecka J, Tirpakova V, Sedliak M, Kern H, Mayr W, Hamar D. Physical activity in elderly. European Journal of Translational Myology [Internet]. 2015;25(4):249. Available from: http://pagepressjournals.org/index.php/bam/article/view/bam.2015.4.249

48. Taylor NF, Peiris CL, Kennedy G, Shields N. Walking tolerance of patients recovering from hip fracture: a phase I trial. Disability and Rehabilitation. 2016;38(19):1900–8.

49. Sarker SJ, Rudd AG, Douiri A, Wolfe CDA. Comparison of 2 extended activities of daily living scales with the barthel index and predictors of their outcomes: Cohort study within the South London Stroke Register (SLSR). Stroke. 2012;43(5):1362–9.

50. Marks RG, Hale WE, Moore MT, May FE, Stewart RB. Resting heart rates in an ambulantory elderly population: an evaluation of age, sex, symptoms, and medication. Gerontology. 1989;35:210–1217.

51. Camm AJ, Evans KE, Ward DE, Martin A. The rhythm of the heart in active elderly subjects. American Heart Journal. 1980;99(5):598–603.

52. Tyson S. The psychometric properties and clinical utility of measures of walking and mobility in neurological conditions: a systematic review. Clinical Rehabilitation. 2009;23:1018–33.

53. NZA. Verkoopprijzen per DBC product [Internet]. 2013. Available from: http://www.opendisdata.nl/msz/zorgproduct/998418018?

54. Kamholz B. DEPRESSION AFTER HIP FRACTURE. 2007;126–7.

55. Seys D, Bruyneel L, Deneckere S, Kul S, Van Der Veken L, Van Zelm R, et al. Better organized care via care pathways: A multicenter study. PLoS ONE. 2017;12(7):1–11.

56. Prior M, Hons B, Guerin M, Hons B, Bphty KGM. The effectiveness of clinical guideline implementation strategies – a synthesis of systematic review findings. 2008;14:888–97.

57. Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: A consolidated framework for advancing implementation science. Implementation Science. 2009;4(1):1–15.

58. Kruizenga HM, de Vet HCW, van Bokhorst-de van der Schueren MAE, Horman J, Schols JMG, van Binsbergen JJ, et al. P152 the Snaqrc, an Easy Traffic Light System As a First Step in the Recognition of Undernutrition in Residential Care. Clinical Nutrition Supplements [Internet]. 2009;4(2):89–90. Available from: http://linkinghub.elsevier.com/retrieve/pii/S1744116109702029

59. Mathias S, Nayak U, Isaacs B. Balance in elderly patients: the “get-up and go” test. Archives of physical medicine and rehabilitation. 1986;67:387–9.

Appendix I: Administered clinimetry

Test	Aim	Score	Outcome measure
FAC (29)	Measures the degree of independence of walking	<u>Ordinal 6-points scale:</u> FAC 0: Not of non-functional FAC 1: Continue dependent FAC 2: Dependent FAC 3: Supervision FAC 4: Dependent restricted FAC 5: Independent	

- When a patient uses a supporting tool to walk, this has to be mentioned
- The FAC is developed for various patient groups with walking disorders
- The trustworthiness of the FAC is not yet sufficiently demonstrated for the nursing home population
- The FAC is too limited to handle within a nursing home situation when a patient can walk independently
- The responsivity of the FAC is SDD 0.12(29)

Test	Aim	Score	Outcome measure
SNAQrc (58)	Determine the degree of disease-related malnutrition in patients in nursing homes	<u>Four questions answered with a 3- or 2-points scale</u> - unintentional weight loss - reduced appetite - nutrition in the past - Body-mass index	A score of ≥2 indicates that action is needed

- The sensitivity of the SNAQrc is 92% and the specificity 95%
- The high prevalence and low recognition of undernutrition in nursing and residential homes urged to develop a quick and easy screening tool for the early detection of undernourished patients in nursing homes (58)

Test	Aim	Score	Outcome measure
Mini-Mental state examination (24)	Screening of cognitive impairment by the elderly	<u>Interval score:</u> The MMSE has a maximum score of 30 points	A score below 24 confirms a cognitive degradation

