Feasibility study of the use of the Vitamove in measuring mobility of patients after surgery

Master thesis

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ONDERGETEKENDE

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Samenvatting

Introductie: Vroege mobilisatie is onderdeel van standaard postoperatieve zorg na buikoperaties. Desondanks is er geen consensus over wat vroege mobilisatie inhoudt. Objectieve informatie over de mobiliteit van patiënten kan bijdragen aan een betere behandeling. Met behulp van ambulante accelerometrie zoals toegepast in het VitaMove-systeem, is het mogelijk gedetailleerde houding- en bewegingsinformatie te verkrijgen. Het VitaMove-systeem is nog niet toegepast bij patiënten die zijn opgenomen in het ziekenhuis.

Doel: Het eerste doel van de studie is vaststellen of gebruik van de VitaMove haalbaar is voor het meten van mobiliteit van patiënten opgenomen in het ziekenhuis voor buikchirurgie. Het tweede doel is vaststellen van de 'face validity' van de VitaMove om de klinisch relevante vormen van mobiliteit na een operatie te meten.

Methoden: Vijf patiënten opgenomen in het Erasmus MC in Rotterdam voor een electieve whipple operatie werden geïncludeerd in de studie. Inclusiecriteria waren: tussen 18 en 85 jaar en geen beperkingen voor vroege postoperatieve mobilisatie.

De mobiliteit werd gemeten gedurende de eerste, derde, zevende en negende postoperatieve dag. De criteria voor haalbaarheid waren: draagtijd, belasting voor patiënten, beïnvloeding van de verpleegkundigen bij de zorg en niet-vastgelegde activiteiten gedurende de meting. Het gebruik van het instrument wordt haalbaar geacht wanneer wordt voldaan aan alle criteria.

De VM is op drie manieren onderzocht op 'face validity'. De rapportages van de VitaMove zijn gecontroleerd op duidelijke fouten en op de waarneming van herstel van mobiliteit. Verder is de activiteitendetectie gedetailleerd bekeken, met focus op subcategorieën van mobiliteit en het optimaliseren van instellingen.

Resultaten: De gemiddelde draagtijd van de VitaMove was 85%, 18% van de patiënten rapporteerde klachten door de VitaMove, 0% van de verpleegkundigen gaf aan beïnvloed te zijn doordat patiënten de VitaMove droegen en 13% van de dagen miste de VitaMove meer dan 2 activiteiten.

Face validity: bij alle patiënten werd buikligging gemeten, hoewel patiënten deze houding na een buikoperatie nooit aannemen. Dit is duidelijk een meetfout. Wel werd het herstel van mobiliteit correct waargenomen en konden twee subcategorieën worden onderscheiden: rechtop en achterover zitten.

Conclusie: Het gebruik van de VitaMove voldoet niet aan twee van de vier criteria. De VM is daarmee niet haalbaar voor het meten van mobiliteit bij patiënten verblijvend in het ziekenhuis na buikchirurgie. Met aanpassingen in het studieprotocol betreffende draagtijd en plaatsing door verpleegkundigen wordt de VitaMove waarschijnlijk als haalbaar beoordeeld.

De 'face validity' is niet eenduidig: de VitaMove meet herstel van mobiliteit correct, maar registreert ook niet-uitgevoerde activiteiten.

Abstract

Introduction: Early mobilisation is part of standard postoperative care after abdominal surgery. Nevertheless no consensus exists on the content of early mobilisation. Impartial information on the mobility of patients can contribute to better treatments. The use of ambulant accelerometrics as applied in the VitaMove system enables a detailed assessment of patient mobility in terms of body postures and movements. Until now, the VitaMove has not been applied in clinical, inpatient settings.
Objective: Primary objective is to determine if the VitaMove is feasible for measuring mobility of patients after abdominal surgery, admitted to the hospital. The secondary objective is to examine the face validity i.e. whether the VitaMove measures the clinically relevant aspects of mobility after surgery.
Methods: Five patients, admitted to the Erasmus MC in Rotterdam for elective whipple operation, were included in the study. Inclusion criteria were: age between 18 and 85 years and no limitations for early postoperative mobilisation. The mobility was measured during the first, third, seventh and ninth day after surgery.
Criteria for feasibility were: wearing time, burden for patients, influencing nursing staff during daily care and missed activities. The VitaMove is considered feasible when all four endpoints are met.
The VM was examined on face validity in three ways: the VM-reports were checked on obvious errors and the observation of recovery of mobility. Further the activity detection was examined in detail, with focus on sub-categories of mobility and optimization of settings.
Results: The average wearing time of the VitaMove is 85%, 18% of the patients reported complaints on wearing the VitaMove, 0% of the nursing staff reported to be influenced by the VitaMove during daily care and in 13% of the days, more than 2 activities were missed.
Face validity: with all patients the posture 'prone' was measured although after abdominal surgery patients never take this posture. This is an obvious error. On the other hand recovery of mobility was observed correctly and two subcategories could be distinguished: sitting upright and backwards.
Conclusion: The use of the VitaMove does not meet two out of four endpoints. Therefore the VM is not feasible for measuring mobilisation with patients staying in hospital after abdominal surgery. With adjustments of study protocol concerning wearing time and placement by nursing staff, the VM will probably be assessed as feasible.
The face validity is ambiguous: the VM measures recovery of mobility correctly, but on the other hand non-performed activities were detected.

Keywords: activity monitoring, postoperative care, feasibility, abdominal surgery, early mobilisation

1. Introduction

Early mobilisation is widely used in hospitals to help patients recover after abdominal surgery. It has been shown that early mobilisation has a positive effect on recovery (1-3). It decreases the incidence of postoperative pulmonary complications and stimulates faster independent ambulation and hospital discharge (4-6). Therefore, nowadays, early mobilisation is part of standard postoperative care, in which physical therapists are often involved.

