Cross–cultural acceptability of interventions that may increase control at the end of life in people with dementia

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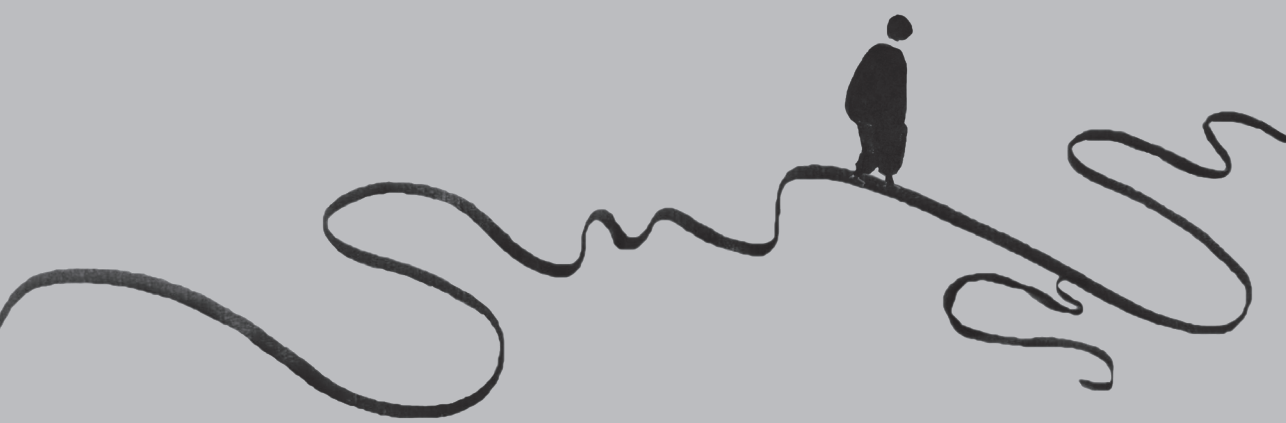

Noninvasive monitoring technologies to identify discomfort and distressing symptoms in persons with limited communication at the end of life: A scoping review

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Abstract

Background: Discomfort and distressing symptoms are common at the end of life, while people in this stage are often no longer able to express themselves. Technologies may aid clinicians in detecting and treating these symptoms to improve end-of-life care. This review provides an overview of noninvasive monitoring technologies that may be applied to persons with limited communication at the end of life to identify discomfort.

Methods: A systematic search was performed in nine databases, and experts were consulted. Manuscripts were included if they were written in English, Dutch, German, French, Japanese or Chinese, if the monitoring technology measured discomfort or distressing symptoms, was noninvasive, could be continuously administered for 4 hours and was potentially applicable for bed-ridden people. The screening was performed by two researchers independently. Information about the technology, its clinimetrics (validity, reliability, sensitivity, specificity, responsiveness), acceptability, and feasibility were extracted.

Results: Of the 3,414 identified manuscripts, 229 met the eligibility criteria. A variety of monitoring technologies were identified, including actigraphy, brain activity monitoring, electrocardiography, electrodermal activity monitoring, surface electromyography, incontinence sensors, multimodal systems, and noncontact monitoring systems. The main indicators of discomfort monitored by these technologies were sleep, level of consciousness, risk of pressure ulcers, urinary incontinence, agitation, and pain. For the end-of-life phase, brain activity monitors could be helpful and acceptable to monitor the level of consciousness during palliative sedation. However, no manuscripts have reported on the clinimetrics, feasibility, and acceptability of the other technologies for the end-of-life phase.

Conclusions: Noninvasive monitoring technologies are available to measure common symptoms at the end of life. Future research should evaluate the quality of evidence provided by existing studies and investigate the feasibility, acceptability, and usefulness of these technologies in the end-of-life setting.

Guidelines for studies on healthcare technologies should be better implemented and further developed.

Introduction

Discomfort and distressing symptoms in the last two weeks of life are common. (1-6) Based on reviews of people dying with dementia and cancer, many may experience pain (12%-96%), difficulty breathing (8%-83%), fatigue (22%-93%), incontinence (32%-65%), and anxiety (6%-57%). (2, 6) Studies in intensive care units (ICU), hospital general wards, nursing homes, and among the general public reported similar percentages of these symptoms, with the addition of agitation (12% - 71%), (4, 5, 7) sleep disturbances (18% - 56%), (7, 8) nausea (9% - 59%), (4, 8) delirium (75% - 91%), (3, 9, 10) fever (16% - 61%), and (4, 8) pressure sores (16% - 42%). (3, 4) To relieve health-related suffering at the end of life, which is a core task of palliative care, (11) it is essential to identify these distressing symptoms in a timely manner.

However, timely recognition of discomfort and distressing symptoms may be challenging at the end of life. People who are dying may have difficulties expressing their discomfort due to fatigue, sedation, delirium, cognitive impairment, loss of consciousness or communication problems such as aphasia. (6, 12, 13) In current practice, the identification of discomfort and distressing symptoms relies upon observations of professional caregivers and family. (14) However, observation may not be the most accurate measurement of discomfort (15, 16), and continuous observation of discomfort by staff is not feasible, (17) so alternatives are needed. Implementing noninvasive monitoring technologies may aid in the early detection of discomfort and distressing symptoms at the end of life.

Various technologies that monitor distressing symptoms have already been developed, for example, actigraphy to monitor agitation, (19) systems to detect stress based on facial expressions,(20) and various devices to monitor nociception. (21) In addition to directly monitoring distressing symptoms, monitoring technologies such as the bispectral index (BIS) may also help detect discomfort by monitoring the level of consciousness of people who receive palliative sedation due to refractory distress. (22-24) However, knowledge

about which technologies may be useful in the end-of-life context is lacking because most of these technologies have not been specifically developed for this setting, and previous reviews mainly focused on populations that were still mobile (25-28) and could self-report their symptoms. (29, 30)

This review aims to generate an overview of noninvasive monitoring technologies that may be applied to people with limited communication at the end of life to identify discomfort and distressing symptoms. The results may provide a useful reference for clinicians who consider implementing technology in the end-of-life care of people with limited communication. Our main research question was: What noninvasive monitoring technologies are described in the literature that may be useful in identifying discomfort and distressing symptoms in persons with limited communication at the end of life? The subquestions were as follows: 1) What noninvasive monitoring technologies are available or under development that identify discomfort and distressing symptoms which can occur at the end of life, 2) What is known about the clinimetric properties (e.g., validity, reliability, sensitivity, specificity, responsiveness) of these technologies, and 3) What is known about the acceptability and feasibility of these technologies for persons with limited communication?

Methods

A scoping review was chosen since the goal was to provide a broad view of technologies to identify discomfort and distressing symptoms in persons with limited communication at the end of life rather than to generate clinical guidance for a specific technology. (31, 32) This review was conducted in accordance with the Joanna Briggs Institute methodology for scoping reviews and reporting followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping review (PRISMA-ScR) checklist. (33) The protocol for this scoping review was registered in the Open Science Framework (24 February 2022, Registration number: E6M8B). (34)

Search Methods

Manuscripts were included if they described a noninvasive technology that may be used to continuously (i.e., for at least 4 hours) monitor discomfort

and distressing symptoms in people at the end of life. The technology needed to serve as a direct or indirect measure of discomfort, potentially distressing symptoms, or level of consciousness. In studies with human subjects, participants must be at least 18 years old. The manuscript had to be written in English, Dutch, German, French, Japanese, or Chinese. The manuscript was excluded if the monitoring technology fully relied on self-report, was applied in the study to all participants during an invasive procedure only, was applied in infants or children only, it was an animal study or a review, no information on the technology was provided, or if the full text article was not available. Technologies that were judged by the screening researchers as not applicable to bed-ridden persons were also excluded, for example technologies that require input from a GPS tracker or step counts. People with limited communication at the end of life include persons who have difficulties expressing their discomfort due to fatigue, sedation, cognitive impairment, or communication problems (e.g. aphasia).(12) This is operationalized in the search by also including populations in similar situations as people with limited communication at the end of life, where they are bedridden and noncommunicative, for example people with dementia, aphasia, profound intellectual disability, and people in critical care. Noninvasive is defined in this review as no penetration in the body of the person with solid material, while weak electric currents, weak laser lights or ultrasounds may be used. (18)On 16 March 2021, a search was conducted in PubMed, MEDLINE (OVID), Embase (OVID), Emcare (OVID), Web of Science, Cochrane Library, PsycINFO (EbscoHOST), Academic Search Premier (EbscoHOST), and Google Scholar. On 23 February 2023, an update search was performed in the same databases. In cooperation with a trained librarian (JWS), a detailed search strategy was composed. The query consisted of the combination of the following three concepts:

- death, end-of-life phase, terminal care, elderly, critical care, profound disability, bedridden persons, nonmobile persons, dementia, aphasia
- activity monitors, activity trackers
- (dis-)comfort, distress, agitation, pain assessment, pressure ulcers, quality of life, breathing difficulty, anxiety, sleep disturbances, fatigue, nausea, delirium, fever, incontinence, sedation depth

For these concepts, all relevant keyword variations were used, not only keyword variations in the controlled vocabularies of the various databases but also the free text word variations of these concepts. The search strategy was optimized for all consulted databases, taking into account the differences in the various controlled vocabularies as well as the differences in database-specific technical variations (e.g., the use of quotation marks). The complete search strategy is available as an appendix to the registered protocol. (34) After data extraction, six experts were consulted for additional, potentially missing information about new technologies under development. The experts were from the Interdem Taskforce Assistive Technologies and professional network of the authors.

Source of evidence screening and selection

After removing duplicates, each title and abstract was independently screened by two researchers. Full-text articles were retrieved after the first screening round, and each article was assessed for eligibility by two independent reviewers. Consensus meetings were held to discuss discrepancies.

Data extraction

Data extraction was performed using a form developed and pilot-tested by the research team. Extracted data were checked by a second researcher, and regular consensus meetings were held to discuss doubts and discrepancies. The following data were extracted from the included articles: author, year of publication, language, country, participants, type of technology, model and brand, and indicators of discomfort monitored by the technology. For studies that described the development of a technology, the aim of the study and the details of the technology (e.g., sensors, parameters) were extracted. For studies mentioning clinimetrics, acceptability, or feasibility of the technology, this information was also extracted, together with the study design and other instruments that were used in the study. The extracted data were then synthesized into tables and narrative summaries for each type of technology. An often used threshold for acceptable clinimetrics is at least 70% for sensitivity, specificity, and area under the curve (AUC). (35, 36)

Results

The flow chart of the screening process is presented in Figure 1. A total of 229 manuscripts were included. Table 1 shows that most manuscripts were written in English by researchers in North America or Europe. The number of publications on this topic has shown exponential growth over the past 3 decades. Based on the bodily functions and signals that are measured, the monitoring technologies included in this review were grouped into 8 categories, of which actigraphy and multimodal systems such as polysomnography accounted for more than half of the included manuscripts. Table 2 lists the identified monitoring technologies for each indicator of discomfort. Multiple technologies measured sleep, pain, and agitation. No technologies monitored difficulty breathing, nausea, or fever. Many monitored sleep disordered breathing, but not the subjective experience of difficulty breathing.

We briefly illustrate each type of monitoring technology and the main findings from the studies regarding the clinimetrics (see Supplement I), acceptability, and feasibility (see Supplement II). Supplement III summarizes manuscripts that did not report clinimetrics, acceptability, or feasibility, mainly because the technology was implemented as standard measurement instruments. The models and brands of the technologies, the settings and the study populations are listed in Supplements I-III.

Actigraphy

Actigraphy uses accelerometers to measure movements with a band or pads that are attached to the wrist, ankle, neck, mattress, (37) or integrated in a garment. (38) The data are usually processed by built-in software. Several researchers developed their own algorithms with machine learning to analyze the construct of interest, for example, agitation, body position or sleep/wake states, using movement data. (38-40) In approximately half of the manuscripts, actigraphy was used as a standard measurement for sleep. When discrepancies were observed between actigraphy results and observations or self-reports, authors of recent manuscripts favored actigraphy as a standard, objective measurement. (41, 42)

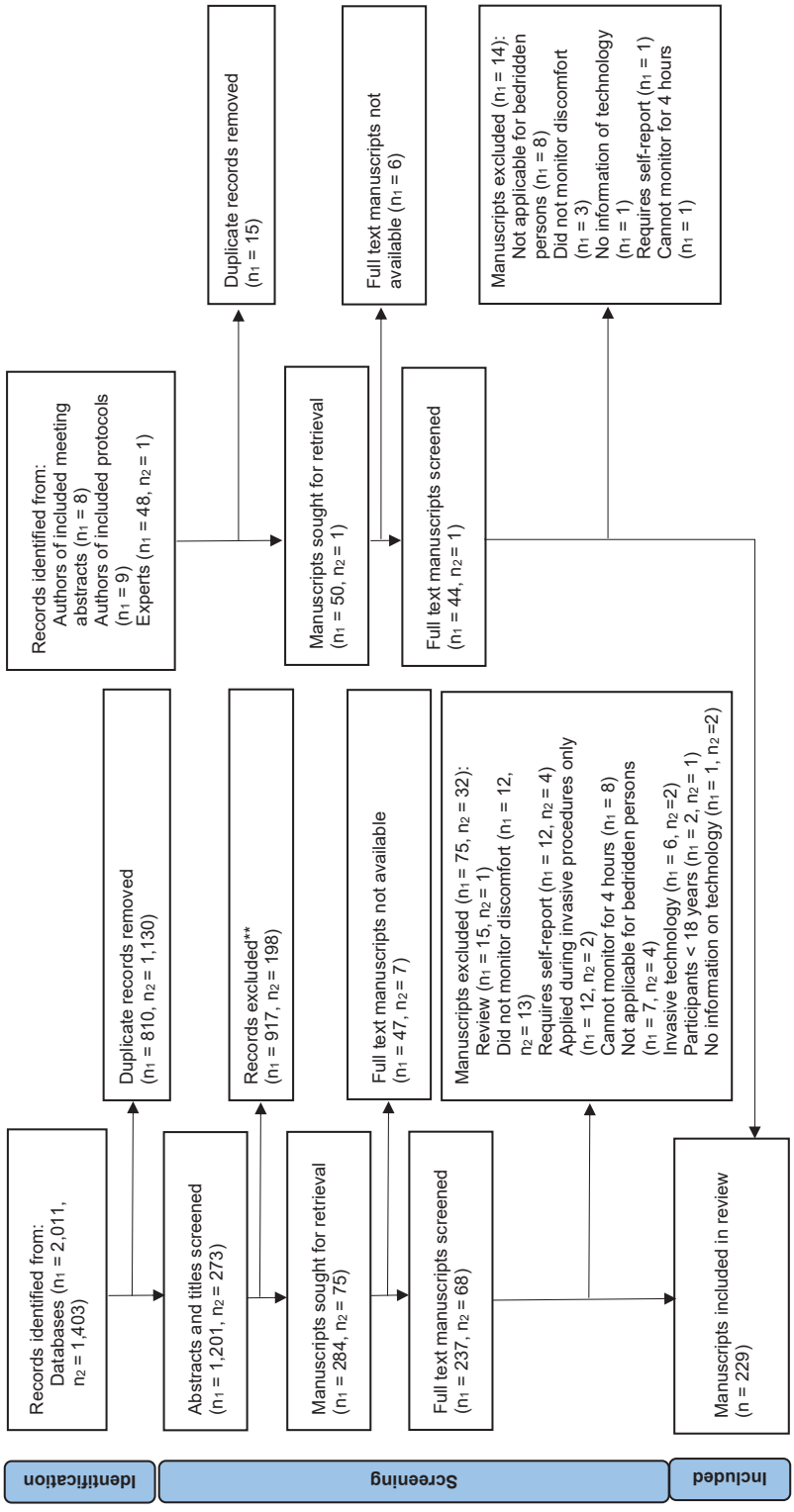

Figure. 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram.

Note: n_1 = first search in 2021, n_2 = update search in 2023

Table 1 Typology of the included manuscripts

	Number of manuscripts	Percentage
Languages		
English	220	96%
Chinese	4	2%
Dutch	2	1%
Japanese	2	1%
German	1	<1%
Countries		
United States of America	63	28%
Canada	13	6%
Netherlands	12	5%
Italy	11	5%
France	9	4%
Germany	9	4%
Japan	9	4%
Australia	8	3%
United Kingdom	8	3%
Belgium	7	3%
China	7	3%
South Korea	7	3%
Finland	5	2%
Spain	5	2%
Switzerland	3	1%
Brazil	2	1%
Denmark	2	1%
India	2	1%
Greece	2	1%
Mexico	2	1%
New Zealand	2	1%
Portugal	2	1%
Singapore	2	1%
Other countries	8	3%
Two or more countries[a]	29	13%

Table 1 Typology of the included manuscripts (continued)

	Number of manuscripts	Percentage
Year of publication		
1991-1995	4	2%
1996-2000	13	6%
2001-2005	15	7%
2006-2010	31	14%
2011-2015	41	18%
2016-2020	79	25%
2021-2023[b]	46	20%
Monitoring technologies		
Actigraphy	57	25%
Brain activity monitors	25	11%
Bispectral Index (BIS)	15	
Other Electroencephalography (EEG)-based[c, d]	9	
Sedation monitor (concept)	1	
Electrocardiography (ECG)[c]	12	5%
Electrodermal activity (EDA) monitor	8	3%
Surface electromyogram (sEMG)	2	1%
Incontinence sensors	11	5%
Multi-modal systems[e]	96	42%
Polysomnography (PSG)	75	
With environmental sensors	6	
Other multi-modal systems	14	
Non-contact monitoring systems[f]	21	9%
Pressure mats	9	
Video/facial expression analysis	4	
Infrared	2	
Radar	3	
Multiple sensors	3	

Table 1 Typology of the included manuscripts (continued)

	Number of manuscripts	Percentage
Aim of studies[g]		
No technology-related aims (the technology is applied as standard measurement)	91	39%
Development of the technology	38	17%
Feasibility/pilot study of the technology	51	22%
Validation of the technology	65	28%

Note: Total number of included manuscripts = 229.
[a]The main countries involved were the USA (11 manuscripts), China (8 manuscripts), Finland (6 manuscripts), and the Netherlands (6 manuscripts). The countries involved in specific manuscripts can be found in etables 1-3 in the supplements.
[b]Manuscripts published before March 13, 2023 were included.
[c]3 manuscripts used both Electroencephalography and Electrocardiography to monitor people under sedation.
[d]Other electroencephalogram-based technologies refer to traditional EEGs and other technologies which use EEG electrodes.
[e]Multi-modal systems use a combination of different technologies within one integrated system or algorithm.
[f]Non-contact monitoring systems use sensors that do not have direct contact with the person being monitored.
[g]16 articles had multiple aims.

