

# EVALUATION OF SENSOR CONCEPTS FOR OPTIMIZED DECUBITUS PROPHYLAXIS AND THERAPY

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## **Abstract**

*Decubitus is a skin disease caused by prolonged pressure exposure of single skin regions; it is a major problem in nursing and up to now no satisfying prevention systems exist. We prototypically implemented and tested the feasibility of several types of sensors in three different scenarios and conducted a survey in a group of specialists in the field. Results indicate that accelerometer based approaches may be useful, affordable and feasible for long-term home care applications, while sensor based on pressure mats should rather be used for short-term equipment optimization.*

**Keywords** – *Decubitus, eCare, eHealth, AAL, Sensor*

## **1. Introduction**

### **1.1. Decubitus Ulcer**

Decubitus ulcers are damages of the skin caused by mechanically induced ischemia. Treatment of decubitus is a difficult, long-term and costly procedure which should be managed by professionals. To prevent the development of those wounds several guidelines have been created by different institutions [1, 2]. Additionally, scoring systems for decubitus risk assessment have been established, such as the Braden Scale, Norton Scale, Medley Scale, Waterlow Scale [3, 4]. By the use of these methods, a person can be classified into risk categories and an adequate risk adjusted reaction becomes possible. Decubitus risk factors include:

- reduced activity (Braden, Norton, Medley),
- reduced mobility (Norton, Braden),
- micro climate (skin moisture in Norton, Braden, Medley; incontinence; temperature),
- nutrition and drinking behavior (Braden, Medley),
- additional diseases (Norton, Medley) and
- reduced blood pressure (Braden q-Scale ... modified Braden Scale).

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## **1. 2. Decubitus prevention and therapy – State of the art**

### 1.2. 1. Pressure monitoring

As described in [5], duration and amount of pressure are mainly responsible for skin ischemia and therefore for decubitus ulcer. Therefore, the most important step in decubitus therapy is to avoid pressure at the affected skin regions. This can be done using pillows or special mattresses and via regular repositioning of the affected person. In the care process, repositioning intervals change with the fitness of the client and his/her ability to move independently. Therefore, devices recording autonomous main body movements can increase the efficiency of the nursing process and reduce costs [6]. Existing pressure sensing mats measure the pressure and the time the pressure is applied to specific skin areas. Unfortunately, such systems are very expensive and, therefore, usually they are used for care bed and wheel chair adjustment only, but not for everyday monitoring [7].

### 1.2. 2. Decubitus mattresses

Special air-filled pressure redistribution mattresses can additionally extend intervals for repositioning by nurses. Such systems consist of a mattress with several air chambers and a compressor which can automatically adjust the pressure in every chamber – leading to slight position changes and reduced pressure exposition [8]. Although these mattresses are very effective in terms of decubitus prevention, they are expensive, noisy due to their compressor, require quite a lot of space and they reduce the users autonomy. Those systems are only used for endangered persons and still caregiver is needed for correct handling.

## **1. 3. Scope of the present work**

Up to now, no affordable system for decubitus prevention and therapy optimization in a home-based setting exists and the involved care professionals are insufficiently involved so far. Therefore, it is one of the aims of our ongoing project “*Wudoku – Wunddokumnetation zur Guideline-konformen Prophylaxe und Pflege von Dekubitus durch Slow-goes- und No-goes-Empowerment*” (wound documentation for guideline-conform prophylaxis and care of decubitus by empowering patient) to optimize decubitus prophylaxis utilizing affordable sensor systems and direct feedback to the elderly themselves as well as to their care givers at the elderly’s home. The present paper summarizes results of the first step of the project – the evaluation process and feasibility analyses concerning possible sensors for decubitus prevention at the client’s home.