Even though there is evidence of the positive effects of early mobilisation and early mobility of patients, no consensus exists on the contents of early mobilisation. Currently, the used clinical protocols contain limited detailed information on key parameters, such as number of times a patient should be mobile each day. In clinical practice, this leads to a variety of mobilisation methods after surgery, with possibly non-optimal outcomes. Well-specified protocols containing the most effective mobilisation guidelines could result into better mobility, better and faster recovery and shorter hospital stay in patients after abdominal surgery (4-6).

In order to design well-specified mobilisation protocols, it must be known which aspects of patient mobility contribute most to better recovery. For that, detailed assessment of mobility is a pre-requisite and must be studied taking into account the length of the hospital stay, type of operation and patients' characteristics. Only one study is available that gives insight in current mobilisation patterns. Browning et al. showed that patients have little uptime, defined as standing and walking in the first four days after upper abdominal surgery (7).

To gain insight in current mobilisation patterns, direct observation can be used. Unfortunately, this requires a lot of resources, which are often unavailable. An alternative method is ambulatory activity monitoring to measure mobilisation methods objectively (8, 9). Browning et al. used the Positional Activity Logger, which has one sensor positioned on the right thigh of the patient and which measures angles larger than 45 degrees to the horizontal axis i.e. standing and walking (7). Even though it is the most used method of mobilisation in the first postoperative days, this logger excludes sitting. Therefore, this monitoring instrument is non-optimal for measuring postoperative mobilisation methods.

Recent technological developments allow detailed and objective measurement of mobility such as lying, sitting, standing, ambulation and climbing stairs. One of such devices is the VitaMove system (VM), the technologically redesigned successor of the Vitaport (VP) Activity Monitor. These devices are validated and frequently-used accelerometry-based

activity monitors that allow detailed assessment of patient mobility and which measures a large set of body postures and movements (10, 11). Until now, the VM has been used in several studies in an outpatient setting, investigating patients with, for instance, neurologic disorders and hip or knee osteoarthritis (12-14). The VM is not yet used in clinical, inpatient settings, and it is not known if the VM is a feasible instrument for measuring mobilisation methods and physical behaviour in inpatient settings. Physical behaviour in outpatient settings differs from patients in inpatient settings. Patients in inpatient settings are often more sedentary. Furthermore, patients admitted to the hospital are often more dependent on hospital staff for daily activities and, for example, installing the VM. It is also not known if the VM interferes in the daily care for patients by the nursing staff. Secondly, it is unclear if the data extracted from the VM contain relevant information which can be used for clinical practice or research in inpatient settings. The hypothesis of this pilot study is that the VM is a feasible instrument that can be used for measuring clinically relevant aspects of mobility in patients admitted to a hospital.

Primary objective is to determine if the VM is a feasible instrument for measuring mobility in patients after abdominal surgery, admitted to the hospital. The secondary objective is to assess the face validity of the VM, i.e. whether the instrument measures the clinically relevant aspects of mobility after surgery and if these measurements can be used as an evidence based basis for physical therapeutic mobilisation protocols.

2. Methods

A pilot study was conducted at the gastric-intestinal surgical department in the University Hospital of Rotterdam, Erasmus MC. The study protocol was assessed by the Medical Ethics Committee of the Erasmus MC, Rotterdam.

2.1 Population

A convenience sample of patients who were admitted for elective Whipple surgery in the Universital Hospital of Rotterdam, Erasmus MC in the period from October 1th 2012 until February 20th 2013 was studied. Patients were included in the study when following inclusion criteria were met: elective Whipple procedure, age between 18 and 85 and willing to sign informed consent. Exclusion of patients when following criteria were met: pre-operative physical limitations for early mobilisation, pre- or per-operative Cerebral Vascular Accident, severe post-operative complications, Intensive Care Unit (ICU) admittance required,

perioperative irresectable tumour and post-operative delirium scored > 5 on the Delirium Observatie Screening Scale (DOS-scale)(15-17).
Sample size calculation was not possible for this type of pilot research. Based on previous studies we assumed that 5 patients were sufficient to answer the questions of this feasibility study.

2.2 Instruments

2.2.1 VitaMove activity monitor

To assess mobility the VitaMove activity monitor (VM) was used (size: 40 x 80 x 15mm; weight 52 g; 2M Engineering ©, Veldhoven, The Netherlands) (figure 1). Van den Berg-Emons et al described the technical features of the VM (18):
"The VM is based on long-term (>24 h) ambulatory monitoring of signals from body-fixed accelerometers and consists of three accelerometer units and a computer with analysis programs (19). From the accelerometer signals, the duration, rate and moment of occurrence of body postures and movements can be automatically detected with a resolution of 1 second. The main activities associated with mobility are defined as the body postures lying, sitting, and standing, and the body movements walking (including climbing/descending stairs), running, cycling, wheelchair-driving and general (non-cyclic) movement. Within these main categories, many sub-categories (e.g. sitting with trunk bent forwards, backwards etc.) can be distinguished. Furthermore, information on the variability of the acceleration signal (motility) can be obtained, which is related to the intensity of body-segment movements (20, 21). Validity studies, in which simultaneously made videotaped registrations (reference method) were compared with the outcome of the VP/VM, have shown that the VP/VM is valid to quantify activities associated with mobility (19). Furthermore, the VM can detect differences in the level of physical activity during everyday life between groups, which supports its validity and applicability in clinical research (22, 23)."

For the analysis of the data from the VM software called VitaScore was used. Figure 2 gives an overview of the data analysis. The process of analysing data starts with a pre-analysis consisting of automatical adjustments for non-optimal attachment (i.e. angular position) of especially the trunk sensor and the compilation of a body analysis activity report using the default settings for the detection of body postures and movements. When the body analysis activity report is not satisfactory the researcher can correct the data for systematic (i.e. more frequent) errors in the detection of specific activities by editing the data manually. Further he

can overwrite the default by more appropriate settings in VitaScore. This is an iterative procedure which ends when the report is satisfactory.
It is possible to choose between several body analysis activity reports, all with different specifications of body postures and physical activity. An example of a body analysis activity report is given in appendix 1.