Table 2 Summary of monitoring technologies per indicator of discomfort

Indicator of discomfort	Types of monitoring technology[a]
Vital signs	Multi-modal systems[b] – other multi-model systems Non-contact monitoring systems[c] – radar
Arrhythmia	Electrocardiography (ECG)
Consciousness/depth of sedation	Actigraphy Brain activity monitors - bispectral index scale (BIS) Brain activity monitors – other electroencephalogram (EEG)-based technologies
Sleep, including sleep disordered breathing	Actigraphy Brain activity monitors - BIS Brain activity monitors – other EEG-based technologies ECG Multi-modal systems[b] – PSG Multi-modal systems[b] – with environmental sensors Multi-modal systems[b] – other multi-model systems Non-contact monitoring systems[c] – pressure mats Non-contact monitoring systems[c] – infrared Non-contact monitoring systems[c] – radar Non-contact monitoring systems[c] – multiple sensors
(Risk of) pressure ulcers	Actigraphy Non-contact monitoring systems[c] - pressure mats
Urinary incontinence	Incontinence sensors Multi-modal systems[b] – with environmental sensors
Pain	Brain activity monitors - BIS Brain activity monitors – other EEG-based technologies ECG Electrodermal activity (EDA) monitor Surface electromyogram (sEMG) Multi-modal systems[b] – other multi-model systems Non-contact monitoring systems[c] – video/facial expression analysis
Agitation	Actigraphy Multi-modal systems[b] – with environmental sensors Multi-modal systems[b] – other multi-model systems Non-contact monitoring systems[c] – video/facial expression analysis Non-contact monitoring systems[c] – multiple sensors
Anxiety	ECG Multi-modal systems[b] – with environmental sensors Multi-modal systems[b] – other multi-model systems

Table 2 Summary of monitoring technologies per indicator of discomfort (continued)

Indicator of discomfort	Types of monitoring technology[a]
Stress	Actigraphy Brain activity monitors – other EEG-based technologies ECG EDA monitor Multi-modal systems[b] – other multi-model systems
Significant moments	Multi-modal systems[b] – other multi-model systems
Emotions	Non-contact monitoring systems[c] – video/facial expression analysis
(Motor subtypes of) delirium	Actigraphy Brain activity monitors - BIS Brain activity monitors – other EEG-based technologies Multi-modal systems[b] – with environmental sensors Multi-modal systems[b] – other multi-model systems
Thermal comfort	Non-contact monitoring systems[c] – infrared
Mental fatigue	Multi-modal systems[b] – other multi-model systems

Note: [a]Cateogries and subcategories (if applicable) of technologies are presented.
[b]Multi-modal systems use a combination of different technologies within one integrated system or algorithm.
[c]Non-contact monitoring systems use sensors that do not have direct contact with the person being monitored.

Clinimetrics

Although there were some mixed results for different models of actigraphy, showing that it could underestimate sleep time in the ICU (40) or overestimate this in people with Huntington's or Alzheimer's Disease compared to polysomnography, (43, 44) and it could be less accurate when the participants had sleep disordered breathing, (45) in general, it demonstrated acceptable sensitivity and specificity of identifying sleep-wake states in ICU patients (40), older adults in nursing homes (46) and people with dementia. (47)

Actigraphy measurement could recognize agitated behaviors (39), distinguish between groups of higher and lower agitation in people with dementia in long-term care facilities or hospital, (48, 49) and was correlated with observational scales for agitation such as the Cohen-Mansfield Agitation Inventory in people with dementia. (49, 50) The correlation with the Neuropsychiatric Inventory was found only in some articles (49) but not in others (48). Among nursing home residents with dementia, actigraphy

demonstrated acceptable discriminant validity compared with the Mini-Mental State Examination, which measured a different concept. (51) Most of these studies were performed in people with dementia who were still mobile. In one study among ICU patients, who may be more similar to people at the end of life, actigraphic data also correlated with observations of agitation using the Richmond Agitation Sedation Scale. (52)

The devices had good precision and sensitivity when used to monitor the risk of pressure ulcers in the hospital (38) and could reduce the chances of patients developing pressure ulcers in the ICU. (53) Actigraphy could recognize stress in nursing home residents with acceptable accuracy but lower precision and sensitivity. (54)

In summary, for populations that are similar to people at the end of life, actigraphy has demonstrated good clinimetrics in monitoring sleep, agitation, and risk of pressure ulcers but is not precise in recognizing stress.

Feasibility and acceptability

Actigraphy was feasible for multiday continuous measurement of older adults with intellectual disability (55) and people with dementia. (49) Although community-dwelling older adults found it easy to use, (56) it can be confusing for some people with less cognitive capacity. (57) The battery life could also be improved. (44, 56) No manuscripts reported on the feasibility and acceptability of actigraphy in bed-ridden participants with limited communication.

Brain activity monitors

Electronic activity of the brain can be measured by electroencephalography. It traditionally uses electrodes with gel attached to the head. Portable versions with few electrodes have been developed. (58)

Bispectral Index (BIS)

BIS is a specific type of device that uses EEG signals to measure the depth of sedation. BIS consists of a sticker on the forehead with four EEG electrodes connected to a small monitor that displays a number ranging from 0 to 100. It has been implemented in the ICU and palliative care units. (59, 60)

Clinimetrics

Sedation indices measured by BIS correlated with those measured by standard EEG in the ICU. (61) BIS scores increased during painful procedures in patients with traumatic brain injury in the ICU (62). It also correlated with PSG and could discriminate between deep and light sleep in healthy adults; (63) however, it was only weakly correlated with self-reported sleep quality in ICU patients. (64) BIS monitoring with density spectral was tested for the detection of delirium in hospitals. Its accuracy was comparable to that of the 3-minute Diagnostic Interview for Confusion Assessment Method and was more accurate in people with dementia than in those without cognitive impairment. (65)

In summary, limited research has been performed on the clinimetrics of BIS. The preliminary results showed that it may have the potential to detect pain and delirium, as well as to monitor sedation and sleep. (61-65)

Feasibility and acceptability

In a study in the ICU, BIS was deemed not possible to implement in a quarter of the eligible participants due to delirium, other medical procedures, discomfort of the sensors or displacement of the sensors. (64) One case study suggested that BIS was helpful for nurses to titrate medication for palliative sedation in the ICU and to educate the family. It reassured the family that the patient died comfortably, and they were pleased to see BIS fluctuations when talking to the patient. (66) Thus, BIS is not always feasible, but it can be acceptable and helpful when it is.

Other electroencephalography (EEG)-based technologies

In recent years, EEG sensors have been developed into more user-friendly forms of dry electrodes, (58) a headband (67) or an earplug. (68) In two older studies, EEG was used to objectively measure sleep. (69, 70) Two recent studies used EEG to objectively monitor the depth of sedation. (71, 72)

Clinimetrics

Compared to PSG, EEG-based technologies showed good accuracy in determining sleep stages in healthy adults (68) and could distinguish sleep and

wake in ICU patients. (73) Good AUC was reported for delirium diagnosis in the ICU. (74) Preliminary results showed differences in EEG signals during stress in healthy adults (67) and pain in people with dementia residing in long-term care settings. (58)

Feasibility and acceptability
A portable device to measure sleep was deemed feasible in the ICU. (73) An EEG-based headband was acceptable for long-term care residents with dementia, while properly positioning the device was challenging. (58) No manuscript reported on the acceptability of other EEG-based technologies.

The concept of sedation monitors

Feasibility and acceptability
An interview study showed that family and professional caregivers considered it acceptable to use monitors during palliative sedation as an objective measurement of sedation and pain, which could reassure the family and guide titration. (75)

Electrocardiography (ECG)
ECG is the measurement of the electronic activity of the heart. Traditionally, electrodes are attached to the torso and connected to a monitor. Among the manuscripts included in this review, the number of electrodes varied between 3 and 12, and the devices could be portable. (76, 77) Heart rate data can also be extracted from smart watches. (78) ECG was used as a standard measurement for arrhythmia (79) and stress. (78, 80, 81)

Clinimetrics
Indices derived from ECG signals correlated with self-rated pain among patients taking physical therapy after surgery (76) and sleep apnea among people with suspected sleep disordered breathing measured by standard PSG. (77) When ECG indications of pain differed from observation, a recent study with patients under palliative sedation favored the ECG measurement and concluded that it was more objective. (72) No studies reported the clinimetrics of ECG in people at the end of life.

Feasibility and acceptability

It was feasible to use ECG to monitor stress in the workplace. (82) After surgery, patients were more satisfied with ECG monitoring for atrial fibrillation than observation. (83)

Electrodermal activity (EDA) monitors

By placing electrodes on the skin, electrodermal activity monitors measure the skin conductance, which drops as the sweat glands are activated by the sympathetic nervous system, indicating stress. (84) It is best measured at the palms and feet, where the sweat glands are dense. An older version of the portable EDA monitor included sensors on two fingers and hardware bound to the arm, (84) while newer versions can take the form of a ring (85) or a sock. (86) EDA monitors have been tested with healthy adults and people in the ICU.

Clinimetrics

EDA measurement has been shown to be more sensitive than vital signs and BIS measurements in detecting pain in sedated patients in the ICU. (87) Among healthy volunteers, tt had good sensitivity, specificity and accuracy in detecting stress (86, 88) and could discriminate between stress and cognitive load. (84)

Feasibility and acceptability

EDA sensors integrated into the sock were feasible for most participants in a study with intellectual disabilities. (88) Factors that hindered the implementation were other garments, such as compression socks, and the participants removing the device.

Surface electromyography (sEMG)

Surface electromyography monitors muscle activity by attaching electrodes on the surface of the skin. Sensors of an older version needed to be attached to a monitor, which hanged in a holster at the waist. (89) A new device integrated multiple sensors into one soft mask and used Wi-Fi to transfer data directly

from the sensor nodes to the server. (90) Only two studies on sEMG were identified in this review.

Clinimetrics

sEMG signals at the shoulder did not seem to be different for people experiencing cervical pain from those without pain. (89) However, facial expressions monitored by sEMG were different for neutral and painful faces in the laboratory setting. (90)

Feasibility and acceptability

No manuscripts have reported on the feasibility and acceptability of sEMG.

Incontinence monitors

Incontinence monitors are systems to monitor urinary incontinence events so that caregivers would only need to change the incontinence materials when an event takes place. Sensors measuring moisture or temperature change are attached to or built into incontinent materials. One device integrated the sensors into the fabric of a mat on top of the mattress. (91) The more recent and commercially available sensors are usually disposable. Data can be transmitted wirelessly to a web portal or mobile app.

Clinimetrics

Although there seemed to be high false positive and false negative rates in earlier systems tested in the laboratory and acute care rehabilitation wards for older adults, (92, 93) more recent manuscripts reported favorable results in the laboratory setting. (94) The incontinence monitors could also reduce urine leakage and the use of incontinence materials in nursing homes. (95, 96) However, some of these reports may need to be interpreted with caution since they were published by the manufacturers.

Feasibility and acceptability

The incontinence sensors did not seem to disturb the patients since they reported not feeling the sensors in laboratory tests. (92) An earlier system was challenging to implement due to several technical problems and the

unwillingness of experienced staff to change their routine in rehabilitation wards. (93) A recent pilot study reported positive reactions of family caregivers and staff in nursing homes. They appreciated the fact that the device helped save time and reduced the occasions where the clients were disturbed unnecessarily. (96)

Multimodal systems

Systems combining different sensors that monitor different bodily functions are grouped into the category multimodal systems.

Polysomnography (PSG)

Standard polysomnography uses multiple parameters (EEG, electro-oculogram, EMG, ECG, oxygen saturation, body position, snoring, airflow and breathing measurements) to monitor sleep. (97) It is considered the gold standard for diagnosing disordered breathing during sleep (e.g., obstructive sleep apnea), which is how it was used in most included manuscripts. Traditionally, PSG is administered by a technician at a sleep laboratory, but portable home monitoring systems have been developed, using only some of the sensors to monitor sleep quality or breathing. (98-100) New portable systems can take the form of a headband, (101) a wristband, (102) a collar around the neck, (103) or a ring. (104) PSG has been used in diverse populations, including adults with sleep problems and nursing home residents with dementia.

Clinimetrics

Portable PSG systems were reported to have good reliability, sensitivity and specificity in diagnosing obstructive sleep apnea among outpatients with heart or lung problems compared with standard PSG (98, 103, 105, 106) but may produce false positives when compared with clinician judgment in the post anesthesia care unit (107) or may produce false negatives when compared with traditional PSG among people using positive airway pressure. (108) It was recommended to lower the cutoff score when using portable PSG to detect hypopnea events. (108) Minute ventilation, measuring the tidal volume and respiration rates with only two chest leads, was effective in detecting respiratory depression in the post anesthesia care unit. (100) With the help of machine

learning models, new potable PSG systems have also demonstrated accuracy in measuring sleep stages in healthy adults. (104) In summary, portable PSG systems had good clinimetrics in monitoring sleep disordered breathing and sleep stages.

Feasibility and acceptability

Portable PSG systems may have occasional technical failure (109-111) but were evaluated as easy to use, comfortable, and did not interfere with sleep among healthy adults, those with sleep apnea, and people with bipolar disorder. (111-113)

With environmental sensors

In recent years, environmental sensors to assess light, sound, humidity, and barometric pressure have been combined with actigraphy to monitor agitation and uncover its environmental determinants in people with dementia in their homes or institutions. (114-116) Sometimes cameras (116, 117), door sensors, pressure mats, and EDA sensors (116) were also used in the systems. Other systems monitored anxiety, (118) delirium, (117) sleep, and urinary incontinence (119). In most of the included manuscripts, data from the various sensors were not yet integrated in a system and needed to be synchronized and processed by the researchers. These systems have been tested with people with dementia and older adults in the ICU.

Clinimetrics

Factors associated with agitation or delirium were identified. For people with dementia, environmental factors (i.e., temperature, pressure, and humidity) strongly correlated with agitation annotated by nurses or family caregivers, although the predictors were specific to each participant. (115) Another study indicated that the combination of actigraphy, skin temperature, and EDA data predicted agitation the best for people with dementia. (116) In the ICU, older adults with delirium differed from those without delirium in facial expressions, movements, postures, visitation frequency, environmental light and sound at night. (117)

Feasibility and acceptability

Studies concluded that their systems were feasible for monitoring people with dementia at a rehabilitation institute (116) and critically ill patients in the ICU. (117) The challenges were Wi-Fi connections (114), trouble-shooting for the installation via the phone, (119) and that people with dementia can take off the sensors when agitated. (120)

Other multimodal systems

Several systems combined ECG, respiration monitors, EDA, sEMG, skin temperature, and breath temperature to monitor the activation of the sympathetic nervous system, which was indicative of pain, (121) mental stress, (122) anxiety, (123) agitation, (124) or significant moments (125) in different studies. In most studies, the sensors were implemented separately, but several studies integrated the sensors into a chest belt, (124) a wristband, (126) or a system worn on the fingertip. (125) New algorithms for analyzing the data were proposed. (127) These multimodal systems have mainly been tested in the laboratory with healthy adults (128, 129) but also with older adults with or without dementia. (124, 125)

Clinimetrics

The multimodals systems could produce accurate measurements of physiological signals, such as ECG, photoplethysmography and respiration signals, changes in heart rate, skin temperature, and EDA, similar to conventional instruments in adults and older adults tested in the laboratory setting. (124, 129) Compared with self-report, the systems had an acceptable accuracy in classifying pain into three severity categories in healthy adults in the laboratory, (121) had good clinimetrics in detecting moderate to severe pain among patients in the ICU, but the results were not optimal when the pain was milder. (130) They could detect significant moments, (125) agitation and aggression in people with dementia, (126, 131) and correlated with mental fatigue (132) and stress in healthy adults. (122, 128) One system could indicate anxiety with high precision but low specificity compared to self-report and observation in healthy adults. (123) In summary, multimodal systems had

good clinimetrics in detecting pain and had some preliminary positive results in monitoring agitation and stress.

Feasibility and acceptability
A chest belt integrating EDA, heart rate, and skin temperature measurements was rated by community-dwelling older adults with a score of 2.7 out of 3 for appearance and 2.8 out of 3 for comfortability. (124) In another study with healthy adults in the laboratory, the authors reported EEG signals to be poor when participants moved. (123)

Noncontact monitoring systems

Pressure mats
Pressure mats are mattresses or films with integrated sensors (e.g., piezoelectric sensors(133)) to measure pressure. They do not need to have direct contact with the person since they can be used under a mattress topper or sheet. Pressure mats can be used to measure the body position and movement on the bed, which can be useful for preventing pressure ulcers. (134) Micromovements measured by pressure mats can be used to monitor sleep stages and sleep disordered breathing. (135, 136) Pressure mats have been tested with healthy adults in the laboratory and were implemented as standard measurements in nursing home residents with dementia, people with sleep apnea, and patients in the ICU and intermediate care units.

Clinimetrics
While older models of pressure mats needed the addition of a percutaneous oxygen saturation sensor to accurately detect sleep disordered breathing, (137) a new model was very accurate on its own compared to PSG in the laboratory among outpatients with sleep problems. (133) Clinimetrics of the pressure mats in measuring other indicators of discomfort were not reported in the included manuscripts.

Feasibility and acceptability
A study in 2009 showed that pressure mats were feasible to use in the ICU for 48 hours. (138)

Video/facial expression analysis

Several algorithms have been developed to recognize agitation, emotions, and pain by analyzing videos taken by commercially available cameras. Using remote photoplethysmography (rPPG), some systems can also estimate heart rhythm based on the change in light transmission and reflection of the skin due to changes in blood flow. (139)

Clinimetrics

The systems could detect faces and facial expressions most of the time, even when they were moving, as in simulated videos, (140) or partially covered, as during group activity with people with Mild Cognitive Impairment. (141). They could recognize grimaces in simulated videos and emotions in people with mild cognitive impairment and were moderately to highly correlated with manual scoring of pain based on facial expressions in community-dwelling older adults and nursing home residents with dementia. (139, 142)

Feasibility and acceptability

No manuscripts have reported on the feasibility and acceptability of these systems.