## **2. Methods**

In order to develop a comprehensive system for decubitus prevention and therapy optimization, sensors for monitoring each of the risk factors described in chapter one have been evaluated. Selected sensors have prototypically been implemented and their possible benefit in decubitus prevention and therapy has been determined. In cooperation with nursing experts we defined three major scenarios for possible sensors:

- *Lying position in bed.* Such sensors were intended to be used for completely immobile persons as well for sleeping periods of others
- *Sitting position in favorite seat* (e.g. in front of the TV set)
- *During movement* (any other scenario, e.g. walking)

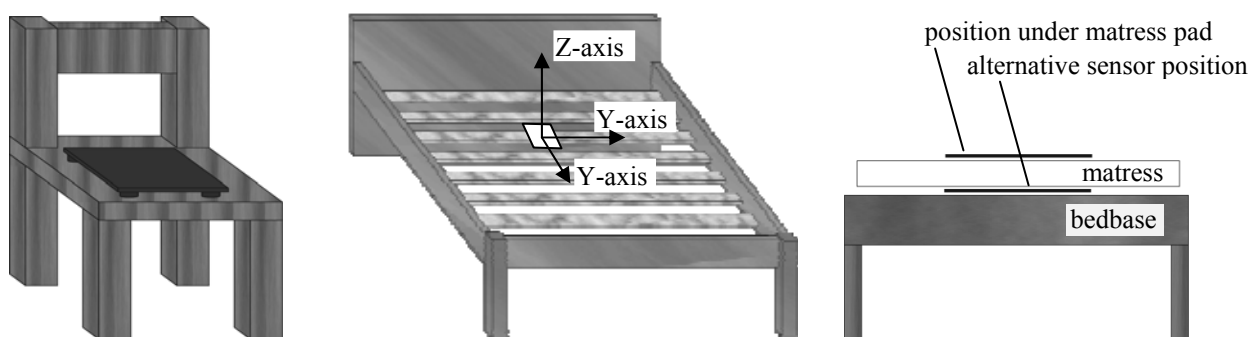
## 2.1. Prototypical sensor development

Several types of sensors have been developed and analyzed concerning their applicability in decubitus prevention and therapy.

### 2.1.1. Lying position in bed

A sample bed was equipped with the sensors developed and tested during sleeping.

For (autonomous) repositioning detection, a *static acceleration sensor* was mounted at the bed base underneath the center of gravity of the user, detecting movements of the lying person. A schematic picture of the experimental setup is shown in *Figure 1*. Additionally, a *mobile acceleration sensor* (Actibelt, Trium Analysis Online GmbH, München, Germany) was attached to the client's belt and recorded the patient's torso-orientation over time during sleep in order to record and analyze the client's sleeping behavior [9].



**Figure 1: Left: Positioning of the scale on the chair, Middle: Position and orientation of the acceleration sensor at the bed base; Right: Two possible positions of the pressure sensor mat in bed**

A “*Pressure sensor mat*” from Plastics Electronics GmbH (Linz, Austria) was positioned underneath the mattress pad in the region of the hip in order to identify long term pressure exposure of individual skin regions (*Figure 1 Right*). The sensor mat consisted of 434 sensors in an area of 63.5 x 30 cm with a resolution of 16 Bit per sensor and represented one of the cheapest among the available pressure sensing mats.

A *moisture sensor* consisting of a mattress pad permeated with thin wires and connected to a microcontroller and a *temperature sensor* situated next to the pressure mat were used to monitor the micro-climate of the skin, e.g. as an indicator to detect incontinence.

### 2.1.2. Sitting position in favorite seat

For movement detection in a chair a *Wii Balance Board* (Nintendo Co. Ltd., Kyoto, Japan) was used. The Wii Balance Board represented a plate with four scales (one in each corner) which were read out separately. With this information the center of gravity was calculated and its variation over time was recorded. In the test set-up the scale was positioned on a solid chair (*Figure 1 left*).

### 2.1.3. During activities of daily living

As for repositioning detection, a *mobile acceleration sensor* was embedded in a belt to record activities during the day, such as getting up from the bed or seat, walking, going to the bath etc.