2.2.2 Questionnaires

Two questionnaires were conducted for this study. The first questionnaire was used for patients in order to assess:

- Wearing time: Did you wear the activity monitor from 8.00 until 22.00?
- Burden: Did you experience burden from the activity monitor?
- Missed activities: did you perform any activities while you were not wearing the activity monitor between 8.00 and 22.00?

The second questionnaire was used for the nursing staff, in order to assess whether the VM influenced the nursing staff during their daily work activities and if the nursing staff thought the patient experienced burden from the activity monitor:

- Influence: Were you influenced by the activity monitor during your daily care for the patient?
- Burden: Do you think the patient experienced burden from wearing the activity monitor?

2.3 Study procedure

Patients who were admitted to the surgical department were informed about the study by the nurse practioner two weeks before surgery. The day before surgery patients were informed regarding the VM and the questionnaire they had to fill in the day after they wore the VM and were asked to sign informed consent. Patient characteristics were obtained from the patients' medical record.

The VM was placed on the patient by the researcher on the first, the third, the seventh and the ninth day after surgery. These days were selected because patients are able to perform different mobilisation methods on different days. The first day after surgery patients are completely dependent. Sitting on the bedside or in a chair are methods used on the first day.

The third day patients should be mobilising more and other methods may be used, such as walking. The seventh day patients may be able to mobilise independently, for longer periods during the day and to use different mobilisation methods, such as stair climbing and cycling. The ninth day patients should come close to their hospital discharge. They should be able to mobilise independently, longer periods of time (almost all day) and use all mobilisation methods. From the measurements of these four days, it should be possible to determine the recovery of mobilisation and patient mobility after surgery.

2.4 Outcomes

2.4.1 *Practical feasibility*

Main outcome of this study is the feasibility of the use of the VM in measuring mobilisation methods and patient mobility after surgery. Four endpoints for feasibility were defined.

Wearing time

First endpoint was the time patients wore the VM. The VM was attached on the thorax and both upper legs of the patient. For accurate measurement the VM had to be in place on the first day from 2 PM until 10 PM and all other days between 8 AM and 10 PM. Patients had to wear the VM 90% of the prescribed time.

Burden

Second endpoint was whether patients experienced irritating burden as a result from wearing the VM. This was asked after every measurement in the questionnaire for patients. This endpoint was met if less than 20% of the patients experiences irritating burden.

Influencing nursing staff

Third endpoint was whether the VM influenced the nursing staff when performing their daily care for patients. Because this is an observational study all health care workers (physicians, nursing staff and physical therapists) were asked to perform their normal work activities. Nurses were asked through the questionnaire if they were influenced by the VM during their care for the patient. Less than 20% of the nursing staff may experience influence of the VM in daily care if this endpoint was met.

Missing activities

Fourth and last endpoint: all activities while not wearing the VM were monitored. After every measurement the patient and nursing staff were asked if the patient did any activities while not wearing the VM. A maximum of 2 activities a day missed by the VM, within the prescribed time, was accepted.

The use of the VM was considered feasible for measurement of mobility after surgery in hospitalized patients when all the defined endpoints were met.

2.4.2 Face validity

A secondary aim was to examine if the VM was able to measure different relevant aspects of mobility in postoperative care. Because it was not possible to use a reference method, the VM was examined in three ways on face validity, i.e. the extent to which the VM is subjectively viewed as covering the concept it aims to measure.

Firstly, the VM reports were examined on obvious errors e.g. the detection of activities that would have been impossible to perform by the patients.

Secondly, the patterns of recovery were examined; it can be expected that in course of their stay in the hospital patients show positive changes in their physical behaviour (e.g. more walking/upright, less lying).

Thirdly, the activity detection was examined in more detail, with focus on the detection of sub-categories of mobility and optimization of settings. It is already known that the VM is able to discriminate between lying, sitting and upright physical activity. For the optimisation of postoperative mobilisation protocols it is possible that more specific measurement is required. For example, from the characteristics of the VM and previous research it is known that the distinction between lying and sitting might be questionable. Furthermore, for inpatient care the difference between "sitting" in bed and sitting in a chair is relevant, and this distinction is not a standard feature of VM. These types of issues were analysed in more detail.

2.4.3 Demographic and medical data

The following baseline parameters were collected: age, gender, medical history and smoking. In addition, during admission the following data were collected: duration of anaesthesia, postoperative complications, type of pain relief (EDA: Epidural anaesthetic, PCA: patient controlled aesthetic or intramuscular aesthetic) and Intensive Care Unit (ICU)/ Post Anaesthetic Care Unit (PACU) admittance.

3. Statistics

Descriptive statistics

The endpoints for feasibility, the description of the participants' characteristics and the outcome of the questionnaires were given in percentages, observed values and descriptive statistics.

All data were analysed using the statistical program SPSS (PASW® Statistics 18, IBM software) and Excel (Microsoft ® excel 2002).

4. Results

4.1 Patients

Five patients were included in this study. Patient's characteristics are shown in table 1. All 5 patients were, as planned, admitted for 1 day to the PACU. Patients 2 and 3 had mild postoperative complications: one patient developed a wound infection; the second one had chyllus leakage. Both patients did not require a prolonged hospital stay due to their postoperative complications. Patient 5 had severe postoperative complications, starting on the tenth day after surgery. This patient was however still included in the study because measurements took place on days one, three, seven and nine. The complications for this patient were delirium, nead leakage, re-operation and respiratory failure. This patient was transferred to the ICU on the fourteenth day after surgery because of respiratory failure and died on the sixty-sixth day of admission.