- The sensitivity and specificity of the MMSE for dementia are reasonable to high: especially patients with moderate to severe cognitive impairment distinguish the MMSE well of cognitively healthy persons. For mild cognitive disorders, the MMSE is less sensitive.
- The MMSE has been compared with the clinical diagnosis: sensitivity 87% and a specificity of 89% (24)

Test	Aim	Score	Outcome measure
Barthel-index (49)(25)	Determine the degree of (physical or verbal) that a person needs to perform general daily actions	<u>Ordinal scale</u>: The scores range from 2-point (0-1) to a 4-point scale (0-3)	A high score on the Barthel Index corresponds to a high degree of independence. A score ≥15 indicates independence

- The Barthel Index is a reliable and valid test, however the test is not very responsive and has a ceiling effect (49)
- The Dutch version of the Barthel Index is a clinimetrically justified restriction scale (25)
- For elderly people the reliability of the Barthel Index has been investigated in the major clinical settings relevant to older people. The Barthel Index was found to be reliable when administered by face-to-face interview and by telephone (ICC 0.89) and on testing by different observers (ICC 0.95–0.97) (20).

Test	Aim	Score	Outcome measure
Timed up & go test (TUG) (59)(21)	Measures balance.	The patient's time needs to stand up from a chair, three meters of walking comfortably (energetically most efficient), to turn around, walk back and sit down	Score <20 sec indicates that a patient can walk independent, a Score >30 sec indicates that a patient is dependent of help

- The get-up and go test proved to be a satisfactory clinical measure of balance in elderly people (59)
- Test results indicate that the time score is reliable (inter-rater and intra-rater); and correlates well with log-transformed Barthel Index of ADL (r = -0.78); and appears to predict the patient's ability to go outside alone safely. These data suggest that the timed "Up & Go" test is a reliable and valid test for quantifying functional mobility that may also be useful in following clinical change over time (21).
- The TUG range for people aged 80 to 99 years expressed as the mean has been estimated to be 11.3 ((95% confidence interval10.0-12.7) seconds and 11 to 20 seconds in frail elderly and disabled patients (21)(1).

Test	Aim	Score	Outcome measure
10 Meter Walking Test (10 MLT) (22)	Determine functional mobility, gait, and vestibular function	Walking speed in meters per second over 10 meters. This score has to be transformed into the maximal walking speed with the formula comfortable speed x 1,382 = walking speed max	When the walking speed is >0,58 m/sec. (10m in 17.2 sec), then independent functioning indoors is likely, when the walking speed is >0,77 m/sec. (10m in 13 sec), then independent functioning outside the house is likely

- The distance covered is divided by the time it took the individual to walk that distance.
- Testers have to collect three trials and calculate the average of the three trials.
- This test can only be administered when a patient has a score of 3< on the FAC-test
- Responsivity SDD 0,16 m/s
- Construct validity FAC vs 10MLT 0,79 (Spearman) (22).

Appendix II: Threshold sensitivity analysis

Threshold for no. of steps	900	**1000**	1100	1300
No. of patients progressed	9	**7**	6	4
% of patients progressed	75%	**58%**	50%	33%
Threshold for active minutes	40	**50**	60	
No. of patients progressed	8	**6**	4	
% of patients progressed	67%	**50%**	33%	
Threshold for activity block	3	**4**	5	
No. of patients progressed	7	**6**	4	
% of patients progressed	58%	**50%**	33%	
Threshold for resting heart rate	7.5%	**10%**	12.5%	15%
No. of patients progressed	8	**6**	6	4
% of patients progressed	67%	**50%**	50%	33%

Appendix III: Comparison of clinimetry and Fitbit parameters per ICF determinant

The matching colours represent the different determinants that are compared in the ICF model as presented in Figure 2 4, their correlations and their significance are shown