## 2.2. Feasibility test

A prototypical system has been developed and its feasibility was evaluated by four volunteers (2 f, 24-26y) during office work and during sleep. Tests lasted in between 15 minutes and 7,5 hours. Testing by volunteers younger than the target group was decided to be sufficient for initial feasibility testing.

## 2.3. Questionnaire for decubitus experts

In the course of a stakeholder workshop, which took place in Salzburg in October 2011, the sensors described above were presented to 9 experts (2 dermatologists, 4 professional care givers, 1 wound manager, and 2 technicians with experience in nursing). A questionnaire was created to elicit how the mentioned methods will change the nursing workflow, change the way of daily living of the user and help the health care provider determine a change in the decubitus ulcer risk or detect an already developed decubitus ulcer. *Table 1* summarizes the questions contained in the questionnaire.

**Table 1: Questionnaire as used at the stakeholder workshop.** Each question was asked for each sensor type and the stakeholders answered with numbers in between 0 = "I don't agree" and 5 = "I fully agree"

<i>Nr.</i>	<i>Headword</i>	<i>Statement</i>
1	Assistance	The sensor is well-suited to assist a person in daily living
2	Handling	The sensor is easy to handle
3	Useful	The collected data are useful for home care management
4	Representation	The implemented data representation is satisfying
5	Robustness	The sensor will withstand stresses in everyday use
6	Effort	The sensor will increase care costs
7	Detection	The sensor is able to detect decubitus ulcer development
8	Prevention	The sensor improves decubitus ulcer prevention
9	Treatment	The sensor is able to support decubitus ulcer treatment
10	New sensor	I have never heard of such a tool
11	Innovation	I have never thought of this kind of use for this sensor

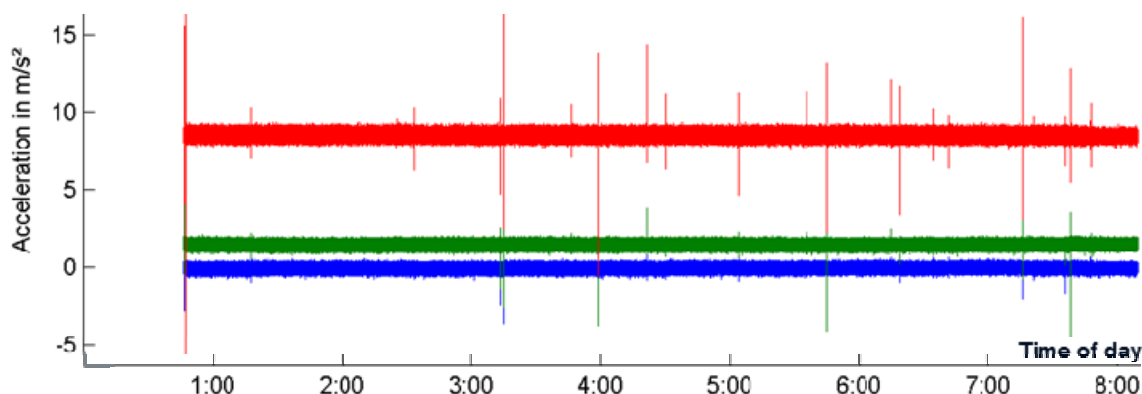
## 3. Results

### 3.1. Feasibility study

#### 3.1.1. Lying position in bed

During the feasibility study, several problems concerning the sensors were identified:

- *Pressure sensor mat:* When using the sensor near the body its rigidity reduces the sleeping comfort and there is a risk in damaging the sensor. If it's used under a layer like a mattress or a mattress pad the collected data are inaccurate.
- *Moisture sensor and temperature sensor* could conveniently be included in the measurement scenario. Sleep was not disturbed by the devices. Temperature varied in between 33°C and 36°C, depending on the position of the body. No analyses concerning sensor accuracy have been done so far. The moisture sensor was destroyed during the nightly tests since due to the participant's body movements a short circuit appeared in between the wires.
- *Static accelerometer underneath the mattress:* *Figure 2* shows acceleration data as recorded during one night. Qualitative comparison of these accelerometer data with reference video recordings showed high correlation in between movements visible at the video and spikes within the signal – giving some evidence that these data might be useful for repositioning-detection during sleep. The sensor did not cause any inconvenience for the user.