4.2 Outcome measures

4.2.1 Practical feasibility

Sixteen of the scheduled twenty measurements were performed (80%). On four days, the measurement could not be performed due to early discharge (three measurements) and collapse of the patient due to hypotension (one measurement).

Of the measurements, 87,5% was performed correctly (14 out of 16). Two times an error occurred because of loss of one of the sensors. One measurement (6,25%) could not be used for analysis because of errors in the software related to the VM, VitaScore.

Wearing time

The results of wearing time are shown in table 2. The average of the time patients wore the VM is 85%. The first day after operation almost all patients wore the VM the prescribed time. On the remaining days the percentages of wearing time vary between 93% and 39%.

Burden

Eighteen per cent of the patients reported complaints about irritating burden from wearing the VM. The only complaint patients reported is itching from the straps. One patient did remove the VM one day because of severe itching. Patients did not feel the sensors because of their light weight and reported this as very pleasant.

Influencing nursing staff

Seventeen questionnaires were filled out by the nursing staff. 0% of the nursing staff reported to be influenced by the VM during their daily care for the patient. Seventeen per cent (3 out of 17) of the nursing staff reported that they think the patient experienced burden from the VM. Twice it was reported that the patient said the straps were itching, once it was reported that the sensors on the legs were sliding down during the transfer to the commode.

Missed activities

In 13% of the days, more than 2 activities were missed by the VM. The VM missed bathing (11 out of 16 measurements) and sitting upright directly after bathing regularly (7 times out of 16 measurements) because the VM was not placed on the patients at that time. Further it missed activities patients performed after 10 PM such as walking to the bathroom (2 times out of 19 measurements) because the VM was only worn between 8 am en 10 pm. Missed activities for every measurement are shown in table 3.

4.2.2 Face validity

Table 4 shows the mobility of the patients for every measurement. The data in the table are derived from a 'body analysis activity report' compiled by the software VitaScore.

The VM measured in all five patients the posture 'prone' with a maximum of 1h and 8 minutes. Prone position is a posture patients are not able to take after abdominal surgery. Furthermore, the VM measured in patients three and five cycling for two and four minutes. This activity is not performed by these patients. Therefore 'prone' and 'cycling' were incorrectly detected by the VM.

In general one can say that all patients showed positive changes in their physical behaviour during their hospital stay. The percentage of time patients stayed in bed (lying, sitting backwards) decreased in the course of time. On the first day after surgery all patients spent 100% of time in bed. On day three the percentage of time they spent in bed ranged from 35% to 87%. For the measurements on day seven and nine it is hard to conclude general patterns because on day seven only two useful measurements are available. One patient was

discharged, one measurement could not be loaded in VitaScore, and one patient showed medical complications. For day nine there were no useful measurements because of one more discharge, one error and two patients with medical complications.
The mirror image of spending less time in bed is seen with sitting upright and standing of which the percentage of time increased during the hospital stay.
Below more specific information is given on the recovery patterns of individual patients.

It looks as if patient 1 showed an increase in staying in bed on day three. However when one takes in account the time the sensors were off on day one and it is known that patients stayed in bed all day, this patient showed an increase in activity on day three in sitting upright and a large number of transitions from lying to standing and vice versa.
With patient 2, lying in bed decreased rapidly in the first seven days after surgery. The logical pendant is more sitting upright and a little walking on day seven. This patient two had a minor complication which is the cause that lying is the most measured posture on day nine.
Patient 3 showed a higher level of mobility compared to the other patients, because of a higher percentage for sitting, in the first days after surgery. Already on day one sitting backwards was the most measured posture, changing to sitting upright in the following days. On day seven the time measured for standing was already considerable. This patient was able to go on early discharge from the hospital on day nine.
After lying the first day after surgery patient 4 showed a quick recovery of activity in the following days and was also able to go on early discharge on day six.
Patient 5 collapsed on day three, due to hypotension and showed little recovery in the following days. Because this patient had a delirium (DOS-score <5) he spent most of the time in bed.

The main categories the VM detects were lying, sitting, standing and walking. Within sitting two sub-categories could be distinguished:

- Sitting backwards: sitting with an angle between 45 and 70 degrees upright;
- Sitting upright: sitting with an angle of more than 70 degrees upright.

The VM was able to discriminate between sitting backwards and sitting upright. However the VM could not discriminate between sitting upright in bed, on the bedside or in a chair. Further it seemed that VitaScore used in this study did not distinguish standing from very slow walking.

Because patients after surgery sometimes did not show enough movement, 5 times the VM turned off the sensors, as the system assessed the situation as being night. After analysis it seemed that the VM used its day-night rhythm procedure based on the movements of the patient. When the VM 'thinks' it is night, the sensors are turned off. These 5 times are reported in table 4 by 'sensors off'.

5. Discussion

Primary objective of this study was to determine if the VM is a feasible instrument for measuring mobility in patients after abdominal surgery, admitted to the hospital. In order to assess the feasibility of the VM, four endpoints were defined. Below the results of the measurements will be confronted with the endpoints.

Patients wore the VM only 85% of the time that was prescribed while the endpoint required a wearing time of 90%. The explanation for this is that the time window patients should be wearing the VM started at 8AM. This is the same time patients took a bath or shower. In both scenarios patients could not wear the VM. The VM was usually attached to the patient around 9.30 AM only. A solution may be to let patients wear the VM 24 hours a day, and to instruct them to only remove it when they take a shower. Another solution could be to instruct nursing staff to place the VM right after bathing or showering. With this solution early hours are still not measured, but patients are little active in the early hours, so not much relevant information would be lost. Although this endpoint is not met, options are available to increase wearing time to 90% or more.