Table 8-1: Statistical analyses per determinant at admission

Admission	Resting heartrate (BPM)	Longest activity block (minutes)	Steps per day	Active minutes	Barthel Index
TUG (n=3)	-				-
SNAQrc	Spearman's rho 0.90 (p=0.819)				Spearman's rho 0.262 (p=0.496)
FAC		Pearson 0.422 (p=0.150)			Spearman's rho 0.877 (p<0.001) *
10 MLT (n=3)		-			-
MMSE			Spearman's rho -0.093 (p=0.799)	Spearman's rho -0,223 (p=0.536)	Spearman's rho -0.914 (p<0.001) *
Barthel Index	Spearman's rho -0.363 (p=0.246)	Spearman's rho 0.153 (p=0.636)	Spearman's rho 0.262 (p=0.412)	Spearman's rho 0.247 (p=0.439)	

Table 8-2: Statistical analyses per determinant at discharge

Discharge	Resting heartrate (BPM)	Longest activity block (minutes)	Steps per day	Active minutes	Barthel Index
TUG	Spearman's rho 0.175 (p=0.629)				Spearman's rho -0.166 (p=0.647)
SNAQrc (measured at admission)	Spearman's rho -0.817 (p=0.007)				Spearman's rho 0.080 (p=0.837)
FAC		Spearman's rho 0.336 (p=0.285)			Spearman's rho -0.66 (p=0.840)
10 MLT		Spearman's rho 0.566 (p=0.112)			Pearson 0.201 (p=0.603)
MMSE (measured at admission)			Spearman's rho 0.093 (p=0.799)	Spearman's rho 0.068 (p=0.852)	Spearman's rho -0.275 (p=0.442)
Barthel Index	Spearman's rho 0.301 (p=0.342)	Spearman's rho 0.063 (p=0.847)	Spearman's rho 0.089 (p=0.784)	Spearman's rho -0.018 (p=0.956)	

Appendix IV: Results mixed model analysis

The F value represents the effect of the week. The Sidak is used as post-hoc test.

Fitbit parameters				
Weeks	*Overall score*	*1 -> 2*	*1 -> 3*	*1->4*
Number of steps	F:47.03 P<0.01	-	p<0.05 Mean difference: -941 95% CI: -1703 : -179	-
Longest activity block	F:5.976 P=0.012	p<0.05 Mean difference: -1.6 95% CI: -2.9 : -0.3	-	-
Active minutes	F:8.633 P=0.004	-	P<0.05 Mean difference: -32 95% CI: - 63 : -1	-
Resting heart rate	F:6.311 P=0.010	p<0.05 Mean difference: 5.3 95% CI: 1.2 : 9.4	p<0.05 Mean difference: 7.6 95% CI: 1.9 : 13.3	p<0.05 Mean difference: 8.2 95% CI: 1.9 : 14.5

Appendix V: Weekly progress for the Fitbit parameters of individual patients

To see if progress throughout the weeks of stay is steady, an overview of the data of all patients is created per week.

To define if in a week progression is made, the thresholds as defined in Table 3-1 are applied, however it is corrected for the current week:

Formula for weekly progression (valid for weeks *i = 2:N*)

$$SW_i - SW_1 \geq \frac{T}{N-1} * (i-1)$$

$$AM_i - AM_1 \geq \frac{T}{N-1} * (i-1)$$

$$AB_i - AB_1 \geq \frac{T}{N-1} * (i-1)$$

$$RH_1 - RH_i > \frac{T}{N-1} * (i-1)$$

Number of steps per day

	Start value week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9
1	412	1189	1682	1472	1551	901	1390		
2	908	1242	1678	1821					
3	753	1121	1539	923	1233	3294			
4	327	725	1295	1095	1185	1251			
5	1825	2568	2692						
6	1709	1275	4284	2667	989	2649	1878	2099	2265
7	75	106	679	795	1191	832	581	769	
8	1459	2228	2058	2097	2423	2915			
9	854	1775	1148						
10	1446	1381	1338	1486					
11	806	859	997	976					
12	1165	1801	3774	5125	5180	3704			

Total number progressed: 33 out of 54 (61%)

Active minutes per day

	Start value week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9
1	13	62	87	72	84	51	54		
2	71	64	67	73					
3	38	59	65	48	60	83			
4	31	56	74	64	76	74			
5	90	111	113						
6	69	57	110	100	42	112	94	98	119