Infrared

Infrared sensors register the infrared waves emitted by warm objects. It can be used to monitor skin temperature and motion, which are further analyzed by researchers to indicate thermal comfort (143) and sleep stages. (144) The sensor can be installed in front of the participants or above their beds. The systems have been tested in healthy adults and nursing home residents.

Clinimetrics

A model to analyze the thermal comfort of nursing home residents was reliable. A lower temperature of the nose indicated feeling cold. (143) Compared to a commercially available bed sensor, the infrared system was able to detect waking states better than other stages of sleep in healthy adults. (144)

Feasibility and acceptability

No manuscripts have reported on the feasibility and acceptability of these systems.

Radar

Radar systems monitor the shape and position of objects by emitting radio frequency waves and receiving reflections. By monitoring the small movements of the chest, radar systems can detect vital signs such as heart rate (145) and respiration rate. (146) Breathing and location can be used to monitor sleep quality. (147) The radar system can be installed on the wall or above the person being monitored. The systems have been tested in healthy adults.

Clinimetrics

Radar systems have demonstrated high accuracy in monitoring respiration rate, (146) heart rate, (145) sleep time, and sleep efficiency (147) in healthy adults.

Feasibility and acceptability

No manuscripts have reported on the feasibility and acceptability of these systems.

Multiple sensors

Only a few studies have experimented with the use of multiple noncontact sensors. Sleep or agitation was monitored using (infrared) cameras, acoustic sensors, and pressure mats in healthy adults, people with COVID-19, community-dwelling older adults, and people with dementia. (148-150)

Clinimetrics

The clinimetrics of systems using multiple noncontact sensors were not yet optimal. Radar and pressure mats overestimated total sleep time and sleep accuracy in the laboratory among community-dwelling older adults. (149) The reliability of the measurements of heart rate and respiration rate of healthy adults and people with dementia differed depending on the setting.

(148) Infrared cameras and a pressure mat complimented each other in their registration of movement of patients with COVID-19. (150)

Feasibility and acceptability

In the study with people with dementia in the emergency department and a geriatric-psychiatric ward, few disruptions occurred during the measurements, and one out of 19 participants with dementia refused to be monitored. (148)

Discussion

A variety of monitoring technologies are available to monitor discomfort and distressing symptoms that can occur at the end of life, including actigraphy, brain activity monitoring, ECG, EDA monitoring, surface EMG, incontinence sensors, multimodal systems, and noncontact monitoring systems. Although there were no validation studies in the end-of-life setting, the clinimetrics of selected technologies, especially actigraphy and portable polysomnography, have been researched and were satisfactory in other settings. Relatively few manuscripts have reported on the feasibility and acceptability of these technologies, and even fewer have been conducted in the end-of-life setting, except for brain activity monitors, which have been reported to be acceptable for palliative sedation. In the other settings, the technologies were deemed feasible most of the time. Challenges for feasibility included positioning of the device, signal quality during movement, problems with Bluetooth or Wi-Fi connections, battery life, and the device being taken off due to agitation.

This review demonstrated the rapid development of monitoring technologies, and we share the expectations of others that user-friendly systems with small, wireless, and noncontact sensors or smart garments will soon be available as minimally invasive options to monitor a wide range of discomfort and distressing symptoms in end-of-life care. (27, 151, 152) Currently, promising research is being conducted on the monitoring of a variety of indicators of discomfort with technology. Specifically, the depth of sedation may be monitored using brain activity monitors; sleep/wake states using actigraphy, brain activity monitors, portable PSG, infrared sensors, and radar; sleep disordered breathing using portable PSG, actigraphy, pressure mats,

and ECG; risk of pressure ulcers using actigraphy; urinary incontinence using incontinence monitors; agitation using actigraphy and multi-modal systems; pain using brain activity monitors, ECG, EDA, multi-modal systems, facial expression analysis; delirium using brain activity monitors, and multimodal systems with environmental sensors; stress using brain activity monitors, EDA, multi-modal systems; fatigue using multi-modal systems; and thermal comfort using infrared sensors. However, we are not yet able to make recommendations for clinical practice due to limited research in this setting. Many studies included in this review contained a small sample, some technologies were only validated by the development team, and previous reviews on specific types of technologies, such as urinary incontinence monitors and BIS, reported very low quality of evidence. (153, 154) The included feasibility studies only focused on technical aspects and employed diverse, often unclear endpoints, which was also the case in a previous review on e-health in geriatric rehabilitation. (155)

More attention is needed to examine the clinimetrics, feasibility, and acceptability of the technologies with solid study designs, a sample to generate enough power for the proposed analyses, and standardized outcome measurements. The Health Technology Assessment (HTA) core model may be a useful tool to guide future studies in systematically evaluating technologies from multiple dimensions. It provides a list of relevant research questions, corresponding outcome measurements and possible sources of information. (156) However, this model primarily guides the synthesis of evidence instead of primary research. For the latter, more detailed instructions would be needed. For example, with the note that the cutoffs for good clinimetrics should not be fixed but depend on the goal of the technology, (157) more information is needed on how to determine these standards. With the accelerated development in the field of healthcare technology, we recommend better implementation of existing evaluation guidelines and further development of the guidelines to directly guide the design of primary studies.

This review has a few limitations and strengths. Many of the included manuscripts were not about the end-of-life setting, and we did not evaluate the quality of the studies. Commercially available technologies without scientific studies were also not systematically searched for. These were beyond the aim of

our scoping review. Since the search terms were in English, manuscripts in other languages without an English title or abstract were not included. Despite these limitations, the authors believe that this review identified most monitoring technologies that were already applied or developed for settings similar to the end of life. We implemented an elaborate search strategy consisting of broad search terms, including manuscripts in multiple languages and gray literature, and conducted an expert consultation to include technologies that are still under development. To the best knowledge of the authors, this is the first review on noninvasive monitoring technologies that may be applied to the end of life, where people are often bed-ridden and have limited communication abilities. Future research is needed to assess the methodological quality of the studies, to identify potentially useful technologies for the end of life, to further develop them and validate them in this setting and to compare different technologies measuring the same symptoms.

Conclusions

This review provides an overview for clinicians, researchers and technology developers of noninvasive technologies that can potentially be used to monitor discomfort and distressing symptoms in persons with limited communication at the end of life. A variety of technologies are available to monitor symptoms such as sleep, level of consciousness, risk of pressure ulcers, urinary incontinence, agitation, and pain. Clinimetrics and feasibility in non-end-of-life settings were promising, while acceptability studies were scarce. Future research should evaluate the usefulness, acceptability and feasibility of the identified technologies in end-of-life care, further develop the technologies and validate them in this setting. Guidelines for studies on healthcare technologies should also be developed.

Declarations

Ethics approval and consent to participate

Not applicable. This study did not involve human participants. No ethics approval was needed according to the Dutch Medical Research Involving Human Subjects Act.

Consent for publication
Not applicable.

Availability of data and materials
Data are available upon reasonable request to the corresponding author.

Competing interests
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Authors' contributions

HS, JTS, and XJ conceptualized the review. JWS performed the literature search. HS contacted the experts. XJ and HS were involved in the screening and data extraction. XJ drafted the manuscript. HS, JTS, JWS, and WA revised the manuscript. All authors read and approved the final manuscript.

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Supplements of "Noninvasive monitoring technologies to identify discomfort and distressing symptoms in persons with limited communication at the end of life: A scoping review"

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Actigraphy				
Alam	2019	USA	Pebble watch (Pebble Technology, Corp., Taiwan), Pixie app	Agitation
Bankole	2012	USA	TEMPO 3.1 (developed by University of Virginia)	Agitation
Chikhaoui	2016	Canada	Shimmer3 GSR (Shimmer, Dublin, Ireland)	Agitation and aggression
Grap	2011	USA	Basic Motionlogger (Ambulatory Monitoring Inc, Ardsley, NY)	Agitation

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To predict agitation of people with dementia using multiple-instance learning models.	Quantitative cross-sectional study with 10 older adults with mild to severe dementia living at home. Participants wore the Pebble watch for 30 days. Agitation events were marked by family caregivers.	Accuracy: 76% - 87%. F-score: 0.69-0.73. Area under the receiver-operating characteristic curves (AUC): 0.78-0.92, indicating significantly higher true positive rates compared with single instance learning models.
To validate the Body Sensor Network (BSN) in measuring agitation.	Quantitative cross-sectional study with 6 older adults with dementia in nursing homes. Each participant wore the devices in the morning, afternoon and evening for 3 hours per session. The Cohen-Mansfield Agitation Inventory (CMAI), the Aggressive Behavior Scale (ABS) and the Mini-Mental State Examination (MMSE) were assessed at each session.	Convergent validity (BSN vs. CMAI and ABS): acceptable for morning sessions, less for afternoon and evening sessions. Discriminant validity (BSN vs. MMSE): strong. Secondary validation (Teager scores calculated from the BSN measurements during agitation vs. pre- and post-agitation): strong support
To compare Microsoft Kinect sensor and actigraphy in detecting aggressive and agitation behaviors, and to develop and validate corresponding algorisms.	Quantitative cross-sectional study with 10 adults. They performed aggressive and agitated behaviors wearing the device. All actions were performed 5 times.*	The algorism developed by the researchers using actigraphic data could recognize aggressive and agitated behaviors (F-Measure = 0.85 – 0.94)
To differentiate behavioral states common in the critically ill population.	Quantitative cross-sectional study with 30 adult healthy volunteers in the laboratory. Participants wore the device on the wrist and ankle and simulated states of calmness, restlessness, and agitation for 10 minutes.	The average movement is significantly different among the three states and between wrist and ankle measurements.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Knuff	2019	USA	wGT3x+ activity monitors (Actigraph, LLC, Pensacola, FL)	Agitation
Mahlberg	2007	Germany	Actiwatch (Cambridge Neurotechnology Ltd, Cambridge, UK)	Agitation
Nagels	2006	Belgium	Basic motion-logger (Ambulatory monitoring, New York, USA)	Agitation
Raj	2014	USA	Actiwatch 2 (Phillips Respironics, Andover, MA)	Agitation/ sedation
Valembois	2015	France	Vivago (Vivago Oy, Espoo, Finland)	Aberrant motor behavior

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To evaluate the feasibility and validity of actigraphy as a measurement of agitation in dementia.	Quantitative cross-sectional study. 20 older adults with dementia living in long-term care facilities wore the wristband continuously for a minimum of 24 hours and maximum of 7 days.	Significant difference in motor activity between the low- and high-agitation groups. Most actigraphic data, except for night time measurements, significantly correlated with the CMAI (r = 0.74 - 0.77, p < 0.001) and the Neuropsychiatric Inventory (NPI, r = 0.47 - 0.56, p = 0.01 – 0.04)
To evaluate the actigraphy in measuring day-night rhythm disturbances and agitated behavior.	Randomized controlled trial with 24 older adults with dementia and agitated behavior in a geriatric psychiatry unit. 14 received medication, 10 received placebo. Control group: 10 young and 10 older healthy subjects. The device was worn for at least two weeks. The NPI was scored before and after the treatment period.	The actigraphic agitation is significantly lower in the treatment group compared to placebo and healthy control groups. No correlation between actigraphy and NPI.
To assess the association between the actigraphic measure of agitation and a validated scale.	Quantitative cross-sectional study with 110 older adults recently diagnosed with dementia. The device was worn for 48 hours. CMAI was rated by nurses during staff briefings. *	Significant association between actigraphic measures and CMAI (F = 126.75, p < 0.001).
To determine the usefulness of actigraphy to measure sedation/agitation in the ICU.	Quantitative cross-sectional study with 86 adults in the ICU of a tertiary care center. Actigraphy was worn for 60 or 70 minutes. The Richmond Agitation Sedation Scale (RASS) was scored every 10 minutes.	Actigraphic data associated with sedation/agitation level as assessed by RASS.
To evaluate the usefulness of actigraphy to measure disorders in motor behavior.	Quantitative cross-sectional study with 183 older adults, of which 126 had dementia admitted to an intermediate care unit in the hospital. The device was worn for 10 days. Apathy, aberrant motor behavior, agitation and anxiety were evaluated with the NPI.	Motor activity measured by the actigraphy was lower in patients with apathy (p = 0.008 - 0.05, depending on time of the day), and was greater in those with aberrant motor behavior (p = 0.003 - 0.04 depending on time of the day). No correlation with agitation and anxiety was observed.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Anusha	2021	India	Not reported	Risk of pressure ulcers and agitation
Cicceri	2020	Italy	developed by the researchers	Risk of pressure ulcers
Minteer	2020	USA	PUMP1 and PUMP2, developed by the authors	Risk of pressure ulcers
Pickham	2018	USA	Leaf Patient Monitoring System (Leaf Healthcare, Inc., San Francisco, CA)	Risk of pressure ulcers
Alessi	1999	USA	Wrist activity monitor (Augmentech Inc., Pittsburgh, PA)	Sleep
Brooks	1993	USA	Actigraph (Ambulatory Monitoring, Inc., Ardsley, NY)	Sleep

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To validate the use of accelerometer on the mattress to monitor movement on the bed.	Quantitative non-randomized experimental study in the laboratory. The number of participants was not reported. Accelerometers were placed on the mattress and the participants performed several actions on it, including sitting up, rolling over, and slightly moving the limbs.	The algorithm categorized the activity with a 100% accuracy for a single participant. 92% accuracy when the system was trained with the accelerometer on more locations on the bed. When the system was trained with seven different beds, the accuracy on an eighth bed was 82%.
To design and implement a wearable sensor system to prevent pressure ulcers with deep learning.	Quantitative cross-sectional study. 6 adult patients wore a hospital gown with integrated sensors in the medicine department. The body position was monitored. The proposed deep learning method was compared with two machine learning models.	The precision was between 99% and 100%. The sensitivity was between 93% and 100%.
To test the accuracy of PUMP1 (garment sensors) and PUMP2 (bed sensors) in detecting body repositioning.	Quantitative cross-sectional study with 10 immobile patients in the hospital. They were monitored by both devices for 10 ± 2 hours. The data was compared to body repositioning events identified from a video footage.	Both PUMP1 and PUMP2 captured repositioning movement with 85% reliability. False positives: 2 events for PUMP1, 1 for PUMP2. False negatives: 11 events for PUMP1, 7 for PUMP2.
To assess the effectiveness of Leaf on preventing pressure ulcers.	Randomized controlled trial. Among 1,312 patients in ICU, 659 wore a Leaf monitor which helps providers know whether the patient has turned recently.	Patients with Leaf had significantly less chance of pressure ulcers (OR=0.33, 95% CI [0.12, 0.90]). The staff complied to the turning scheme of these patients more (67% vs. control=51%, $p < 0.005$).
To evaluate the effect of daytime physical activity and night time environment on sleep and agitation.	Quantitative cross-sectional study with 29 older adults with incontinence living in nursing homes. The monitor was worn on the wrist for 5 nights during the night.	Wrist activity monitors had a sensitivity of 95.5% and a specificity of 82.0% monitoring sleep-wake status, compared to behavioral observations.
To evaluate the sensitivity of the actigraph to detect insomnia treatment effects.	Quantitative cross-sectional study with 9 older adults with insomnia, without dementia. They wore the actigraph for one night at home.	Change in total sleep time measured by actigraphy correlates with the sleep log ($r = 0.69$, $p = 0.04$). No correlations between the two measurements in changes of time to sleep onset, wake after sleep onset and sleep efficiency.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Delaney	2021	Australia	Actiwatch Spectrum Plus (Phillips Respironics Inc, Murrysville, PA)	Sleep
van Someren	2007	Netherlands	Actiwatch and Sleep 5 software (Cambridge Neurotechnology, Cambridge, UK)	Sleep
Gibson	2019	New Zealand	Actiwatch-2. Software: Actiware 2015, Version 6 (Mini Mitter, Respironics)	Sleep
Maskevich	2017	Australia	Actiwatch Spectrum Pro (Philips Respironics, Murrysville, PA), Jawbone UP2 and Fitbit One	Sleep
Stavitsky	2010	USA	Actiwatch AW-64 (Mini Mitter, Sunriver, Orlando)	Sleep

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To evaluate the feasibility and reliability of actigraphy to monitor sleep compared with polysomnography (PSG).	Quantitative cross-sectional study. 80 adult patents in the ICU were monitored for 24 hours.	Agreement in identifying sleep and wake states compared with PSG (69.4%; K = 0.386, $p < 0.05$), with a moderate level of sensitivity (65.5%) and specificity (76.1%). Amongst non-ventilated patients: specificity 83.7%; sensitivity 56.7%. Moderate correlation with PSG reported total sleep time ($r = 0.359$, $p < 0.05$, underestimated) and wakefulness ($r = 0.371$, $p < 0.05$, overestimated).
To investigate the reliability of actigraphy sleep monitoring depending on the recording duration.	Quantitative cross-sectional study with 10 adults with insomnia living at home and 12 older adults with dementia at group-care facilities. Participants wore the device continuously for 20 days.	Reliability: 59% - 97%, increasing with the recording duration. The authors recommended at least 7 days of monitoring for reliable data.
To evaluate the reliability of actigraphy to score sleep patterns.	Quantitative cross-sectional study with 15 older adults with dementia and their family caregivers. Both groups wore the device at home for one week and used an event marker to register relevant events such as bedtime.	People with dementia: Sleep: sensitivity: 87%, specificity: 80% Wake: sensitivity 77%, specificity: 61% Family caregiver: Sleep: sensitivity: 90%, specificity: 93% Wake: sensitivity 92%, specificity: 57%
To validate the monitoring devices for sleep measurement.	Quantitative cross-sectional study with 7 adult Huntington's gene carriers. They wore the devices overnight while undergoing a PSG at the laboratory.	All the actigraphy devices are less accurate than PSG and overestimate sleep time by more than an hour and sleep efficiency by 15%. The researchers concluded that they are sufficient to estimate general sleep-wake patterns.
To compare self-report with actigraphic data on sleep quality	Quantitative cross-sectional study with 30 community-dwelling adults with Parkinson's Disease and 14 normal control participants. The device was worn 24 hours a day for 7 days at home. Sleep diaries were kept for the same period.	Actigraphic data of sleep quality correlated with self-report in the Parkinson group but not in the control group.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
McClure	2020	USA	BioStamp nPoint (MC10, Inc., Lexington, MA, USA)	Sleep – disordered breathing
Mehra	2008	USA	Sleepwatch-O (Ambulatory Monitoring, Inc., Ardsley, NY)	Sleep
Mokhtaran	2022	Italy	Fitbit Charge 3 (Fitbit Inc., San Francisco, California)	Sleep