**Figure 2: Raw data example for the static acceleration sensor monitoring the sleep behavior**  
(upper graph: z axis; middle graph: y axis; lower graph: x axis)

### 3.1. 2. Measurement during sitting

Using the Wii Balance Board, body weight position of the center of gravity could successfully be monitored. Even slight movements could be detected.

### 3.1. 3. Measurement during activities of daily living

Using the Actibelt for this kind of measurement was quite comfortable although the original belt for the fixation was not available and, therefore, the accelerometer was mounted at a regular belt.

## 3. 2. Sensor capabilities

Sensors analyzed proved to be able to monitor different decubitus risk factors:

- Pressure at a certain skin region (pressure sensor mat)
- Mobility and micro movements, quantification of mobility during sleep (mobile and static accelerometer, pressure sensor mat, Wii balance board)
- Activity (mobile accelerometer)
- Micro climate (moisture sensor, temperature sensor)

## 3. 3. Questionnaire for decubitus experts

*Table 2* summarizes the results of the questionnaire. Answers were scored as 0 (I do not agree) to 5 (I fully agree). Median, upper and lower interquartile range (25% to 75%) are shown.

## 4. Discussion

The present paper describes the results of a feasibility test and a questionnaire completed by 9 professionals concerning several types of sensors for decubitus prevention and therapy optimization. Due to the small number of subjects the results of the questionnaire are not representative. Feasibility was tested with a small number of young subjects only. No data concerning accuracy, sensitivity, specificity etc. are available so far. As a next step, based on our results, a decubitus monitoring system will be developed which will be evaluated in the course of a field study in a much more realistic scenario. Nevertheless, the preliminary results already give us some guidance in designing this field trial.

Nutrition and drinking behavior are also very important decubitus risk factors. They have deliberately not been considered in the present project since they are examined in the course of another project [10] – nutrition monitoring in a lifestyle management system is investigated. Results of that project are intended to be adapted and included in the final decubitus management system during the field study.

**Tabelle 2: Opinion of the experts concerning the questionnaire.** The answers reach from 0 = “I don’t agree” to 5 = “I fully agree”. Colored areas represent interquartile range from 25% to 75%; the red marker represents the median.

STMT Nr.	Pressure sensor mat	Mobile acceleration sensor	Static acceleration sensor	Temperature	Moisture	Scales
1 Assistance						
2 Handling						
3 Usefulness						
4 Data Presentation						
5 Robustness						
6 Effort						
7 Detection						
8 Prevention						
9 Treatment						
10 New sensor						
11 Innovation						

We found that the two most promising sensors are the two acceleration sensors used statically in bed and mobile in the belt, respectively, since they are cheap and provide useful data. Also a good variety of algorithms for that kind of signals already exist. Up to now, the mobile accelerator cannot transmit data in real-time, but real-time capability is subject of ongoing work.

Due to their low price and the variety of available products, micro climate sensors such as temperature or moisture sensors may be useful as well. However, several problems concerning their applicability in a real life scenario need to be solved (sterilization, power supply, patient contact, regulatory aspects, etc.).

During the experiments the pressure sensor mat turned out to provide limited benefits in home monitoring scenarios, since the measurement of the pressure distribution in bed is a) hard to implement and b) expensive (approximately 10 times the price of other sensors). As can be seen from the outcome of the questionnaire (Table 2), even though the experts expect only

limited sensitivity of the sensors in decubitus early detection (*Table 2 Statement 7*), and limited use of the sensors for treatment of existing ulcer (*Table 2 Statement 9*), most of the experts agreed, that data collected from such sensors (especially acceleration based sensors) can be useful for home care management. since they are suspected to monitor activity and mobility – two of the most important factors for decubitus risk assessment.

## 5. Acknowledgements

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