Eighteen per cent of the patients experienced irritating burden, which was an itching. The straps for attaching the VM have little knots, which are causing the itching. A simple solution was to place the straps above the clothing of the patients. However, patients did not always wear pants which made it impossible to place the leg sensors on clothes. Placing a gauze between legs and straps solved the itch and it did not cause the VM to slip down. The endpoint required 20 % or fewer complaints, meaning that this endpoint is met.

None of the nursing staff reported to be influenced by the VM. None of the patients had to go for x-ray of the thorax, CT-scan or MRI-scan while wearing the VM and none of the patients wore the VM when the nursing staff was helping patients with bathing. This possibly is the reason that the nursing staff was not influenced. The endpoint required 20 % or fewer complaints, meaning that this endpoint is met.

Missed activities were most of all bathing and sitting in the chair after bathing. The VM cannot be worn during bathing, since it is not water resistant. To complete the measurement to assess patients' activity, the activity of bathing or showering can be found in reports from the nursing staff. To reduce the number of missed activities the same options can be applied as given by wearing time. Although also this endpoint is not met, there are options available for improvement.

The secondary aim of the study was to examine the face validity of the VM, i.e. whether the VM is able to measure relevant aspects of mobility after surgery.
The VM measured 'prone' in all five patients and cycling in two patients, but these posture and activity were not performed by any of these patients. Analysing the data in detail did not give an answer why VM detected these. Using the edit function of VitaScore and change the data manually for this mistake is a possible solution. In this way the actually performed activity can be included in the data and the body activity analysis report.
In general the recovery of mobility was visible in de data obtained on day one and three. For day seven and nine no definite conclusions can be drawn because of the limited number of usable measurements. The results are positive, but need further exploration and preferably a larger sample size which takes medical complications and early discharges more in account.
A notable issue is that the patients did not show the expected recovery of mobility. According to treatment protocol after Whipple surgery, all patients should be out of bed for at least one hour the first day after surgery. Measurements with the VM however show that all patients stayed in bed. It seems that patients are lagging behind treatment protocol directly on day one and this continues in the following days. When according to treatment protocol patients should be walking multiple times a day, this is not performed by the patients when looking at the measurements. The measurements show that the treatment protocol was not followed. Then the question rises whether the treatment protocol is too optimistic on the conditions of patients after abdominal surgery, patients are not aware of the importance of mobilisation or the nursing staff does not follow the treatment protocol because of other priorities. This lagging behind protocol could result into longer hospital stay and should be addressed in clinical practice.
A limitation the VM showed was that it is not able to discriminate sitting in a chair from sitting in bed. In postoperative care this difference is important because sitting in a chair is considered very different from sitting in bed, from a mobilisation point of view.

To resolve this deficiency the following practical assumptions could be applied. When sitting upright is preceded by a transfer, which can be detected through analysis of the VM-data, one can assume a patient is sitting in a chair. When sitting upright is not preceded by a transfer, the patient is sitting upright in bed or on the bedside.
When the VM measures sitting backwards, one can assume the patient is in bed because it is hardly possible to sit in a chair with an angle between 45 and 70 degrees upright.

A limited amount of literature exists on measurement of mobility in an inpatient setting after abdominal surgery. A study by Browning et al.(7) is the only one available where mobilisation after abdominal surgery is measured. In that study, the quantity of uptime after surgery was examined, as opposed to feasibility and validation. Nevertheless, the result from Browning et al. that patients have low quantity of upright mobilisation corresponds with the results of the present study concerning the recovery of mobility after abdominal surgery.
Two other studies assessed feasibility of the VM to measure patient mobility (23,24). Schasfoort et al examined the upper limb sensors of the VM, which are not used in the present study (24). Tulen et al. studied feasibility for an objective quantitative assessment of daily functioning in migraine (25). They concluded that ambulatory accelerometry can provide the objective behavioural effect parameters for the evaluation of migraine and its treatment on daily functioning. This conclusion is in conformity with this study, because in both cases the VM is assessed to be able to measure correctly and objectively posture and physical activity.

The present study is the first study that explores the practical feasibility for ambulatory activity monitoring during hospital stay. Until now, no information was available on how patients or nursing staff experiences these measurements and how these activity monitors work in inpatient settings. The present study provides a lot of information on the above mentioned subjects of which future research can benefit.
The study described here has as limitations that the criteria for feasibility were quite firm, all endpoints had to be met. However, the researcher did not take into account that endpoint one is correlated to endpoint four. This implies that is hardly possible to meet all four endpoints because when the VM is worn less than 90% of the prescribed time the change of missing more than two activities becomes higher. This can be solved quite easily by changing the study protocol using the options described above.

The VM measured all postures and physical activity, but in number of cases the VM measured postures or activities that not had been performed by the patients. Validation and optimization of settings for inpatient settings could have been more certain when direct observation or videotaping was used in combination with the VM.
In the software VitaScore, many adjustments can be made to the data. Many problems and mistakes can be detected when an in VitaScore experienced researcher is analysing the data. In this study no full use is made of all features of VitaScore because of the inexperience of the researcher. Although help was offered and accepted several times, not every feature in the software was used, with a possible risk that some data are misinterpreted.

6. Conclusion

According to the criteria of this study, the VM is not feasible for measuring mobilisation after surgery while admitted to the hospital. Two out of 4 endpoints are not met: wearing time and missed activities. These endpoints however are correlated. Wearing time is limited because of bathing and most missed activities are bathing and sitting up right after bathing. With adjustments of study protocol concerning wearing time and placement by nursing staff, the VM will probably be assed as feasible.
The examination of the face validity is ambiguous: the VM reports show recovery patterns, but at the same time some activities are detected that were surely not performed. With respect to body postures, especially the difference between sitting in bed and sitting in a chair could not be made reliably.