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To develop an analysis system to detect breathing patterns.	Quantitative non-randomized experimental study with 100 healthy adults in the laboratory. Participants simulated central sleep apnea, coughing, obstructive sleep apnea, sighing, and yawning, while being monitored with wireless sensors on the chest and abdomen.	F1 score was 92% for normal breathing, 87% for central sleep apnea, 72% for coughing, 51% for obstructive sleep apnea, 57% for sighing, and 63% for yawning.
To examine the association between actigraphic measures and PSG-determined sleep-disordered breathing (SDB) and/or periodic limb movement disorder (PLMD).	Quantitative cross-sectional study with 455 older women living in the community. The device was worn for three 24-hour periods. The PSG was administered for one night at their home by staff.	Poor sleep efficiency measured by wrist actigraphy was associated with SDB (OR = 2.43, 95% CI: 1.43-4.14) and PLMD (OR = 2.36, 95% CI: 1.34-4.15). Reduced sleep duration was also associated with SDB (OR = 3.18, 95% CI: 1.51-6.68) and PLMD (OR = 3.77, 95% CI: 1.78-7.95).
To explore the use of Fitbit to monitor sleep quality.	Quantitative cross-sectional study with 26 adults with obstructive sleep apnea. Participants were observed by standard PSG and Fitbit simultaneously for three nights in the hospital (baseline, before treatment, after treatment).	Fitbit correlated with PSG in the estimation of total sleep time (r = 0.8-0.9, p < 0.001), sleep efficiency (r = 0.8-0.9, p < 0.001), the percentage of four sleep stages (r = 0.5-0.9, p = 0.001-0.03). Sensitivity: 90%-93% Specificity: 56%-59% Accuracy: 59%-61% The measurement of Fitbit improved after the treatment for obstructive sleep apnea. The authors concluded that it is less able to measure abnormal sleep patterns.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Svetnik	2021	USA	Garmin Vivosmart	Sleep
Kikhia	2016	Sweden, Greece, Netherlands	Philips sensor DTI-2 (Philips Research, Eindhoven, The Netherlands)	Stress
Brain activity monitors - Bispectural Index (BIS)				
Arbour	2015	Canada	BIS VISTA bilateral BIS (Aspect Medical Systems, Newton, MA)	Pain
Arbour	2015	USA	BIS A-2000 XP (Aspect Medical Systems, Inc. Norwood, MA)	Sedation
Dahaba	2011	Australia, China	BIS-Vista version 1.4 (Aspect Medical Systems, Newton, MA)	Sleep

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To investigate the usefulness of a wearable in measuring treatment effects of insomnia in people with dementia.	Randomized experimental study with 285 older adults with Alzheimer's disease and insomnia. During insomnia treatment of four weeks, participants were instructed to wear the device all the nights at home. Three overnight measurements with standard PSG were performed in the laboratory at screening, baseline, and at the end of the treatment.	Compared to PSG, the device overestimated total sleep time (e.g., placebo baseline = 412 min for watch and 265 min for PSG) and underestimated the change in total sleep time before and after treatment.
To validate the sensor system in recognizing stress.	Quantitative cross-sectional study with 6 older adults living in nursing homes. Participants wore the device when they are awake for 2 months. Observation notes were made by the staff.	With sampling rate of an hour and stress level threshold of 3: precision: 19%, recall: 48%, accuracy: 76%
To validate BIS in pain detection of people with traumatic brain injury.	Quantitative cross-sectional study with 25 critically ill adults in the ICU with acute traumatic brain injury and altered level of consciousness. They were monitored 1 min before, during, and 15 min after turning and non-invasive blood pressure measurements. Pain behaviors were observed.	BIS measurements increased during turning (nociceptive) but not during non-invasive blood pressure measurements (non-nociceptive). Only BIS of the right hemisphere correlates with pain behavior and only for people with left-sided traumatic brain injury ($r = 0.99$, $p < 0.001$).
To evaluate the predictive value of BIS in determining level of burst suppression during drug-induced coma, compared with EEG.	Quantitative prospective, observational cohort study with 4 adults in the ICU under drug-induced coma. 33 hours of monitoring was performed in total.	BIS value, BIS suppression ratio, and BIS burst counts had medium to strong correlations with EEG burst counts.
To assess whether BIS can quantify sleep depth.	Quantitative cross-sectional study with 10 healthy sleep-deprived adults. Participants were monitored during one sleep.*	BIS value showed a temporal decline corresponding to sleep stages. The lowest score was about 40.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Giménez	2017	Spain	BIS A-2000 XP Monitor (Aspect Medical Systems, Inc. Norwood, MA) with Quatro Sensors	Sleep
Pedrao	2020	Brazil	BIS™ Vista Monitoring System (Covidien LLC, Mansfield, United States)	Sleep
Luo	2021	USA	BIS-VISTA with density spectral array (Aspect Medical Systems, Inc. Norwood, MA)	Delirium
Brain activity monitors – other electroencephalography (EEG)-based technologies				
Haenggi	2004	Switzerland	EMMA (Department of Clinical Neurophysiology, Kuopio University Hospital, Kuopio, Finland)	Sedation
Lee	2022	South Korea	Amp GS5001 (SOSO H&C, Kyungpook University, Daegu, Korea)	Delirium

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To assess the feasibility and reliability of BIS for sleep monitoring.	Quantitative cross-sectional study with 12 healthy adults. Sleep was measured with PSG and BIS both at baseline and after sleep deprivation at the laboratory.	BIS value was highly correlated with the hypnogram and could discriminate between deep and light sleep.
To test the feasibility of using BIS to evaluate sleep in critically ill patients.	Quantitative cross-sectional study with 29 critically ill patients on ICU. BIS monitoring was performed for a whole night (12 hours). The participants filled in the Richards-Campbell Sleep Questionnaire (RCSQ) the next morning.	Total sleep volume, total sleep time, and continuous sleep volume measured by BIS were weakly correlated with the RCSQ depth of sleep domain score, overall sleep quality domain score, and total score. Total volume, total time, and continuous volume were moderately correlated with the occurrence of awakenings domain score of RCSQ.
To evaluate the use of BIS to identify delirium.	Quantitative cross-sectional study with 40 adults with delirium and 83 adults without delirium. Participants were monitored for 20 minutes at the hospital that they were recruited from.	BIS with density spectral array was similar to the 3-minute Diagnostic Interview for Confusion Assessment Method in identifying delirium. Visual inspection of the density spectral array was not associated with delirium.
To explore the use of long latency evoked potential (EP) in measuring depth of sedation.	Quantitative cross-sectional study with 10 healthy adults under sedation. EP, which is the brain activity 100ms after a standard auditory stimuli, was measured in different stages of sedation based on the Ramsay Sedation Score.	The brain activity 100ms after a standard auditory stimuli (EP) decreased as the depth of sedation increased.
To test a compact EEG device as diagnostic tool for delirium by analysing differences in EEG signals in patients with and without delirium both before and after spinal surgery.	Quantitative cross-sectional study with 37 older adults who had spinal surgery. EEG measurements were performed before, one week after and three months after the surgery in the hospital or outpatient clinic. Delirium was diagnosed by a psychiatrist. Patients with delirium were compared to those without.	Compared to the group without delirium, people with delirium showed more increase in the H-beta waves (19%, $p = 0.003$), gamma (19%, $p = 0.006$) waves, the tension index (8%, $p = 0.011$), and more decrease in the theta waves (–23%, $p = 0.016$) one week after the surgery.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Urdanibia-Centelles	2021	Denmark	NicoletOne™ Version 5.71 (Nicolet, Natus Medical Incorporated)	Delirium
Nakamura	2020	UK	Not reported	Sleep - stages
Vacas	2016	USA	SedLine Brain Function Monitor (Masimo Corp., Irvine, California)	Sleep - stages
Pu	2021	Australia	MUSE 2 (InteraXon Inc., Toronto ON, Canada)	Pain
Roh	2012	South Korea	developed by the authors	Stress

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To compare visual analysis and automatic analysis of continuous EEG in diagnosing delirium in septic patients.	Quantitative cross-sectional study with 102 older adults with sepsis in the ICU. Delirium was evaluated six times per day with the Confusion Assessment Method in the ICU.	Delirium was associated with several parameters of the continuous EEG. The AUC is slightly higher for visual analysis (88%) than automatic analysis (74%). The authors concluded that the automatic analysis can complement the visual analysis in delirium diagnosis.
To investigate the validity of in-ear EEG monitoring of sleep.	Quantitative cross-sectional study with 22 adult participants. Sleep was monitored by both the in-ear EEG and PSG for a whole night in their homes.	Accuracy in five sleep stage classification: 74% compared to PSG (k = 0.61).
To validate the device in laboratory setting and to test the feasibility of its use in the ICU.	Quantitative cross-sectional study with three adult outpatients in the laboratory and 23 ICU patients. The system was validated against PSG in the laboratory, where participants were monitored for one night. The mean recording time in the ICU was 19.1 hours.	The system could distinguish sleep from wakefulness and the transition between sleep stages, although the latter is less accurate.
To assess the feasibility of a headband EEG to monitor pain in long-term care residents with dementia.	Quantitative cross-sectional study with 4 older adults with dementia and chronic pain in a long-term care facility. Each participant was monitored for 10 minutes. The Pain Assessment in Advanced Dementia (PAINAD) scale was administered before and after the measurement.	The detrended fluctuation analysis of EEG signals fluctuated in participants experiencing pain, but not in the participant without pain.
To develop a portable system to measure stress and mental state.	Quantitative non-randomized experimental study with 10 healthy adults in the laboratory. For 10 minutes, participants wore a headband and did three stressful tasks with rest in between.	Compared to the resting state, the largest lyapunov exponent value (the physiological marker for stress and mental state) decreased to 0.734 and the standard deviation of heart rate variability (HRV), also derived from EEG data, increased to 73ms during stressful tasks.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Electrocardiography (ECG)				
De jonckheere	2014	France	Developed by the authors	Pain
Grasso	2018	USA	Mortara H12 (Mortara Instrument, Milwaukee, Wis, USA)	Sleep – apnea
Li	2022	China	myBeat-WHS-1 (Union Tool Co., Ltd., Japan)	Stress
Miranda	2017	USA	HxM Bluetooth chest belt (Zephyr)	Anxiety
Electrodermal activity (EDA) monitors				
Aslanidis	2018	Greece	Med Storm Pain Monitor System (MED Storm® Innovation AS, Oslo, Norway)	Pain

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To present an ambulant device which monitors pain with HRV analysis.	Quantitative cross-sectional study with 12 adults having physical therapy after surgery. Pain was scored with the Visual Analogue Scale (VAS) during the first and second therapy session.	The HRV was correlated with the VAS (r = - 0.50, p = 0.002). HRV was lower in the VAS > 30 subgroup than in the VAS ≤ 30 one (p=0.002).
To evaluate the portable ECG system in its detection of sleep disordered breathing compared to standard PSG.	Quantitative prospective cohort study with 30 adult patients with the suspicion of sleep disordered breathing. The ECG monitor and PSG were worn simultaneously overnight in the laboratory.	ECG parameters correlated with PSG parameter of apnea (r = 0.77 - 0.81). The ECG system was accurate and sensitive but relatively imprecise in detecting the severity of the apnea.
To use a wearable ECG monitor to measure workplace stress in nurses.	Quantitative cross-sectional study with 17 healthy nurses during one work day at the hospital. Participants wore the device and filled in the Chinese Nurses Stress Response Scale (CNSRS) after work.	The HRV parameters were correlated with time, work and rest phases, postures, and subscales of the CNSRS (physiological reaction, irritability, social phobia, and fatigue).
To present a system to detect internal states of anxiety during caregiving tasks.	Quantitative non-randomized experimental study with 10 healthy adults in the laboratory. During 30 min sessions, participants had a relaxation stage and performed cognitive therapy tasks with a simulated person with dementia. Video recordings of each 30s of the session were coded by the participants for the presence of anxiety.	Using inter beat interval as classification feature, the accuracy of the model was 73%.
To monitor electrodermal activity changes during pain.	Quantitative cohort study with 25 adult patients under sedation in the ICU. Participants were monitored for four hours. During a 10-second pain stimulus, electrical dermal activity changes in the palm were measured and compared to observation, BIS, cardiovascular and respiratory measurements.	EDA monitoring was more sensitive to pain compared to cardiovascular, respiratory and BIS measurements.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
De Vries	2022	Netherlands	Sentisock (Mentech, Eindhoven, the Netherlands)	Stress
Leborgne	2023	Netherlands	Developed by the author	Stress
Setz	2010	Switzerland	Emotion Board (developed by the authors)	Stress
Surface electromyogram (sEMG)				
Carlson	1996	USA	BioPrompt 3000 (Physical Health Devices)	Pain

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To validate the sock-integrated EDA sensor in monitoring stress.	Quantitative non-randomized experimental study with 28 healthy adults in the laboratory. Measurements were taken at baseline, during mental stress and physical stress in a 75 min session. Sock-integrated EDA data was compared to wrist EDA measured by Empatica E4 and self-report of the participants using the Self-Assessment-Manikin scale.	Sentisock: F1-score: 0.84, sensitivity: 81%, specificity: 86%, balanced accuracy: 83% Empatica E4: F1-score: 0.83, sensitivity: 81% , specificity: 84%, balanced accuracy: 82%
To develop a sock garment to detect stress in people with intellectual disabilities.	Quantitative non-randomized experimental study. Sixty adults with severe intellectual disabilities in long-term care facilities tried on the garment. It was not clear whether the experiment was conducted with other participants in the laboratory, where the sock sensor was compared with Empatica E4 (Empatica Inc, Boston, USA) during sitting, walking, standing, and doing math.	The signal quality was good for neural and stable positions, but more noise was present during movement. The sock sensors recognized EDC changes in stressful situations with an accuracy of 85%.
To investigate accuracy of EDA in discriminating stress from cognitive load.	Quantitative randomized controlled trial with 33 healthy adults in the laboratory. Participants went through a 2-hour stress session with social and cognitive stress, as well as a 2-hour cognitive load session.	Maximum accuracy of discriminating stress from cognitive load: 83%
To determine whether there is difference in ambulatory sEMG signals in the upper trapezius muscle for people with and without pain.	Quantitative case-control study with 10 adult participants with cervical pain and 10 adult participants without pain. Participants were monitored by the ambulatory device in their normal life for three consecutive days during daytime.	No difference in sEMG signals was found between the group with pain and the group without.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Yang	2018	China, Finland, Austria, France, and Sweden	Developed by the authors	Pain
Incontinence sensors				
Boerakker	2022	Netherlands	Abena Nova (Abena Group, Denmark), WeSense (Seneca Sense Technologies, Canada)	Incontinence
Cusick	2003	UK	Developed by the authors	Incontinence
Ouslander	1998	USA	Not reported	Incontinence
Not reported (This manuscript is the device website)	2022	Denmark	TENA Identifi Sensor Wear (Essity Hygiene and Health AB, Denmark)	Incontinence
Tekcin	2022	Tekcin	Developed by the authors	Incontinence

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To present a facial expression monitoring system for automatic pain assessment.	Quantitative non-randomized experimental study with one healthy adult in the laboratory. The participant mimicked painful expressions, which were compared to frowning and neutral expressions. The duration of the measurement was not reported.	Muscle activities in the face during painful expressions and neutral expressions could be differentiated.
To investigate the use of intelligent incontinence material in nursing homes.	Mixed-methods pilot study with 25 older adults in nursing homes with urinary incontinence. Abena Nova and WeSense were compared to the regular incontinence material.	Abena Nova reduced the use of incontinence materials by 34%, WeSense reduced it by 16%.
To develop and test an incontinence sensor.	Quantitative cross-sectional study with volunteers. No details on the participants were reported. A total of 71 events were simulated, of which 20 simulated incontinence events.*	5 false-positive events, 2 false negatives events. The authors concluded that the system met the technological requirements.
To investigate the relationship between incontinence and sleep disruption.	Quantitative cross-sectional study with 73 older adults in nursing homes. Night-time incontinence was recorded both by a device and by staff.	The records of the device (wet/dry status) coincide with the records made by staff.
To report customer results.	Quantitative cross-sectional study with 324 adults. Further details not reported.*	Leakage was reduced by 66%, Time saved (per client per year): 86.7 hours, incontinence material changes reduced by 22%, toilet visits reduced by 6%, urine loss reduced by 14%, rubbish reduced by 36%. Clients can use materials with less absorption capacities.
To develop a humidity sensor to measure urinary incontinence.	Quantitative non-randomized experimental study in the laboratory. No participants were involved. The sensor was tested in a humidity chamber and water was dripped on it to measure the change in resistance.	In the humidity chamber, the resistance decreased as the humidity increased. Change in resistance of the sensor was measurable with 0.1ml of water dripped on it.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Toba	1996	Japan	Not reported	Incontinence
Van der Hurk	1998	Netherlands	Developed by the authors	Incontinence
Wang	2009	USA	Developed by the authors	Incontinence
Multi-modal systems - polysomnography (PSG)				
Koley	2013	India	Alice LE (Philips Respironics)	Sleep - apnea