7	4	13	39	42	66	60	59	45
8	53	98	102	100	113	119		
9	51	107	76					
10	107	87	68	88				
11	51	63	64	56				
12	85	143	167	195	198	138		

Total number progressed: 33 out of 54 (61%)

Longest activity per day

	Start value week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9
1	3,2	7,1	8,1	9,1	9,6	7,0	7,8		
2	4,3	5,9	6,0	5,5					
3	4,7	5,9	7,4	5,7	6,1	12,3			
4	2,7	5,4	5,1	6,5	9,1	7,0	7,0		
5	8,5	9,4	7,0						
6	5,7	5,6	9,2	8,9	7,3	9,7	7,0	7,4	10,0
7	2,0	2,0	3,7	4,1	4,6	3,7	3,4	3,6	
8	6,2	9,3	7,0	8,9	8,1	11,0			
9	3,6	6,9	4,7						
10	7,5	7,0	5,8	8,0					
11	4,2	5,4	4,9	6,8					
12	5,0	6,8	7,0	9,1	11,9	10,5			

Total number progressed: 31 out of 54 (57%)

Resting heart rate

	Start value week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9
1	86	74	72	67	67	65	64		
2	73	69	69	68					
3	90	79	72	74	65	67			
4	69	66	62	63	63	67	62		
5	75	67	69						
6	68	68	64	65	78	72	65	64	69
7	80	73	72	71	72	74	74	68	
8	79	68	65	63	73	67			
9	74	70	69						
10	79	78	77	73					
11	76	72	66	66					
12	70	71	74	76	68	73			

Total number progressed: 33 out of 54 (61%)

Appendix VI: Overview of individual outcomes on the clinimetry

In the table below the outcomes of the clinimetry per patient is shown. When a test can be used to define independence, the colours represent independence (green) and dependent of help (orange)

	Admission					
	SNAQrc	Barthel	FAC	10 MLT	TUG	MMSE
1	2	12	2			
2	0	12	3	0.44	41	26
3	0	12	3	0.38	52	28
4	1	12	2			27
5	0	17	4			
6	0	12	3			27
7	0	7	1			29
8	0	11	2			28
9		13	3			25
10		9	2			28
11	1	14	4			25
12		13	3	0.56	34	26

	During rehabilitation				
	FAC week 1	FAC week 2	FAC week 3	Barthel week 3	Barthel week 6
1	3				
2	4				
3					
4	3	4	5	14	
5					
6					
7	2	3	4	12	15
8	3				
9	4				
10	3	4			
11	4				
12	4			16	

	Discharge			
	Barthel	FAC	10 MLT	TUG
1	16	4	0.43	31.7
2	17	4		
3	18	5	0.71	19
4	14	5	0.83	19
5	17	4		
6	15	4		13.9
7	15	4	0.28	40.5
8	13	4	0.50	39.0
9	16	4	0.43	42.0
10	19	4	0.48	22.2
11	19	4	0.76	21.57
12	17	4	0.58	22.30

Appendix VII: overview of individual variability

In the table below per patient is specified how much times the patients made progression / no progression on the total of the four Fitbit parameters. Progression is defined from the second weekend in rehabilitation and in total 4 Fitbit parameters are measured (i.e. (stay in weeks-1) *4 = no. of progression data points).

Patient	Stay in weeks	Progression	No progression	Discrepancy	% Progression
1	7	20	4	+16	83
2	4	5	7	-2	42
3	6	13	7	+6	65
4	6	17	3	+14	85
5	3	2	6	-4	25
6	9	13	19	-6	41
7	8	19	9	+10	68
8	6	17	3	+14	85
9	3	4	4	0	50
10	4	0	12	-12	0
11	4	3	9	-6	25
12	6	15	5	+10	75

Appendix VIII: Progression per week

The table below shows the progression/no progression of the four Fitbit parameters for the complete group of patients (i.e. number of patients*4 = number of progression data points).

Week	Number of rehabilitating patients	Progression	No progression	% progression
1	12			
2	12	31	17	64,6
3	12	28	20	58,3
4	10	26	14	65
5	7	18	10	64
6	7	19	9	67,9
7	3	3	9	25
8	2	1	7	12,5
9	1	2	2	50