Future research

It is recommended that in further research for measuring mobility in patients admitted to the hospital the sensors of the VM are placed for longer periods or even for 24 hours a day or should be placed by the nursing staff. Furthermore, the software needs to be updated for the distinction between sitting in or out of bed and standing or slow walking when measuring patients with sedentary activity, such as patients in a hospital. With this adjustments the VM can be used in future research as evidence based basis for physical therapeutic mobilisation protocols containing the most effective mobilisation guidelines that could result into better mobility, better and faster recovery and shorter hospital stay in patients after abdominal surgery.

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Tables

Table 1: Patients characteristics

Patient number	Gender	Age	Operation	Duration of operation	Type of pain relief	Complications *Yes/No*	Length of hospital stay
1	Female	75	Whipple	7h 20	EDA	No	16 days
2	Male	64	Whipple, cholecystectomy	7h	EDA	Yes Woundinfection	13 days
3	Female	48	Whipple, roux-y reconstruction, cholecystectomy	5h 28m	EDA,	Yes, Chyllusleakage	8 days
4	Female	53	Whipple, entero-enterostomy, adhesiolysis	11h 55 m	EDA	No	6 days
5	Male	82	Whipple, cholescystectomy	7h 20	EDA	Yes, Nead leakage Re-surgery Delerium Respiratory failure	66 days

EDA: Epidural anaesthetic, PCA: patient control anaesthetic or intramuscular anaesthetic

Table 2: Wearing time of the VM

	Day 1	Day 3	Day 7	Day 9
Patient 1	100%	93%	82%	86%
Patient 2	100%	86%	89%	86%
Patient 3	81%	70%	79%	--
Patient 4	100%	89%	--	--
Patient 5	100%	--	39%	89%

-- = no measurement available

Table 3: Missed activities by the VM

	Day 1	Day 3	Day 7	Day 9
Patient 1	0	1	2	2
Patient 2	0	1	2	2
Patient 3	0	4	4	--
Patient 4	0	2	--	--
Patient 5	0	--	2	2

-- = no measurement available

Table 4: Postures per patient in percentages of total measured time

	Patient 1				Patient 2				Patient 3				Patient 4				Patient 5			
Posture \ Day	**1**	**3**	**7**	**9**	**1**	**3**	**7**	**9**	**1**	**3**	**7**	**9**	**1**	**3**	**7**	**9**	**1**	**3**	**7**	**9**
Lying	52%	87%	ER	ER	68%	63%	12%	87%	3%	5%	20%	--	98%	45%	--	--	26%	--	66%	24%
Sitting	24%	6%	ER	ER	11%	9%	82%	2%	65%	95%	48%	--	1%	53%	--	--	44%	--	33%	73%
- Backwards	*24%*	*0%*	*ER*	*ER*	*10%*	*3%*	*63%*	*2%*	*65%*	*30%*	*3%*	--	*1%*	*16%*	--	--	*43%*	--	*31%*	*66%*
- Upright	*1%*	*6%*	*ER*	*ER*	*0%*	*6%*	*19%*	*0%*	*0%*	*65%*	*45%*	--	*0%*	*37%*	--	--	*0%*	--	*3%*	*7%*
Standing	0%	6%	ER	ER	0%	0%	3%	8%	0%	0%	26%	--	0%	3%	--	--	0%	--	0,5%	1%
Walking	0%	0%	ER	ER	0%	0%	2%	2%	0%	0%	0%	--	0%	0%	--	--	0%	--	0,5%	0%
Movement	0%	0%	ER	ER	0%	1%	1%	0%	0%	0%	6%	--	0%	0%	--	--	0%		0%	1%
Transitions [1)]																				
- Lying > Stand	*0*	*15*	*ER*	*ER*	*0*	*5*	*6*	*11*	*3*	*1*	*8*	--	*0*	*7*	--	--	*0*	--	*0*	*1*
- Stand > lying	*0*	*8*	*ER*	*ER*	*0*	*1*	*1*	*1*	*0*	*2*	*14*	--	*0*	*1*	--	--	*0*	--	*0*	*5*
Total time measured [1)]	9,5	13,4	ER	ER	8,5	13,8	10,7	8,8	6,5	9,9	10,7	--	8,7	12,3	--	--	6,5	--	14,1	12,9
Sensors off	23%	0%	ER	ER	20%	28%	0%	0%	31%	0%	0%	--	0%	0%	--	--	30%	--	0%	1%