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To evaluate the effects of wearing a thin-film urinary drainage sensor in the incontinence material on urinary quality of life and nursing work hours.	Mixed-method cross-sectional study with 4 older adults with urinary incontinence in long-term care facility. Incontinence materials were changed regularly (4 times a day) and as needed (as soon as possible after sensor detection) for 4 days each. The wetting times were compared. Working time was recorded and asked through a caregiver questionnaire.	Incontinence material wetting time was reduced from 1 hour 21 ± 11 minutes with the regular change to 9±1 minutes with the sensor. Total working time increased from 52 minutes to 90 minutes because of the change of the sensors.
To evaluate the applicability and validity of the Urine Leakage Recording Device.	Quantitative non-randomized experimental study with 5 older adults. Participants were instructed to turn and void during the experiment. 3 human assessors scored the data generated from the device to determine incontinence events. This was compared with the self-report of participants. The setting was probably laboratory, but not stated in the manuscript.	Interscorer reliability: 0.92. True positive events: 5.3 out of 10, False positive events: 9.3. The authors concluded that the device was not useful.
To validate the system to record urinary leakage in women doing intense physical activities.	Quantitative non-randomized experimental study with one adult woman. The sensitivity of the sensor was first tested in the laboratory with a burette dropping urine onto it. Then the participant wore the device during a 25-minute jog, releasing urine at the end.	The lab test suggested that the sensor could always detect a leakage of more than 0.5ml. The jogging experiment demonstrated that the sensitivity of the sensor was not influenced by sweat disturbance.
To develop an algorism to detect apnea or hypopnea events using airflow data from PSG.	Quantitative cross-sectional study with 36 adult participants with a variety of diseases. 28 participants received one recording session for a night. 8 participants had repeated test. Recordings were conducted at a Center for sleep disorders. The algorism results were compared with full PSG.	Accuracies of event detection: hypopnea: 92%, apnea: 95%, and combined 97%.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Supe	2017	USA	Capnostream 20 Bedside Monitors (Covidien, Needham, Massachusetts, USA)	Hypopnea
Koskinen	2021	Finland	Collare (Nukute Ltd, Finland)	Sleep - apnea
Makinen	2022	Finland	Collare (Nukute Ltd, Finland)	Sleep - apnea
Rotariu	2013	Romania	Developed by the authors	Sleep - apnea
Jungquist	2019	USA	ExSpiron 1Xi Minute Ventilation Monitor (Respiratory Motion)	Hypopnea
Acebo	1991	USA	Home monitoring system, brand not reported	Sleep -apnea

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To implement continuous monitoring to identify alarm conditions of respiratory distress.	Quantitative cross-sectional study with 25 adult patients with obstructive sleep apnea on a post anesthesia care unit. The time of the monitoring ranged from a few hours to several days.	True positive rate: 57%, compared with clinician judgement. True negative rate: 100%.
To validate the Nukute Collare in diagnosing sleep apnea.	Mixed-methods cross-sectional study with 71 adults with or without sleep apnea. Collare measurement was compared with standard PSG.*	91% sensitivity, 97% specificity, 91% positive predictive value, 97% negative predictive value, and 0.9-1.0 balanced accuracy.
To validate the Nukute Collare in screening sleep apnea.	Quantitative cross-sectional study with 41 adults. Collare measurement was compared with standard PSG.*	Accuracy of diagnosing sleep apnea automatically: 88% - 95%, accuracy of automatically classifying apnea severity: 76%.
To develop a system to monitor sleep apnea using wireless sensor nodes.	Quantitative cross-sectional study with 3 patients in the hospital. The patients simulated apnea events to test the system.	Simulated apnea events were detected by the system and alarms were triggered.
To compare Minute ventilation, capnography, and pulse oximetry in identifying respiratory depression and to develop and algorism for early detection.	Quantitative cross-sectional study with 48 adult participants in the post anesthesia care unit. The participants were the devices during their whole stay in the unit.	Minute ventilation and capnography were both effective in detecting respiratory depression, while pulse oximetry was not. A machine learning model could predict an opioid-induced respiratory depression event 10 min in advance with 80% accuracy.
To investigate the reliability and validity of measures of sleep and apnea using the home sleep monitoring system.	Quantitative cross-sectional study with 14 adults (Study 1) and 8 older adults living in nursing facilities (study 2). Study 1: One night, together with standard PSG in the Sleep Disorders Center. Study 2: Four weekly 24-h recordings were made on successive weeks at the participants' homes.	Study 1: Significant agreement was found for each sleep measure and the apnea index between the home monitoring system and standard PSG. Study 2: There were significant individual differences, and the measurement is reliable for each sleep measure and the number of apneas.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Buyse	2023	Belgium	Hospital PSG, model and brand not reported	Sleep -apnea
Ravishankar	2014	India and USA	ICU bedside monitors, brand not reported	Hypopnea
Li	2021	China, USA	Nox-T3 (Nox Medical, Reykjavik, Iceland)	Sleep – disordered breathing
To	2021	China	Nox-T3 (Nox Medical, Reykjavik, Iceland)	Sleep - apnea
Xu	2017	China	Nox-T3 (Nox Medical, Reykjavik, Iceland)	Sleep - apnea

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To investigate whether lowering the cut-off scores for type 3 portable monitoring would benefit the diagnosis and treatment of obstructive sleep apnea.	Quantitative cross-sectional study with a database of 865 adults who started continuous positive airway pressure. Apnea-hypopnea index (AHI) of both the in-hospital PSG and portable monitoring were simulated from the existing data. Calculations of negative tests were performed with different Portable monitoring- respiratory event index (PM-REI) cut-of scores.	Portable monitoring underestimated the hypopnea events by 15 events/ hour, compared to in-hospital PSG. Lowering the PM-REI cut-off score for portable monitoring reduced the negative test rate from 57% to 34%.
To develop an algorithm to detect respiratory distress.	Quantitative cross-sectional study using ICU patient records. Preliminary analysis: 50 records with acute respiratory failure and 48 records without. Extended analysis: 157 records with no acute respiratory distress.	True Positive Rate: 88-92%; False Positive Rate: 6-12%. The algorithm would be able to detect respiratory instability when existing systems would not.
To evaluate the portable monitor in diagnosing sleep disordered breathing.	Quantitative cross-sectional study with 84 adults with chronic heart failure. Participants were monitored at home for one night. Another measurement was conducted with both PSG and the portable monitor in the laboratory.	Diagnosing sleep disordered breathing at ≥ 5 AHI events per hour: 87% sensitivity, 77% specificity. Detecting of Cheyne-Stokes respiration: 95% sensitivity, 91% specificity, compared to PSG.
To test the reliability of Nox-T3 in diagnosing sleep apnea in people with major diseases.	Quantitative cross-sectional study with 74 adults with psychiatric illnesses, stroke, ischemic heart diseases, chronic kidney diseases or other major diseases, suspected of having obstructive sleep apnea. Participants were simultaneously monitored by standard PSG and Nox-T3 overnight for at least four hours in the hospital.	Nox-T3 respiratory event index was significantly lower than the PSG AHI. Nox-T3 can reliably diagnose obstructive sleep apnea, but can underestimated the severity.
To validate the portable monitor in the diagnosis of sleep apnea.	Quantitative cross-sectional study with 80 adults. Participants were monitored at home for one night. Another measurement was conducted with both PSG and the portable monitor in the laboratory.	At ≥ 5 AHI events per hour: 95% sensitivity, 69% specificity. At ≥ 15 AHI events per hour: 93% sensitivity, 85% specificity, compared to standard PSG

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Wang	2015	China	Oximeter (Konica Minolta, Japan)	Sleep - apnea
Chang	2019	China, USA	PM, Nox-T3 (Nox Medical, Reykjavik, Iceland)	Sleep -apnea
Alvarez	2017	Spain	Reslink™ module (ResMed Inc. SanDiego, CA)	Sleep - hypopnea
Ganglberger	2022	USA	Respiration belt: AirGo (brand not reported), standard PSG: Natus System (brand not reported)	Sleep -apnea
Tedeschi	2013	Italy	Somtè PSG (Compumedics, Abbotsford, Victoria, Australia)	Sleep - apnea

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To evaluate the use of oximeter in diagnosing obstructive sleep apnea.	Quantitative cross-sectional study with 244 patients with obstructive sleep apnea hypopnea syndrome in the hospital. Participants were monitored overnight with both an oximeter and a full PSG.	Oximeter demonstrated a sensitivity of 68% and a specificity of 73% in diagnosing obstructive sleep apnea hypopnea syndrome, compared with PSG.
To evaluate a portable monitor in diagnosing obstructive sleep apnea.	Quantitative cross-sectional study with 90 adults with chronic obstructive pulmonary disease. Participants were monitored at home for one night. Another measurement was conducted with both PSG and the portable monitor in the laboratory.	95% sensitivity and 78% specificity in diagnosing obstructive sleep apnea compared to a standard PSG.
To evaluate the reliability of the built-in software compared to ventilatory Polygraphy.	Quantitative cross-sectional study with 26 adults with stable obesity hypoventilation syndrome under nocturnal non-invasive ventilation. Participants were monitored at home for a full night.	The built-in analysis is reproducible and reliable to assess quality of non-invasive ventilation when compared with Polygraphy ($r^2 = 0.71$, $p < 0.001$), but is less consistent than manual scoring.
To develop an algorithm to detect sleep-related respiratory abnormalities measured by a wearable device.	Quantitative cross-sectional study with 404 overweight adults. Participants were monitored with both devices for at least one night in the laboratory.	The AHI from the PSG, labeled by experts, correlated with those predicted by models using data from the respiration belt and oxygen saturation ($r = 0.96$), respiration-only ($r = 0.78$), and saturation only ($r = 0.93$). The AUCs were 94%, 86%, and 82% for the receiver operating characteristic curves, and 48%, 32%, and 51% for the precision-recall curves.
Compare home unattended portable monitoring and automatic continuous positive airway pressure titration to an attended in-laboratory program.	Randomized controlled trial with 131 adults with high suspicion of obstructive sleep apnea. 66 participants received home monitoring and 65 received in-laboratory standard PSG.	Reliability: 97% for the home portable monitoring. 2 out of 66 recordings had low quality.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Polese	2013	Brazil	Stardust II® (Philips Respironics, Inc., Murrysville, PA, USA)	Sleep - apnea
Lazazzera	2022	France	UpNEA (developed by the authors)	Sleep - apnea
Kang	2012	China	WatchPAT (Itamar Medical, Israel)	Sleep - apnea
Lachenmeier	2022	Germany	SleepU (Wellue Health, Shenzhen Viatom Technology Co., Ltd., Shenzhen, China)	Sleep - dyspnea

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To evaluate the effectiveness of a type 3 portable monitor.	Quantitative cross-sectional study with 43 older participants. Sleep was assessed for two nights, one at home with the portable monitor (Stardust), the other at the hospital with Stardust and standard PSG.	No difference in the apnea–hypopnea index values between the portable and standard PSG. Good correlation between standard PSG and portable monitor (r=0.67) and the combination (r=0.84). The area under the receiver operator curve indicated good sensitivity and a positive predictive value for AHI with cutoffs of 5, 15, and 30 and good specificity and negative predictive value for AHI values above 15.
To present a system aimed to predict respiratory and cardiovascular disorders. UpNEA was part of the whole system.	Quantitative cross-sectional study with 96 adults with apnea/hypopnea syndrome in a hospital. Participants wore the glove-life device for a night. It was not reported with which device the results were compared. One healthy adult also wore the device for four nights.*	Within the patient group, the device detected central and obstructive apnea or hypopnea with a sensitivity of 73% - 87%, a specificity of 55% - 68%, and an accuracy of 65% - 72%. The data from the healthy adult showed a specificity of the device in detecting apnea or hypopnea was 96%.
To validate WatchPAT in diagnosing obstructive sleep apnea hypopnea syndrome.	Quantitative cross-sectional study with 35 adults complaining of snoring. Participants were monitored with Watch PAT and standard PSG simultaneously in the laboratory.	The apnea hypopnea index registered by WatchPAT correlated with PSG (r = 0.96, p < 0.001). Sensitivity = 92%, specificity = 100%. Accuracy is lower in patients with a high BMI.
To present a case where wearable oximetry device with haptic feedback was used to treat sleep disturbances in a person with lung cancer.	Case report with a home-dwelling older adult with lung cancer and sleep disturbances due to drops of oxygen saturation during sleep. The device vibrated when the oxygen saturation dropped. The recording of one whole night was reported.	The detection of decrease in oxygen saturation was reliable. By waking the patient with the vibration, events of oxygen saturation drop were reduced, so did sleep disturbances and anxiety symptoms associated with them.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Arnal	2020	France	Dreem Headband (developed by the authors)	Sleep - stages
Cooray	2021	UK	Signals from standard PSG (model and brand not reported)	Sleep – stages and rapid-eye-movement sleep behavioral disorder (RBD)
Hirnoven	1997	Finland	8-channel 9000-11 recorder (Oxford Medilog)	Sleep - stages
Altini	2021	Finland	Oura Ring, Gen2M (Oura Health Ltd, Oulu, Finland)	Sleep - stages

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To validate the Dreem Headband, containing EEG, pulse oximetry and accelerometer in determining sleep stages.	Quantitative cross-sectional study with 25 healthy adults at a sleep center. The sleep stages determined by Dreem Headband was compared with standard PSG.	The error of Dreem Headband compared with standard PSG: EEG signals: 10% - 16% Heart rate: 1.2 ± 0.5 beats per minute Breathing frequency: 0.3 ± 0.2 cycles per minute Respiration rate variability: 3.2 ± 0.6%
To develop a RBD screening tool with minimal sensors.	Quantitative cross-sectional study with 50 adults with RBD and 50 healthy controls. Participants were monitored for one night with standard PSG for one night. The results of the algorithm were compared to results based an earlier algorithm using EEG, electrooculogram (EOG), and EMG.	The optimal model combined EOG and EMG and could classify sleep stages with 0.57 ± 0.19 kappa (3 stage) and detect RBD detection with an accuracy of 90% (sensitivity 88% and specificity 92%).
To develop an algorism to score drowsiness and sleep onset.	Quantitative cross-sectional study. An algorism was developed based on 30 min recording at sleep onset of seven healthy adult participants and a 6-hour daytime recording, including drowsy and sleep episodes, of seven adult patients with obstructive sleep apnea syndrome was used to test the algorism. *	Total agreement between the visual and computer scorings: 92% Non-REM sleep: 64% sensitivity, 82% specificity. Drowsy stages: 19% sensitivity, 61% specificity. Alpha activity detection: 5% sensitivity, 11-13% specificity.
To test the accuracy of sleep stages determination by Oura Ring, combined with machine learning.	Quantitative cross-sectional study with 106 adults. In total, 440 nights of sleep were monitored by Oura Ring and standard PSG. Some of the recordings took place at home, the setting of other recordings was not reported. Machine learning models were build using different numbers of parameters derived from Oura Ring signals.	Accuracy for 2-stage detection (sleep, wake) with accelerometer data was 94%. Including other parameters (temperature, HRV, and circadian features) increased the accuracy to 96%. Accuracy for 4-stage detection (light NREM sleep, deep NREM sleep, REM sleep, and wake) with accelerometer data was 57%. Including other parameters increased the accuracy to 79%.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Ghorbani	2022	Singapore	Oura Ring, Gen2 and Gen3 (Oura Health Ltd, Oulu, Finland)	Sleep - stages
Kinnunen	2020	Finland	Oura Ring Gen3 (Oura Health Ltd, Oulu, Finland)	Sleep -heart rate
Multi-modal systems - with environmental sensors				
Au-Yeung	2020	USA	Ambient sensors: model not reported (NYCE Sensors, Vancouver, BC), Pressure mats: model not reported (Emfit, Finland), Actigraphy: Actiwatch Spectrums (Philips Respironics, Murrysville, PA), Environmental sensors: Thunderboard Sense 2- SLTB004A (Silicon Labs, Austin, TX)	Agitation
Bankole	2020	USA	BESI system (developed by the authors)	Agitation

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To compare two generations of Oura Ring algorithms in classifying sleep stages.	Quantitative cross-sectional study with 58 healthy adults, each went through 3 nights of home monitoring with standard PSG and Oura Ring.	Gen3 accuracy: 92.6%, sensitivity: 94.9% (0.03), specificity: 78.5%. Gen3 algorithm outperformed Gen2 and is comparable with PSG in measuring sleep latency, light sleep, rapid eye movement, and wake after sleep onset durations.
To validate the Oura Ring in monitoring nocturnal heart rate.	Quantitative cross-sectional study with 49 healthy adults. Recordings were made at home with both the Oura Ring and an ECG during the night.	High correlation between the Oura Ring and ECG on the average heart rate ($r^2 = 0.996$) and HRV ($r^2 = 0.980$).
To provide a proof of concept of monitoring and predicting agitation in memory care facilities with by monitoring the activity, sleep, and the environment (temperature, light, sound, humidity).	Quantitative case study with one adult with dementia in a memory care unit. The participant was continuously monitored by the system for 138 days. Agitation was recorded by nurses.	Sleep, total activity, humidity, ambient sound during the night, humidity and light and in the living room of the previous evening correlated with the presence of agitation at night ($p < 0.05$)
To develop and validate a home monitoring system for agitation and its environmental triggers in people with dementia. The system includes an actigraphy and environmental sensors for acoustic, light, humidity, barometric pressure, and movement.	Mixed-method study with two healthy volunteers and 12 community-dwelling people with dementia and their family caregivers. The BESI system was first tested in the laboratory and then applied in each home of the people with dementia for 30 days. Family caregivers recorded the activities and agitation events of the people with dementia.	Environmental factors (temperature, pressure, and humidity) strongly correlated with agitation ($r = 0.70$ to 0.85, $p = 0.05$). However, the predictors were person-specific.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Khan	2019	Canada	Developed by the authors	Agitation
Davoudi	2019	USA	Developed by the authors	Delirium
Multi-modal systems – other multi-modal systems				
Chen	2019	Singapore	Study 1: chest-worn biosensor (model and brand not reported), Study 2: Everion® CD, analyzed by the Biovitals™ analytics platform	Change in vital signs, hypoxia

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To develop a system to automatically detect agitation in people with dementia. The proposed system includes actigraphy, EDA monitor, pressure mat, video cameras, environmental motion sensors, and door sensors.	Quantitative cross-sectional study with two older adults with dementia at a rehabilitation institute. The participants were monitored for 15 and 13 days respectively. Agitation episodes were noted by nurses. Different algorithms were tested using different combinations of sensor data.	The highest AUC (89%) was achieved by combining actigraphy, skin temperature, and EDA data.
To pilot test a system that includes a camera, three actigraphy, a light sensor, and a microphone in the ICU.	Quantitative cross-sectional study with 17 older adults in the surgical ICU, nine of them had delirium. Participants were monitored continuously for a maximum of seven days.	Participants with and without delirium significant differed in facial expressions, functional status entailing extremity movement and postures, and environmental factors including the visitation frequency, light and sound pressure levels at night.
To present an analytic platform to monitor the changes in vital signs, including heart rate, respiration rate and activity.	Quantitative non-randomized experimental studies. The first study used data of 26 older adults with heart failure after discharge. They were monitored for seven to 60 days. Disturbance was added by the researchers to a few days of the data to validate the system. In the second study, 50 healthy adults wore the device for four days in their daily life and for two hours in a hypobaric chamber where they performed controlled exercises. The Biovitals results of daily life was compared with those in the chamber.	Study 1: The system could recognize randomly added disturbance to the data with an AUC of 80%-94%. Study 2: The system could distinguish the daily life from the hypobaric chamber condition with an AUC of 99%, a sensitivity of 91%, and a specificity of 98%.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Ramirez-Moreno	2021	Mexico	Ultracortex "Mark IV" EEG headset, (OpenBCI, New York, NY, USA) Empatica E4 (Empatica, Milano, Italy)	Mental fatigue
Gelinas	2021	Canada	Nociception Level (NOL) Index PMD200™ (Medasense Biometrics Ltd, Ramat Gan, Israel)	Pain
Jiang	2019	Finland, USA, Austria	Developed by the authors	Pain

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To develop a model to detect mental fatigue in workplace.	Quantitative non-randomized experimental study with 17 healthy adults in the laboratory. Participants were monitored for 30s with eyes open, 30s with eyes closed, and four minutes during an auditory oddball task. Correlations to self-reported mental fatigue levels (using the fatigue assessment scale) were calculated to find the best predictors.	EEG features correlated with the self-report of mental fatigue. The parameters measured by Empatica E4 did not have statistically significant correlations. The best model using three EEG features had an accuracy of 88%.
To test a system to monitor pain in patients after an operation. The device is worn on the finger and monitors EDA, and heart rate.	Quantitative non-randomized experimental study with 70 participants in the ICU after cardiac surgery. The NOL index calculated by the system was compared to self-reports of pain and anxiety (0-10 numeric rating scale), as well as observation of pain using the Critical-Care Pain Observation Tool (CPOT) measured before and during a non-nociceptive procedure and before, during, and after a nociceptive procedure.	The NOL index was higher during nociceptive procedures and correlated with self-reported pain intensity and unpleasantness. It did not correlate anxiety and CPOT. The NOL recognized pain with a self-reported intensity above 1 (out of 10) with an AUC of 70%, sensitivity of 76%, and specificity of 61%. For pain intensity above 5, the AUC was 74%, the sensitivity was 85%, and the specificity was 75%.
To develop a system to continuously monitor pain by measuring respiration rate, heart rate, EDA, and face sEMG.	Quantitative non-randomized experimental study with 30 healthy participants in the laboratory. Participants received electrical or thermal pain stimuli on the forearm of ring finger while being monitored by the system. The monitoring results were compared to self-report of no pain, mild pain, or moderate/severe pain based on a VAS.	They system could classify pain in three severity categories with an accuracy of 70.6%. Respiration rate, heart rate, EDA correlate more strongly with pain intensity than face sEMG.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Lai Kwan	2019	Canada	Triple Point Sensor (TPS) (ought Technology Ltd.)	Significant moments
Miranda	2016	USA	Heart rate: Hxm (Zephyr); EDA: Empatica E3; EEG: Muse band	Anxiety
Rajasekaran	2011	USA	Portable Autonomous Multisensory Intervention Device (PAMID, developed by the authors)	Agitation
Spasojevic	2021	Canada	Empatica E4	Agitation

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To present a system which detects significant moments of people with dementia and their family caregivers by measuring EDA, skin temperature, and heart rate.	Quantitative cross-sectional study with three older people with dementia and their family caregivers. Participants wore the sensor during 45-min sessions of a movement program for 8 times. Significant moments, carrying physical, emotional, or interpersonal significance, were detected by the system and participants were asked to watch 20s recordings of these moments and evaluate whether these were significant or memorable.	The agreement between the automatic detection and subjective report was 70%.
To describe an experiment eliciting anxiety in informal caregivers for people with dementia, while measuring heart rate, EDA, and EEG.	Quantitative non-randomized experimental study with 10 healthy adults in the laboratory. During 30 min sessions, participants had a relaxation stage and performed therapy with a simulated person with dementia. The level of anxiety was recorded by the participants and researchers. Models were developed using the physiological parameters to predict the presence of anxiety.	The average precision of different models using EDA and inter-beat interval was 78%. The best model used only inter-beat interval, reaching a precision of 80%. Specificity was 38% on average and 47% for the inter-beat interval model.
To test the reliability of the chest belt which integrated measurements for heart rate, skin temperature and EDA, and to evaluate its appearance and comfortability.	Quantitative non-randomized experimental study with six community-dwelling older adults in the laboratory. During a 40-minute experiment, participants took four sets of STROOP tests while being monitored by the device and conventional instruments.	PAMID was sensitive in detecting changes in heart rate, skin temperature and EDA.
To detect agitation in people with dementia using a multi-modal wearable device which monitored movement, blood volume pulse, EDA, and skin temperature.	Quantitative cross-sectional study with 17 people with dementia in a dementia unit. Participants wore the device in day time for a maximum of two months. Agitation events were noted with observation through video cameras.	Multi-modal prediction models were better than single-model ones. The best model had an AUC of 82%. Skin temperature was the least relevant signal.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Choi	2012	USA, Qatar	Developed by the authors	Stress
Wijsman	2011	Netherlands	Developed by the authors	Stress
Wu	2012	South Korea	Developed by the authors	Stress
Non-contact monitoring systems - pressure mats				
Boissy	2011	Canada	Developed by Université de Sherbrooke, Québec, Canada	(risk of) pressure ulcer
Dietz-Terjung	2020	Germany	VitaLog (SWGSportwerkGmbH&Co. KG, Dortmund, Germany)	Sleep – disordered breathing

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To validate a system to distinguish stress from relaxation by monitoring respiration, HRV, EDA, and sEMG.	Quantitative non-randomized experimental study with 10 healthy adults in the laboratory. During a 48-minute experiment, participants performed various mentally stressful tasks, with deep breathing in between.	The system could distinguish mental stress from relaxation with a classification rate of 81%, a true positive rate of 87%, and a true negative rate of 71%.
To find physiological parameters that can best predict mental stress. ECG, respiration, EDA, and sEMG were measured.	Quantitative non-randomized experimental study with 30 healthy adults in the laboratory. During an experiment of around 20 minutes, the participants performed three cognitive tasks with time pressure and distraction. Social stress was also induced. Resting periods were scheduled between the tests.	Using seven physiological features, the system could distinguish stressful periods from rest periods with an accuracy of 80%.
To test the effectiveness of stress reduction training with a wearable biofeedback system, consisting of ECG, Pulse rate, respiration, ambient and breath temperature measurements.	Quantitative non-randomized experimental study with 67 adults in the laboratory and during a 3-week biofeedback training for stress reduction. For the validation of the device, several adults were measured by it and a commercially available PolyG-A system in the laboratory.	The proposed device produced similar ECG, photoplethysmography and respiration signals compared to the commercial system. HRV and pulse rate variability were extracted accurately.
To present the functioning of two type of carbon nano tube films (multi-layered vs purified) in detecting pressure.	Quantitative experimental study without participants. The electrical and mechanical properties of the films were tested.	The loosely woven, multi-layered film had lower sensitivity (resistance change was 8 times higher) compared to the purified film. The purified film was less affected by the mechanical noise of the testing system (noise ratio 5% vs. 50%).
To assess the accuracy of VitaLog in estimating respiratory rate variability.	Quantitative cross-sectional study with 103 adults referred to the sleep lab. The VitaLog data were compared to nasal flow signal obtained by PSG.*	The VitaLog estimation of respiration rate variability had a correlation of $r = 0.99$ and a bias of 0.2 inhale-exhale cycles per minute compared with nasal flow signal. The Mann-Whitney U test showed no significant difference between participants with or without sleep disturbed breathing.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Kobayashi	2012	Japan	SD-101 (manufacturer not reported); Percutaneous oxygen saturation (SpO2)sensor: SX Module SX-2007 (Kenzmedico Co. Ltd., Saitama, Japan)	Sleep – apnea
Motoi	2009	Japan	Developed by the authors	Sleep – apnea and hypopnea
Non-contact monitoring systems – video/facial expression analysis				
Becouze	2007	New Zealand	Camera: Canon IXUS 40 digital camera; Algorithm developed by the authors	Agitation
Palestra	2020	Italy	RGB cameras; Algorithm developed by the authors	Emotions

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To investigate whether adding a SpO2 measurement increases the accuracy of recognizing mild to moderate obstructive sleep apnea syndrome by SD-101.	Quantitative cross-sectional study with 60 adult patients from an out-patient clinic. Overnight sleep was simultaneously monitored by PSG and SD-101 at the laboratory.	Adding SpO2 measurement improved the accuracy of the SD-101 for OSAS detection for AHI >15 (sensitivity: 97% vs. 88%; specificity: 90.5 % vs. 85.7 %, compared to the SD-101 alone). The SD-101 measurements significantly correlated with the PSG data (SD-101 alone: $r = 0.871$, $p < 0.0001$; SD-101 with SpO2: $r = 0.965$, $p < 0.0001$). Bland–Altman plots showed a smaller dispersion for the SD-101 with SpO2 than for the SD-101 alone.
To study the applicability of non-contact sensors in a hospital room. Only the results about the pressure mat were presented in this manuscript.	Quantitative cross-sectional study with two adults with sleep apnea in the hospital. Participants were monitored for one night with both the pressure mat under the pillow and a standard PSG.	There was good agreement on the number of apnea or hypopnea events per hour between the pressure mat and the PSG.
To develop an algorithm to detect grimacing independent of the head movement.	Quantitative non-randomized experimental study with two simulated videos of the face, one grimacing and the other with a neutral expression.	The algorithm could successfully track the reference point on the forehead and identify the face area when the head was moving. The grimacing level determined by the system corresponded with observation.
To evaluate a robot-facilitated memory training in its effects of engaging the participants.	Quantitative cross-sectional study with 21 adults with Mild Cognitive Impairment. Videos of an hour were taken during robot-facilitated group memory training sessions and emotions were identified by automatic facial expression analysis.	The system could detect all faces, including partially covered faces (success rate 56%), and recognize emotions reliably when the face was detected.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Castillo	2020	Canada	Algorithm: FaceReader version 8 (Noldus Technology Information)	Pain
Rezaei	2021	Canada	Algorithm developed by the authors	Pain
Non-contact monitoring systems - infrared				
Casaccia	2019	Italy	Passive InfraRed motion sensor (brand not reported)	Sleep - stages
Tejedor	2020	Spain	Camera: FLIR E60bx	Thermal comfort

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To validate the FaceReader in its estimation of pain and heart rate.	Quantitative cross-sectional study with pre-existing video recordings of two older long-term care residents with dementia and two community dwelling older adults. FaceReader automatically analysed pain based on facial expressions and estimated the heart rate. Pain was also manually scored using the Facial Action Coding System (FACS) and heart rate was estimated with the well-established Video Magnification (VM) algorithm.	FaceReader rating of pain scores strongly correlated with FACS during and around facial pain expression (r = 0.99 – 1.00). Its heart rate estimation strongly correlated with VM (r = 0.99 – 1.00).
To develop a technology to automatically recognize pain in long-term care facilities.	Quantitative experimental study with pre-existing video recordings of the faces of 25 adults with shoulder injury, 47 community-dwelling older adults, and 48 older adults with severe dementia in long-term care facilities. Automatic recognition of pain was compared with Prkachin and Solomon Pain Index (PSPI), scored by trained human annotators.	The algorithm outperformed baseline in recognizing pain. Pain prediction with the final model correlated with PSPI (r = 0.48 – 0.70), had an average precision of 0.71 (people with dementia) and 0.84 (in older adults without dementia). The AUC was 0.85 – 0.86.
To test the possibility of classifying sleep stages using infrared signal.	Quantitative case report on 25 nights of sleep data of one healthy adult. The sleep stages classified by the Passive InfraRed system was compared to the sleep pattern measured by a Ballistocardiographic bed sensor (Nokia Sleep bed sensor) under the mattress.	Passive InfraRed sensor could detect the waking states (R = 0.67 - 0.86, R^2 = 0.45 - 0.69) better than REM (R = 0.40, R^2 = 0.16), deep sleep (R = -0.03, R^2 = 0.00). and light sleep (R = 0.61, R^2 =0.37).
To propose a model to determine indoor thermal comfort for nursing home residents.	Quantitative case study with 15 older adults in a nursing home during winter. Participants were monitored for five minutes. A thermal questionnaire was filled in by the participants.	The proposed numerical model was reliably. The temperature of the nose could reliably indicate feeling cold. The self-report of the participants was concluded as not reliable.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Non-contact monitoring systems - radar				
Hsu	2017	USA	EZ-Sleep (developed by the authors)	Sleep
Resuli	2021	USA	Vayyar radar system	Sleep -respiration rate
Schnellenberge	2020	Germany	Developed by the authors	Vital signs
Non-contact monitoring systems - multiple sensors				
Dimitrievski	2021	Macedonia, Portugal, Spain	Piezoelectric sensor: (Angelcare, Montreal, QC, Canada), passive infrared sensors (Sunfounder, Shenzhen, China)	Sleep

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To present a radio-based sleep monitor.	Quantitative cross-sectional study with 10 healthy community-duelling adults. More than 100 nights of sleep was monitored by EZ-Sleep and compared to a wearable SleepProfiler and sleep diary.	Compared to SleepProfiler, the EZ-Sleep had an average error of 3.15 min in estimating time in bed, 10.3 min in total sleep time, 4.9 min in sleep latency, 8.2 min in wake after sleep onset, and 2.8% in sleep efficiency. EZ-Sleep can simultaneously monitor more than one people, although there can be a little disturbance if two people are sleeping close to each other.
To test the accuracy of respiration rate estimation in different sleeping positions with a radio frequency sensor.	Quantitative non-randomized experimental study with five healthy adults in a laboratory. Participants took different sleeping positions, each for at least six minutes. The radio frequency based estimation of breathing was compared with a respiration belt.	The accuracy of respiration estimation by the radar system was 92% in back postures, 84% in side postures, 76% in stomach position, 90% with a blanket covering the participant, 87% when sleeping on the back with the face turned sideways, and 86% in the sitting position.
To present a dataset with radar signals of the vital signs with synchronized reference.	Quantitative non-randomized experimental study with 30 healthy adults in the laboratory. Participants lay on a tilted table and five scenarios triggering the automatic nervous system and hemodynamics were simulated. Radar recording of the chest was conducted simultaneously with ECG, impedance cardiogram, and blood pressure.	The interbeat-intervals measured by the radar highly correlated with the ECG data ($r = 0.96$, $p < 0.001$)
To present a non-invasive system that monitors movement during sleep, aiming to detect sleep disturbances due to COVID-19.	Quantitative cross-sectional study with adults with COVID-19 in the hospital. Participants were monitored for eight hours.	Data from the Piezoelectric sensor correlated with the infrared sensors ($r = 0.32$ - 0.43). The five infrared sensors also correlated with each other ($r = 0.83$). There was built-in delay in the infrared sensors and oscillation in the piezoelectric sensor, but these could be adjusted with the post-processing of the data.

eTable 1 Manuscripts reporting clinimetrics of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Ravindran	2023	UK	Radar: Somnofy (VitalThings, Norway); Pressure mats: Withings Sleep Analyser (WSA, Withings, France), Emfit-QS (Emfit Ltd, Finland)	Sleep
Kroll	2020	Germany	Camera: Mini-Webcam (Conrad Electronics SE, Hirschau, Germany); Acoustic sensor: ME32 (Olympus Imaging Europa GmbH, Hamburg, Germany) Pressure mat: SafeBed IP system (Emfit® Ltd., Vaajakoski, Finland)	Agitation

Note: Adults = mean age between 18 and 65; Older adults = mean age over 65;
ICU = intensive care unit
References can be found in Supplement IV.
*The setting was not reported.