1) absolute numbers

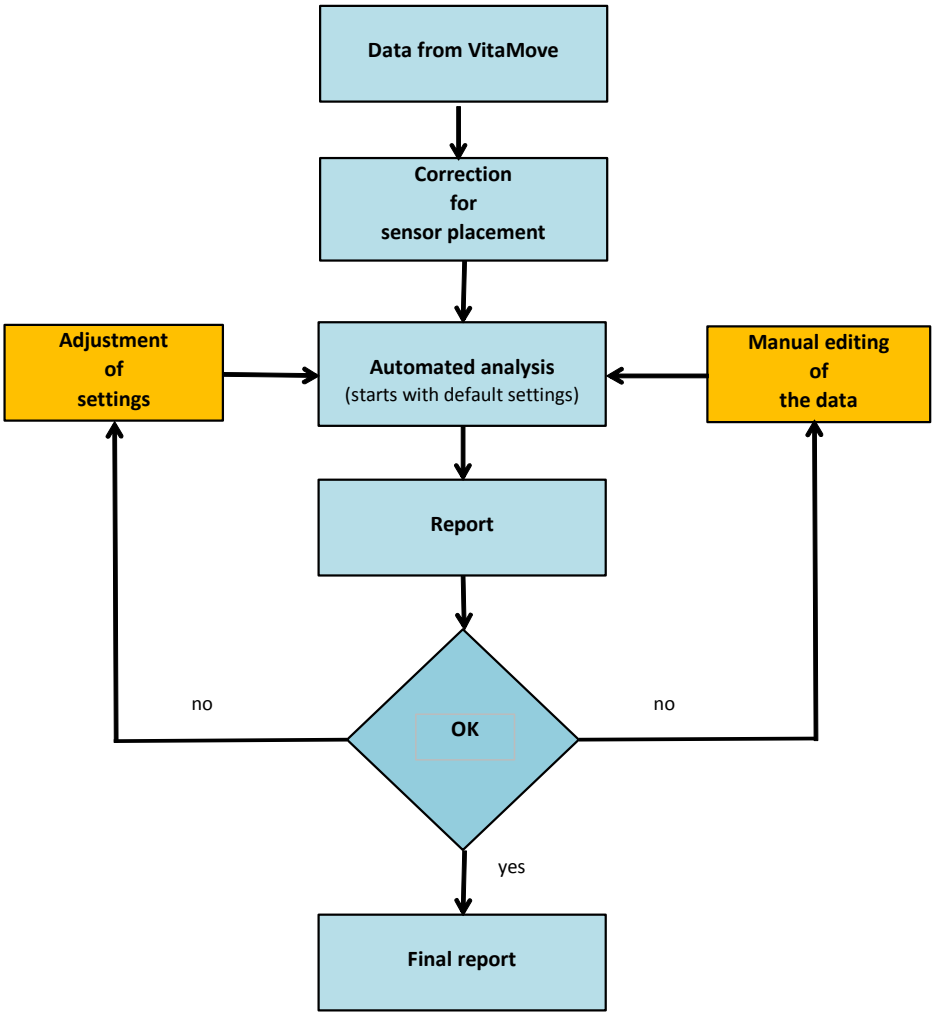
Sitting backwards = less than 45 degrees upright in bed; Sitting upright = more than 45 degrees upright

-- = no measurement, ER = Error in software
Due to rounding percentages do not always add to (sub)totals

Figures

Figure 1 Vitamove system

Figure 2 Data analysis of VitaScore



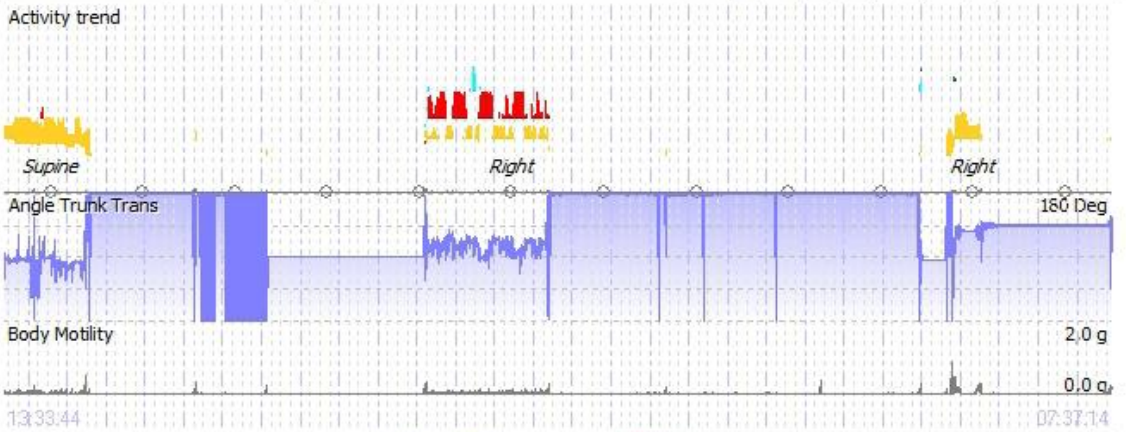
Appendix *Appendix 1 body activity analysis report*

Hospital Name
Department / Physician

Body Activity Analysis Report

Sedentary Activity and Symmetry Report

Last Name	[redacted]	Subject ID	[redacted]	Date / Time	[redacted]
Date of Birth		Gender		Weight / Height (BMI)	



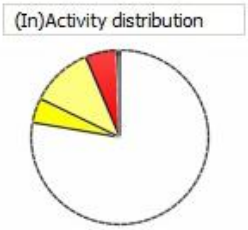
Lying Periods	#	Hrs.	Supine	Left	Right	Prone
Total	201	18.22	5.21	2.4	9.45	1.17
0 - 5 Min	150	1.92	0.44	0.35	1.03	0.1
5 - 30 Min	43	8.55	2.53	1.42	4.11	0.49
30 - 60 Min	7	5.09	2.24	0.63	1.65	0.57
60 - 120 Min	0	0	0	0	0	0
120 - .. Min	1	2.66	0	0	2.66	0

Sitting Periods	#	Hrs.	BodyMot (g*100)	Trunk Angle	Trunk Transv.
Total	82	6.62	2.5	138	23.6
0 - 10 Sec	18	0.03	6.3	138	30.5
10 - 60 Sec	31	0.23	3.4	140	29.2
1 - 5 Min	15	0.6	3	134	31.2
5 - 30 Min	14	2.46	2.4	146	30.2
30 - .. Min	4	3.3	2.4	132	16.9

Lying Sides	Hrs.	% Left/Right	FF: 150 d	F: 120 d	90 deg	B: 60 deg	BB: 30 d
Left	2.4	20	0	0.22	0.19	0.36	1.61
Right	9.45	80	0.01	0	1.27	6.94	1.16

For / Back Sitting	Hrs.	% For/Back	45 deg	60 deg	75 deg	90 deg	105 deg	120 deg	135 deg	150 deg
	6.62	1	0.01	0.01	0.03	3.34	0.54	0.6	1.19	0.91

Transitions from / to	Sitting	Supine	Left	Right	Prone
Sitting	-	5	0	63	0
Supine	5	-	30	8	0
Left	1	29	-	7	0
Right	59	11	6	-	0
Prone	0	0	1	1	-