Aim of study	Methods: Study design; Participants (age, disease, setting); Procedures	Clinimetrics of the technology (validity, sensitivity, reliability, specificity, responsiveness)
To compare three non-contact sleep monitors with PSG and actigraphy (Actiwatch Spectrum).	Quantitative cross-sectional study with 35 older adults, some with sleep apnea. Participants used the non-contact devices at their own homes for 8-14 days and had one overnight measurement with all the devices in the laboratory.	Compared to PSG, all three devices overestimated total sleep time (bias > 90 min) and sleep efficiency (bias > 13 %), and underestimated wake after sleep onset (bias > 50 min). Bedside radar accurately measured sleep onset latency (bias < 6 mins) while the under-mattress devices overestimated it (bias >16 mins). These performances were less optimal than actigraphy. The bedside radar performed better in discriminating sleep vs wake (Matthews Correlation Coefficient (MCC) [mean and 95% CI] = 0.63 [0.57 0.69]) than the under-mattress devices (MCC = 0.41 [0.36 0.46]; Emfit-QS = 0.35 [0.26 0.43]). Accuracy of identifying REM and Light sleep was poor for all three devices, but deep sleep was predicted with moderate accuracy (MCC >0.45) by both Somnofy and Withings Sleep Analyser.
To validate the non-contact monitoring system and a tent-like shelter for people with dementia.	Quantitative cross-sectional study with six healthy adult volunteers in the laboratory and 19 patients, most of whom had dementia, in the emergency department and a geriatric-psychiatric ward. Participants were monitored for two hours, the first hour without the tent-like shelter, the second hour with it.	In the laboratory test, the measurement of heart rate was reliable between the first and second hour, but that of respiration rate was not. The camera and mattress registration of movement complimented each other. The measurements in the emergency department and geriatric-gerontopsychiatric ward were reliable.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort

Actigraphy				
First author	**Year**	**Country**	**Monitoring technology (model and brand)**	**Symptom monitored**
Knuff	2019	USA	wGT3x+ activity monitors (Actigraph, LLC, Pensacola, FL)	Agitation
Favela	2020	Mexico	Fitbit Charge 2 HR, Fitbit Alta (Fitbit Inc, CA, USA)	Behavioral symptoms of dementia
LeBlanc	2022	USA	MisFit Shine	Sleep

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To evaluate the feasibility and validity of actigraphy as a measurement of agitation in dementia.	Quantitative cross-sectional study. 20 older adults with dementia living in long-term care facilities wore the wristband continuously for a minimum of 24 hours and maximum of 7 days. Feasibility was evaluated by the researchers.	Actigraph monitors recorded for almost 1 week. Agitation severity did not influence compliance. The authors concluded that multi-day continuous actigraphic monitoring is feasible.
To evaluate an intervention program lead by a social robot.	Mixed methods non-randomised experimental study with 10 older adults in a long-term care facility. The wristwatch form of actigraphy was worn for 54 days on average. Feasibility was evaluated by the researchers.	One participant refused to wear the device at night. Two other participants needed persuasion to take the device off for charging. One participant feared losing or damaging the device and discontinued wearing it. The other participants did not experience anxiety about the device.
To describe the experience of using a sleep monitor for sleep self-management.	Qualitative study with 25 community-dwelling older adults with sleep disturbances. The participants wore the device for four weeks and received an interview afterwards.	Regarding the device, participants could understand how it worked and considered it easy to use. The plain design was appreciated, although some participants wanted the device to look more like a watch and found it bothersome having to tap it to see the time. The device was comfortable and light-weighted. The wrist clamp and battery life could be improved. There was concern about privacy of the data and some did not trust the results of the device. Both financial and time costs were important issues to consider. More than half of the participants had the intention to continue using the device.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Svetnik	2021	USA	Garmin Vivosmart	Sleep
Van Dijk	2012	Netherlands	Actiwatch AW7 (Cambridge Neurotechnology Ltd, Cambridge, UK)	Sleep
Brain activity monitors – Bispectural Index (BIS)				
Gambrell	2005	USA	Not reported	Depth of sedation

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To investigate the usefulness of a wearable in measuring treatment effects of insomnia in people with dementia.	Randomized experimental study with 285 older adults with Alzheimer's disease and insomnia. During insomnia treatment of four weeks, participants were instructed to wear the device all the nights at home. Three overnight measurements with standard polysomnography (PSG) were performed in the laboratory at screening, baseline, and at the end of the treatment. The challenges of using the device were reported by the researchers.	74% of the participants had usable data of the device, which is at least three nights of measurements in a week. The challenges were patient compliance, battery life and Bluetooth connectivity between the watch and tablet.
To evaluate the feasibility of using actigraphy to monitor sleep in older people with intellectual disability.	Quantitative cross-sectional study. 563 older adults with intellectual disability wore the actiwatch continuously for a maximum of 14 days. Feasibility was evaluated by the researchers.*	A successful measurement was obtained from 200 (35%) of the participants. Unsuccessful measurements were mainly due to problems wearing the device and incomplete bedtime information. 354 (92%) of those who started wearing the device wore it for more than 7 days.
To present a case where the BIS monitor is used successfully in the ICU.	Case study of a 78-year-old woman with intraventricular haemorrhage. She was monitored in the last few hours of her life in the ICU. The nurse and family expressed their opinions on the device.	The nurse saw BIS as an additional tool to help titration and to educate the family. The family is more confident of a comfortable death and are pleased to see the BIS values fluctuate when they talked to the patient.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Pedrao	2020	Brazil	BIS™ Vista Monitoring System (Covidien LLC, Mansfield, United States)	Sleep
Brain activity monitors – other electroencephalography(EEG)-based technologies				
Pu	2021	Australia	MUSE 2 (InteraXon Inc., Toronto ON, Canada)	Pain
Vacas	2016	USA	SedLine Brain Function Monitor (Masimo Corp., Irvine, California)	Sleep - stages
Brain activity monitors – the concept of sedation monitors				
Six	2020	Belgium	Not reported	Sedation

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To test the feasibility of using BIS to evaluate sleep in critically ill patients.	Quantitative cross-sectional study with 29 lucid patients in ICU. BIS monitoring was performed for a whole night (12 hours). The participants filled in the Richards-Campbell Sleep Questionnaire (RCSQ) the next morning. The feasibility was evaluated by the researchers.	Among 49 patients who were eligible for the study, seven refused to participate, two could not be monitored because of delirium, five could not be monitored because of other procedures they underwent, five dropped out because of discomfort of the sensors or displacement of the sensors. The authors concluded that BIS had limited feasibility in lucid patients in the ICU.
To assess the feasibility of a headband EEG to monitor pain in long-term care residents with dementia.	Quantitative cross-sectional study with 4 older adults with dementia and chronic pain in a long-term care facility. Each participant was monitored for 10 minutes. The Pain Assessment in Advanced Dementia (PAINAD) scale was administered before and after the measurement.	The device was acceptable to people with dementia and no participant tried to remove the device. No discomfort was reported. Appropriately positioning the device was challenging.
To validate the device in laboratory setting and to test the feasibility of its use in the ICU.	Quantitative cross-sectional study with three adult outpatients in the laboratory and 23 ICU patients.	The system is feasible in the ICU.
To investigate what influences professional caregivers and family members' attitudes towards the use of monitors during continuous sedation until death.	Qualitative interview study with 20 professional caregivers and 15 family members of patients in a palliative care setting.	Family members and professional caregivers found the use of monitors during continuous sedation until death acceptable because this would be a more objective assessment of consciousness and pain, which gave reassurance to family and guides titration for the professional caregivers.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Electrocardiography (ECG)				
Li	2022	China	myBeat-WHS-1 (Union Tool Co., Ltd., Japan)	Stress
Tao	2021	China, United Arab Emirates, Bahrain	Not reported	Atrial fibrillation
				EEG
Tiihonen	2008	Finland	Developed by the authors	Depth of sedation

	Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
	To use a wearable ECG monitor to measure workplace stress in nurses.	Quantitative cross-sectional study with 17 healthy nurses during one work day at the hospital. Participants wore the device and filled in the Chinese Nurses Stress Response Scale (CNSRS) after work. The feasibility was evaluated by the authors.	The authors concluded that it was feasible to use the portable device to monitor stress in nurses in their work environment.
	To improve diagnostic efficiency of severe fever with thrombocytopenia syndrome bunyavirus (SFTSV) complicated by atrial fibrillation	Quantitative randomized controlled study with 200 older adults with SFTSV and hypertrophic cardiomyopathy in the hospital and 20 healthy adults. After surgery for cardiac sympathetic block, patients were randomly assigned to a monitoring group using ECG, supported by a new algorithm, or a routine observation group to monitor atrial fibrillation. Patients reported their satisfaction.	Patients were significantly more satisfied with the ECG atrial fibrillation monitoring technology than clinical observation ($p < 0.05$).
and ECG			
	To develop and validate a portable device to measure the depth of sedation with auditory event-related potentials (ERP).	Quantitative cross-sectional study with four healthy adults in the laboratory. Technical validation of the device was performed. ERP, EEG, ECG, and somatosensory-evoked potentials were measured. The quality of the signals were evaluated by an experienced neurophysiologist.	ERP and somatosensory-evoked potential measurements generated distinct responses. The quality of the signal recordings was good. The noise amplitudes were acceptable. The interface was easy to use. (Note: The study reported results of the technical validation, but no clinimetrics.)

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Electrodermal activity (EDA) monitors				
Leborgne	2023	Netherlands	Developed by the author	Stress
Incontinence sensors				
Boerakker	2022	Netherlands	Abena Nova (Abena Group, Denmark), WeSense (Seneca Sense Technologies, Canada)	Incontinence
Nikoletti	2004	Australia	Not reported	Incontinence

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To develop a sock garment to detect stress in people with intellectual disabilities.	Quantitative non-randomized experimental study. Sixty adults with severe intellectual disabilities in long-term care facilities tried on the garment. It was not clear whether they also participated in the experiment. The feasibility was evaluated by the researchers.	Of the 60 clients, 48 accepted and wore the sock. The others did not wear it due to other garments necessary for their comfort, such as compression socks, or due to repeated behavior resulting in removing the clothing. The researchers concluded that the sock was comfortable and user-friendly for most people with intellectual disabilities.
To investigate the use of intelligent incontinence material in nursing homes.	Mixed-methods pilot study with 25 older adults in nursing homes with urinary incontinence. Abena Nova and WeSense were evaluated by the clients, family caregivers, and staff.	The clients did not feel the presence of extra sensors in the incontinence material. Family caregivers valued less dirty laundry and less unnecessary care moments. The staff reported that the technology is time-saving and they could trust it. The downsides were that the bowel incontinence is not measured and that the sensors are sometimes difficult to attach.
To evaluate an incontinence alarm in acute elderly care setting.	Mixed-method study with 41 older adults on acute care rehabilitation wards. Incontinence was monitored for 72 hours for each patient.	Numerous problems were reported: false alarms, false negatives, shorter transmission range than claimed by the manufacturer, the need to recharge frequently, and sensors being discarded with pads. Resolving these issues was time-consuming and frustrating for staff and patients. There was resistance of experienced staff to learn the technology and to change personal routines.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Toba	1996	Japan	Not reported	Incontinence
Van der Hurk	1998	Netherlands	Developed by the authors	Incontinence
Multi-modal monitoring systems – polysomnography (PSG)				
Abdenbi	2002	France	CID 102 and CID 108 (CIDELEC, Sainte-Gemmes-sur-Loire, France)	Sleep
Koskinen	2021	Finland	Collare (Nukute Ltd, Finland)	Sleep - apnea

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To evaluate the effects of wearing a thin-film urinary drainage sensor in the incontinence material on urinary quality of life and nursing work hours.	Mixed method cross-sectional study with 4 older adults with urinary incontinence in nursing homes. Participants were asked about the comfort of the sensors once a day for four days. Nursing staff filled in a survey about the burden.	Among the 16 responses from the older adults, 14 (87.5%) were "not at all uncomfortable," 2 (12.5%) were "it does not bother me". 3 out of 4 nursing staff commented that the interruption of other working activities led to reduced efficiency. They didn't perceive the changing and cleaning of the incontinence materials as burdensome.
To evaluate the applicability and validity of the Urine Leakage Recording Device.	Quantitative non-randomized experimental study with 5 older adults. Participants were instructed to turn and void during the experiment. The experimenter evaluated the operation of the device. The setting was likely a laboratory, but not reported in the manuscript.	No restriction nor inconvenience was reported by the participants. The device was easy to operate.
To evaluate an ambulatory sleep monitoring set-up.	Quantitative cross-sectional study with 25 adults with possible sleep apnea. 15 had both 102 (respiratory recordings) and 108 (full polysomnographic recordings) at home for one night. 10 had CID 102 set up at the hospital and recorded at home.	Technical failures occurred in 2/15 with CID 108. No failure with CID 102.
To validate the Nukute Collare in diagnosing sleep apnea.	Mixed-methods cross-sectional study with 71 adults with or without sleep apnea. Collare measurement was compared with standard PSG. Participants filled in a questionnaire to evaluate the device.*	45 out of 71 measurements were completed valid. Most participants (93%) considered Collare easy to use, 85% reported that it did not disturb their sleep, 90% did not feel pain or tenderness in the neck after the measurement, 75% considered Nukute Collare more comfortable than the standard PSG, 85% said that they would use it again.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Morales	2012	USA	ResCare AutoSet™ (ResMed, Sydney, Australia)	Sleep - apnea
Silvia	2014	USA	M1 (SleepImage, Denver, CO, USA)	Sleep - insomnia
Lazazzera	2022	France	UpNEA (developed by the authors)	Sleep - apnea
Multi-modal monitoring systems – with environmental sensors				
Au-Yeung	2020	USA	Ambient sensors: model not reported (NYCE Sensors, Vancouver, BC), Pressure mats: model not reported (Emfit, Finland), Actigraphy: Actiwatch Spectrums (Philips Respironics, Murrysville, PA), Environmental sensors: Thunderboard Sense 2-SLTB004A (Silicon Labs, Austin, TX)	Agitation

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To assess the feasibility of a two-stage screening procedure for obstructive sleep apnea syndrome (OSAS).	Quantitative cross-sectional study with 452 older adults in the community. Participants conducted an overnight home recording of nasal pressure on their own, kept a diary and received a separate, standard PSG.	Complete data on 442 of 452 (98%) home recordings
To evaluate a brief sleep intervention and to investigate the feasibility and effectiveness of sleep monitoring of the M1 device.	Quantitative cross-sectional study with 8 adults with bipolar disorder. Participants wore the device for two seven-night periods at home and kept a sleep diary. They filled in a M1 acceptability questionnaire after each week of wearing the device.	The M1 device was evaluated as easy to use, easy to apply and did not interfere with the participants' sleep. The device was worn for at least two nights by all participants and on average 6.12 and 5.50 days in each week. The willingness to wear the device again declined after the second week, but was still high.
To present a system aimed to predict respiratory and cardiovascular disorders. UpNEA was part of the whole system.	Quantitative cross-sectional study with one healthy adult. The participant wore the glove-life device for four nights and reported on its comfort.*	The device did not cause discomfort to the participant.
To provide a proof of concept of monitoring and predicting agitation in memory care facilities with by monitoring the activity, sleep, and the environment (temperature, light, sound, humidity).	Quantitative case study with one adult with dementia in a memory care unit. The participant was continuously monitored by the system for 138 days. Agitation was recorded by nurses. The feasibility was evaluated by the researchers.	Ambient motion sensors functioned well with no technical problems. Sleep was successfully monitored for 91 out of 137 nights due to Wi-Fi problems or the participant not sleeping on the bed. Actigraphy was off-wrist 2% of the time. Environmental data was successfully collected 48% of the time.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Khan	2019	Canada	Developed by the authors	Agitation
Davidoff	2022	Belgium, Netherlands	Wearables: Chill+, LYS (LYS Technologies), Blooloc tracker; Pressure mat: EMFIT QS (EMFIT, Finland); Environmental sensors: Metatracker (MbientLab), micrphone: Nokia 6.1 Android phone, Blooloc	Anxiety
Davoudi	2019	USA	Developed by the authors	Delirium
Rose	2015	USA	Tab-like bed sensor: Wireless Identification and Sensing Platform (WISP, brand not reported); Watch: Technology-Enabled Medical Precision Observation (TEMPO, brand not reported); Incontinence sensor: DryBuddy (brand not reported) Microphone: model and brand not reported	Sleep, agitation, and urinary incontinence

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To develop a system to automatically detect agitation in people with dementia. The proposed system includes actigraphy, EDA monitor, pressure mat, video cameras, environmental motion sensors, and door sensors.	Quantitative cross-sectional study with two older adults with dementia at a rehabilitation institute. The participants were monitored for 15 and 13 days respectively. Agitation episodes were noted by nurses. Different algorithms were tested using different combinations of sensor data. The feasibility was evaluated by the authors.	The system was feasible to monitor people with dementia.
To pilot test a system that identifies physiological markers and contextual triggers of agitation in people with dementia. EDA, heart rate, activity, skin temperature, light, sleep, position of the participant, and environmental sound were monitored.	Quantitative cross-sectional study with older adults with dementia with severe behavioral symptoms in a neuropsychiatric ward. The number of participants was not reported. Agitation was scored by the nurse at nine random moments per day using the Pittsburgh Agitation Scale and the Richmond Agitation Sedation Scale.	Some participants took off the wearables when they were most agitated. Connectivity problems and some rooms not installing the devices complicated the data collection. Synchronizing all the data was intensive and errors lead to loss of data.
To pilot test a system that includes a camera, three actigraphy, a light sensor, and a microphone in the ICU.	Quantitative cross-sectional study with 17 older adults in the surgical ICU, nine of them had delirium. Participants were monitored continuously for a maximum of seven days. The feasibility was evaluated by the authors.	The system was feasible to monitor critically ill patients in the ICU.
To investigate the feasibility and acceptability of the wireless devices, including a tab-like bed sensor, a smart watch, an incontinence sensor, and a microphone, in community-dwelling people with dementia.	Quantitative cross-sectional study with 50 community-dwelling older adults with dementia. Participants were monitored for five to seven days. Family caregivers set up the devices with help from the study team via the phone and they received an interview about the feasibility after the study.	Minimal effort was required to operate the system, but it was still challenging for caregivers who were not very familiar with technology. Troubleshooting via the phone was challenging, but reviewing the data helped. Adding another bedside receiver solved problems with the incontinence sensors. Bowel incontinence complicated the measurement.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Multi-modal monitoring systems – other multi-modal systems				
Iaboni	2022	Canada	Empatica E4 (Empatica)	Agitation and aggression
Rajasekaran	2011	USA	Portable Autonomous Multisensory Intervention Device (PAMID, developed by the authors)	Agitation
Miranda	2016	USA	Heart rate: Hxm (Zephyr); EDA: Empatica E3; EEG: Muse band	Anxiety
Non-contact monitoring systems – pressure mats				
Sakai	2009	Japan	KINOTEX sensor (NITTA Corp. Osaka, Japan)	Risk of pressure ulcers

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To develop personalized machine learning models for detecting behavioral and psychological symptoms of dementia (BPSD). The device monitored motion, blood volume pulse, EDA, and skin temperature.	Quantitative cross-sectional study with 17 older adults with dementia and BPSD in a dementia care unit. Participants wore the Empatica wristband for eight weeks during waking hours. Agitation and aggression events were annotated by trained nurses.	The models could recognize the presence of motor agitation (median Area under the receiver-operating characteristic curves (AUC) = 90%), verbal aggression (median AUC = 86%), and physical aggression (median AUC = 82%)
To test the reliability of the chest belt which integrated measurements for heart rate, skin temperature and EDA, and to evaluate its appearance and comfortability.	Quantitative non-randomized experimental study with six community-dwelling older adults in the laboratory. During a 40-minute experiment, participants took four sets of STROOP tests while being monitored by the device and conventional instruments. The appearance and comfort of the device were evaluated by the participants.	The appearance of the device was rated 2.7 out of 3, and the comfortability was rated 2.8 out of 3.
To describe an experiment eliciting anxiety in informal caregivers for people with dementia, while measuring heart rate, EDA, and EEG.	Quantitative non-randomized experimental study with 10 healthy adults in the laboratory. During 30-min sessions, participants had a relaxation stage and performed therapy with a simulated person with dementia. The level of anxiety was recorded by the participants and researchers. Models were developed using the physiological parameters to predict the presence of anxiety. The feasibility was evaluated by the authors.	When participants moved during the sessions, EEG signal was poor. No reliability information was reported about the other sensors.
To examine the feasibility of using continuous interface pressure monitoring to prevent pressure ulcers in the ICU.	Quantitative cross-sectional study with 30 postoperative patients in the ICU. They were monitored for up to 48 hours.	Continuous monitoring of the intensity and duration of whole-body interface pressure using the KINOTEX sensor is feasible in intensive care patients.

eTable 2 Manuscripts reporting on the acceptability or feasibility of the monitoring technologies to detect distress and discomfort (continued)

First author	Year	Country	Monitoring technology (model and brand)	Symptom monitored
Non-contact monitoring systems – multiple sensors				
Kroll	2020	Germany	Camera: Mini-Webcam (Conrad Electronics SE, Hirschau, Germany); Acoustic sensor: ME32 (Olympus Imaging Europa GmbH, Hamburg, Germany) Pressure mat: SafeBed IP system (Emfit® Ltd., Vaajakoski, Finland)	Agitation

Note: Adults = mean age between 18 and 65; Older adults = mean age over 65; ICU = intensive care unit.
References can be found in Supplement IV.
*The setting was not reported.