Sedentary Duration	%	Hrs.
Total	99.6	113.75
Left	2.1	2.4
Right	8.3	9.45
Supine	4.6	5.21
Prone	1	1.17
Sitting	5.8	6.62
Movement NC	0.1	0.13
..Sitting....(% Mov.)	99.2	0.13
..Lying.....(% Mov.)	0.4	0
? Snsr_Off	77.7	88.65

BR (#/m)	Res-Ampl	HR (bpm)	StD
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Recorded channels: Tru Battery, Error Status, Temperature, Tru Tra, Tru Lon, Tru Sag, Tru Marker, UIR Battery Ulr Sag, Ulr Lon, Ulr Tra, UIR Marker, UIL Battery, Ull Sag, Ull Lon, Ull Tra, UIL Marker

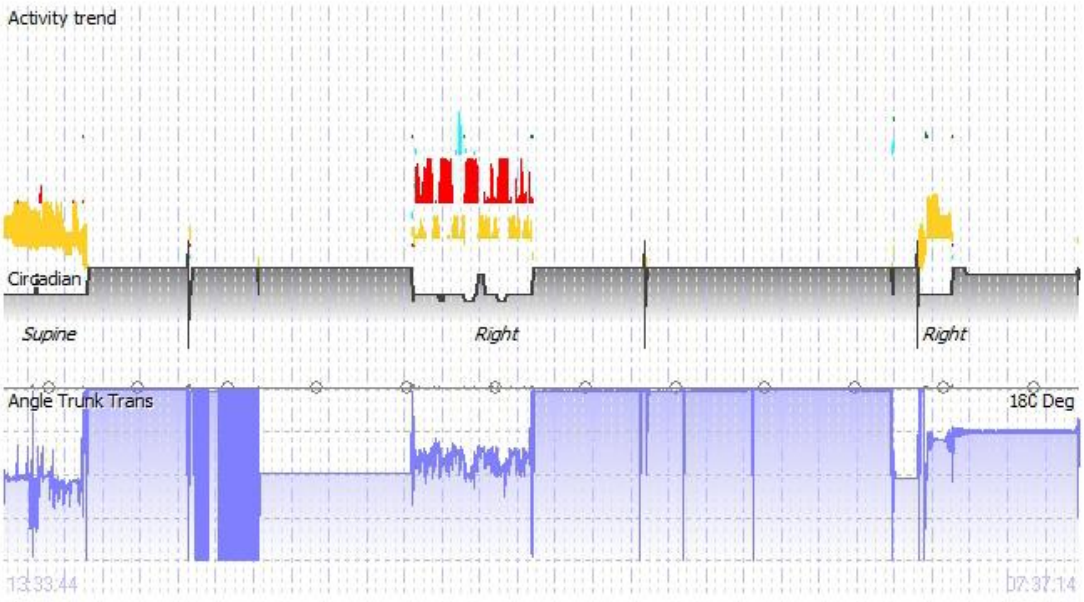
Patient ID: 005 **Scored by:** Administrator **Recorded:** 18-12-2012 **KB:** Activity 2.1 **Page 1 of 2**

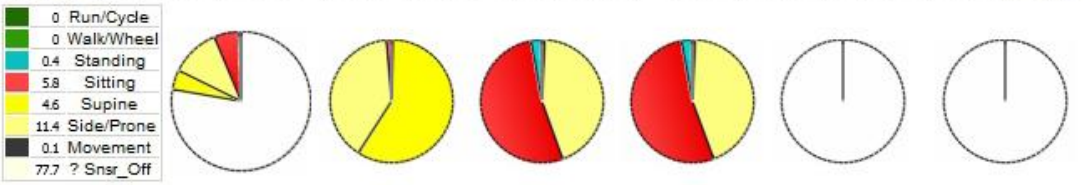
Hospital Name
Department / Physician

Body Activity Analysis Report

Sedentary Activity and Symmetry Report

Last Name	[redacted]	Subject ID	[redacted]	Date / Time	[redacted]
Date of Birth		Gender		Weight / Height (BMI	





Sedentary Duration	%	Hrs.	P1: %	P1: Hrs.	P2: %	P2: Hrs.	P3: %	P3: Hrs.	P4: %	P4: Hrs.	P5: %	P5: Hrs.
Total	*100*	**113.75**	*100*	**8.72**	*97*	**12**	*97*	**11.98**				
Left	**2**	**2.4**	**24**	**2.07**	**0**	**0**	**0**	**0**				
Right	**8**	**9.45**	**10**	**0.89**	**44**	**5.38**	**44**	**5.35**				
Supine	*5*	5.21	*59*	5.11	*1*	0.09	*1*	0.09				
Prone	*1*	1.17	*6*	0.48	*0*	0	*0*	0				
Sitting	*6*	6.62	*1*	0.11	*53*	6.47	*53*	6.48				
Movement NC	*0*	0.13	*0*	0.01	*0*	0.03	*0*	0.03				
..Sitting....(% Mov.)	*99*	*0.13*	*100*	*0.01*	*99*	*0.03*	*99*	*0.03*				
..Lying.....(% Mov.)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*				
? Snsr_Off	*78*	88.65	*0*	0.04	*0*	0	*0*	0				

Transitions	#	#	P1: #	#	P2: #	#	P3: #	#	P4: #	#	P5: #	#
Supine-Left/Right	30	8	30	8	0	0	0	0				
Left-Supine/Right	29	7	29	0	0	0	0	0				
Right-Supine/Left	11	6	10	0	1	0	1	0				

Recorded channels: Tru Battery, Error Status, Temperature, Tru Tra, Tru Lon, Tru Sag, Tru Marker, UlR Battery
Ulr Sag, Ulr Lon, Ulr Tra, UlR Marker, UlL Battery, Ull Sag, Ull Lon, Ull Tra, UlL Marker