Aim of study	Methods: Study design; Participants being monitored; Setting; Procedures; Participants evaluating the technology;	Acceptability or feasibility of the technology
To validate the non-contact monitoring system and a tent-like shelter for people with dementia.	Quantitative cross-sectional study with six healthy adult volunteers in the laboratory and 19 patients, most of whom had dementia, in the emergency department and a geriatric-gerontopsychiatric ward. Participants were monitored for two hours, the first hour without the tent-like shelter, the second hour with it.	There were little perturbations during the measurements in the emergency department and geriatric-gerontopsychiatric ward. One out of 19 measurements did not take place because of non-cooperation of the patient.

eTable 3 Manuscripts in which the clinimetrics, acceptability or feasibility of the technologies that monitor distress and discomfort were not reported (the technology is either used as standard measurement or is newly developed)

First author	Year	Country	Monitoring technology (model and brand)
Actigraphy			
Burnett-Zeigler	2018	USA	Not reported
Godfrey	2009	UK, Ireland	activPAL Professional (PAL Technologies Ltd, Glasgow, UK)
Mahlberg	2007	Germany	Actiwatch (Cambridge Neurotechnology Ltd, Cambridge, UK)
Blytt	2017	Norway	Actiwatch Spectrum (Philips Respironics Inc, Murrysville, Pennsylvania)
Buratti	2021	Italy	Actiwatch Spectrum or Actiwatch-2 (Philips Respironics Inc, Murrysville, Pennsylvania)
Jaiswal	2023	USA	Actiwatch Spectrum Plus (Phillips Respironics Inc, Murrysville, Pennsylvania)
Wilcox	2019	Canada	Actiwatch Spectrum Plus (Phillips Respironics, Bend, Oregon, USA)
Hoekert	2006	Netherlands	Actiwatch (Cambridge Neurotechnology Ltd., Cambridge, U.K.)
Meadows	2010	UK	Actiwatch (Cambridge Neurotechnology Ltd, Cambridge, UK)
Most	2012	Netherlands	Actiwatch (Cambridge Neurotechnology Ltd., Cambridge, UK)
van Someren	2019	Netherlands and Italy	Actiwatch (Cambridge Neurotechnology Ltd, Cambridge, UK)
de Feijter	2021	Netherlands	Actiwatch AW4 (Cambridge Neurotechnology Ltd, Cambridge, UK)
van den Berg	2008	Netherlands	Actiwatch AW4 (Cambridge Neurotechnology Ltd, Cambridge, UK)
van den Berg	2009	Netherlands	Actiwatch AW4 (Cambridge Neurotechnology Ltd, Cambridge, UK)
Kazui	2017	Japan	Actiwatch-L (Mini Mitter Co., Inc.-Respironics, Inc. Co. Bend, Oregon, USA)
Rowe	2010	USA	Actiwatch-L (Mini Mitter Co., Inc.-Respironics, Inc. Co. Bend, Oregon, USA)
Leary	1998	Ireland	Accelerometer (Gaewihler Electronics, Hombrechtikon, Switzerland)
van Hilten	1994	Netherlands and Canada	Activity monitor (Gaehwiler Electronic, CH-8634, Hombrechtikon, Switzerland)

Symptom monitored	Participant population and setting
Stress	Adults with depressive symptoms*
Delirium (motor subtypes)	Adults receiving palliative care in hospice
Agitation	Older adults with Alzheimer's disease from a geriatric psychiatry unit
Sleep	Older adults with or without dementia, living in nursing homes
Sleep	Older adults with Alzheimer's disease, mild cognitive impairment, or no cognitive impairments living at home
Sleep	Adults in the ICU, with or without delirium
Sleep	Adults in the hospital, after discharge from the ICU where they received at least 3 days of mechanical ventilation
Sleep	Older adults with dementia living in group care facilities
Sleep	Older adults both institutional care residents and community dwelling poor sleepers
Sleep	Older adults with Alzheimer's disease and control group*
Sleep	Older adults*
Sleep	Adults and older adults living at home
Sleep	Older adults living at home
Sleep	Older adults living at home
Sleep	Older adults with Lewy Body dementia and control group*
Sleep	Adults who take care of their family members with dementia at home
Sleep	Adults: hypertensive patients and control group*
Sleep	Older adults with Parkinson's disease and control group at an outpatient neurology department

eTable 3 Manuscripts in which the clinimetrics, acceptability or feasibility of the technologies that monitor distress and discomfort were not reported (the technology is either used as standard measurement or is newly developed) (continued)

First author	Year	Country	Monitoring technology (model and brand)
Guarnieri	2020	Italy	Fitbit Flex (Fitbit Inc., San Francisco, California)
Yesavage	2020	USA	Motionwatch (Ambulatory Monitoring Inc., Ardsley, New York)
Mulin	2011	France	Micro- Mini MotionLogger (Ambulatory-Monitoring, Inc., Ardsley, New York)
Currie	2003	Canada	Mini-motion logger actigraph units (Ambulatory Monitoring Inc., Ardsley, New York)
Watanabe	2002	Japan	Mini Motion Logger (Ambulatory Monitoring Inc., Ardsley, New York)
Kotschet	2023	Australia	Parkinson's Kinetigraph (PKG, Global Kinetics Corporation™, Australia)
Jones	2020	Australia	SenseWear Professional 8.0 (Temple Healthcare, BodyMedia, Inc.)
Spira	2017	USA	SleepWatch-O (Ambulatory Monitoring Inc., Ardsley, New York)
Yaffe	2007	USA	Sleepwatch-O (Ambulatory Monitoring Inc., Ardsley, New York)
Cabanel	2020	Germany	SOMNOwatch system (Somnomedics, Randersacker, Germany)
Westerberg	2010	USA	Not reported
Elías	2020	USA	Not reported
Brain activity monitors – Bispectural Index (BIS)			
Barbato	2017	Australia	Bispectral Index monitor (Covidien Pty Ltd.), with Quatro sensors.
Bass	2019	USA	Not reported
De Deyne[o]	1998	Belgium	Aspect A-1000 EEG analyser (Aspect, Natick, USA)
Monreal-Carrillo	2017	USA	BIS Vista Bilateral Monitoring System 1.2 (Aspect Medical Systems, Inc. Norwood, MA, USA)
Quraishi	2011	USA	BIS (Aspect Medical Systems, Inc. Norwood, MA)

Symptom monitored	Participant population and setting
Sleep	Adults and older adults with Alzheimer's disease or amnestic Mild Cognitive Impairment in a multicenter setting
Sleep	Older adults with Alzheimer's disease*
Sleep	Older adults with Alzheimer's disease, with or without apathy*
Sleep	Adults: insomnia patients and control group*
Sleep	Older adults with or without hypertension living at home
Sleep	Adults with Huntington's disease
Sleep	Older adults with dementia and sleep problems*
Sleep	Older adults living at home
Sleep	Older adults. Data was taken from a previous study about osteoporotic fractures*
Sleep	Older adults: memory clinic patients
Sleep	Older adults with amnestic Mild Cognitive Impairment and control group living at home
Sleep	Older adults: ICU survivors
Sedation and comfort	Adult patients at the end of life in palliative care units of the hospital
Sedation and pain	Adults in the ICU
Sedation	Adult patients with a Ramsay sedation score of 6 in the ICU
Sedation	Adults on palliative sedation in the hospital
Sedation	Adult with locked-in syndrome in the ICU

eTable 3 Manuscripts in which the clinimetrics, acceptability or feasibility of the technologies that monitor distress and discomfort were not reported (the technology is either used as standard measurement or is newly developed) (continued)

First author	Year	Country	Monitoring technology (model and brand)
Brain activity monitors – other electroencephalography (EEG)-based technologies			
Espie	1998	UK	Walter-Graphtex System and Oxford Medilog 9000-II ambulatory system
Sato	2002	USA, Japan	Not reported
Electrocardiography (ECG)			
Estrada	2000	USA	78720 ASDN system (Hewlett Packard)
Gerber	2019	Switzerland	Carescape Monitor B650 (GE Healthcare, Little Chalfont, United Kingdom)
Gerber	2019	Switzerland	Carescape Monitor B650 (GE Healthcare, Little Chalfont, United Kingdom)
Park	2022	Korea	Apple Watch Series 4, 5, or 6 smartwatch (Apple Inc)
EEG and ECG			
Six	2019	Belgium	EEG: NeuroWave Systems Inc. ECG: ANI (Mdoloris Medical Systems SAS)
Six	2021	Belgium	EEG: NeuroWave Systems Inc. ECG: ANI (Mdoloris Medical Systems SAS)
Electrodermal activity (EDA) monitors			
Jusilla	2018	Finland	Moodmetric smart ring (Vigofere Oy, Finland)
Massot	2010	France	EmoSense (developed by the authors, based on Programmable Systemon-Chip, Cypress MicroSystems, Inc.)
Melander	2018	Sweden, Norway	Discrete Tension Indicator (DTI-2) (Philips Research); Empatica E4 (Empatica Incorporation)
Quad Industries	2022	Netherlands	Model not reported, developed by Mentech (the Netherlands) and Quad Industries (Belgium)
Incontinence sensors			
Fischer	2019	Austria	Developed by the authors
Wai	2008	Singapore	Developed by the authors
Multi-modal systems – Polysomnography (PSG)			
Bell	1996	USA	Model 8-16 EEG machines (Grass Instruments)

Symptom monitored	Participant population and setting
Sleep	Adults with severe or profound intellectual disability and epilepsy. Assessment was performed in the hospital and at home.
Sleep	Older adults in the community.
Arrhythmia	Adults in non–intensive-care telemetry unit
Stress	Critically ill adults in the ICU
Stress	Healthy adults. The experiment was conducted in the ICU environment.
Stress	Healthy nurses during cardiopulmonary resuscitation training
Depth of sedation and pain	Older adult in the palliative care unit undergoing palliative sedation
Depth of sedation and pain	Older adults undergoing palliative sedation until death
Stress	No participants. The manuscript presented the design of a system
Stress	Healthy blind adults in an urban space
Stress	Older adults with dementia in nursing homes
Stress	No participants. The manuscript presented a printed electronic patch for people with severe intellectual disability.
Incontinence, occupancy of the bed	No participants. The manuscript reports the development of the electronic system.
Incontinence	No participants. The manuscript reports the design of the system.
Sleep	Older healthy adults at a sleep laboratory

eTable 3 Manuscripts in which the clinimetrics, acceptability or feasibility of the technologies that monitor distress and discomfort were not reported (the technology is either used as standard measurement or is newly developed) (continued)

First author	Year	Country	Monitoring technology (model and brand)
Bugalho	2019	Portugal	XLTEK-TREX (Natus Medical Inc., Middleton, USA)
Bugalho	2019	Portugal	XLTEK-TREX (Natus Medical Inc., Middleton, USA)
Cooke	2009	USA	Embla recording system (Flaga Medical Devices/ Medcare, Reykjavik, Iceland)
Dew	2003	USA	Not reported
Dijkstra	2019	Belgium	BrainnetMorpheus (MEDATEC)
Djonlagic	2019	USA, Germany	Compumedics Siesta Portable PSG (Abottsville, Australia)
Eisensehr	2001	Germany	A digital 32-channel system (Brainlab, Schwarzer, Munich, Germany)
Fanfulla	2011	Italy	N-S 7000 (Embla, Denver, CO, USA)
Fleming	2015	USA	ExSpiron (Respiratory Motion, Inc. USA)
Gelber	2015	USA	Not reported
Gebran	2009	Canada	AR-B1831 single-board-computer (Accroser Technology Co. Ltd., Cypress, California)
Herring	2020	USA	Not reported
Heude	1996	France	Schwarzer ED24 (Madhaus, Germany)
Jiang	2013	China, Italy	Polysmith 5.0 (Nihon Khoden, U.S.)
Joo	2011	South Korea	ApneaLink (ResMed, Australia)
Kim	2017	South Korea	Embla™ N7000 (Embla, Reykjavik, Iceland)
Kim	2011	South Korea	Embla S7000 (Medcare system, NY)
Kardiol	1999	Germany	4-channel recording system, brand not recorded
Koo	2019	USA	Not reported
Lankford	2008	Canada, USA	Not reported
Low	2012	USA	Not reported

Symptom monitored	Participant population and setting
Sleep	Older adults with dementia, Parkinson Disease, or ideopathic rapid eye movement (REM) sleep behavior disorder at a sleep laboratory
Sleep	Older adults with REM sleep behavior disorder at a sleep laboratory
Sleep	Older adults with Alzheimer's disease and obstructive sleep apnea at home and at a sleep laboratory
Sleep	Healthy older adults at a sleep laboratory
Sleep - Isolated REM sleep without atonia	Adults with sleep problems at a sleep laboratory
Sleep - stages	Older adults with or without cognitive impairment at home
Sleep - REM behavioral disorder	Older adults with Parkinson Disease and adults without Parkinson Disease at a sleep laboratory
Sleep	Older adults in the step-down units after ICU discharge
Hypopnea	Adult with obstructive sleep apnea in post-anesthesia care unit
Sleep - disordered breathing	Older adults without moderate or severe dementia at home
Sleep – narcolepsy episodes	No participants. The manuscript introduces a prototype of the devices.
Sleep - insomnia	Older adults with Alzheimer's Disease and insomnia at a sleep laboratory
Sleep	Adults with snoring and daytime somnolence at a laboratory
Sleep	Adults with VCIND (vascular cognitive impairment, no dementia), stroke or healthy controls at sleep laboratory
Sleep - apnea	Older adults with acute cerebral infarction and a healthy control group at a hospital
Sleep - disordered breathing and sleep disturbances	Older adults with or without asthma*
Sleep - apnea and hypopnea	Older adults with mild cognitive impairment and controls at a laboratory
Sleep - apnea	Adults with acute myocardial infarction in the ICU
Sleep - apnea	Older adults with acute stroke or transient ischemic attack in the hospital
Sleep	Adults and older adults with insomnia at a sleep laboratory
Sleep	Adults with insomnia, with or without Human Immunodeficiency Virus (HIV) at a sleep laboratory

eTable 3 Manuscripts in which the clinimetrics, acceptability or feasibility of the technologies that monitor distress and discomfort were not reported (the technology is either used as standard measurement or is newly developed) (continued)

First author	Year	Country	Monitoring technology (model and brand)
McCall	2006	USA	Not reported
Maglavera	2006	Greece	SENSATION Medical System (developed by the authors)
Martinez-Nicolas	2021	Spain	Thermochron iButton DS1921H (Maxim Integrated Products, Sunnyvale, CA), HOBO Pendant G Acceleration Data Logger UA-004–64 actimeter (Onset Computer, Bourne, MA). Standard PSG: model and brand not reported
Onen	2008	France	Embla digital portable recording system (Flaga hf., Reykjavik, Iceland)
Pao	2013	USA	Not reported
Patout	2019	UK	ALICE 5 (Philips-Respironics, Murrysville, PA, USA)
Piano	2017	Italy	Not reported
Piano	2015	Italy	Not reported
Pittsley	2005	USA	a modified Respitrace/Medilog portable recorder
Prasad	2016	USA	Embletta™ PDS system (Natus Neurology Inc., Middleton, WI)
Smith	2009	Australia	E series (Compumedics, Melbourne, Vic., Australia)
Soderstrom	2004	Sweden	Embla (Flaga hf Reykjavik, Iceland)
Targa	2020	Spain	Embletta (Embla, Canada); Sibelmed Exea Serie 5 (Sibel SAU, Spain); Alice 6 LDx (Philips Respironics, USA); ApneaLink (Resmed, Canada)
Terzaghi	2013	Italy	SD LTM 32 BS (Micromed, Treviso, Italy)
Várady	2002	Hungary	Not reported, algorism developed by the authors
Varri	2001	Finland, France	Not reported, scoring system developed by the authors
Walsh	2010	USA, UK, Germany	Not reported
Wang	2019	China	Embletta (Embla, Suffolk, UK) BI9800 (Biomedical Instruments Co., Ltd., Osaka, Japan)
Wilcock	2008	UK	Pulsox 3i (Minolta, USA)

Symptom monitored	Participant population and setting
Sleep - insomnia	Adults with insomnia at a sleep laboratory
Sleep	No participants. The manuscript presented a system and proposed its possible applications.
Sleep and circadian rhythm	Adults with or without sleep disordered breathing at home and in the hospital
Sleep - apnea	Older adults with possible sleep apnea at a sleep center
Sleep	Older adults with Lewy body dementia at a hospital
Respiration	Adult patients with chronic obstructive pulmonary disease (COPD) – obstructive sleep apnea overlap*
Sleep	Adult patients with Huntington Disease at a center for movement disorders
Sleep	Adult patients with Huntington Disease at a laboratory
Sleep - disordered breathing	Older adults at home
Sleep - apnea	Older adults with obstructive sleep apnea at home
Sleep - apnea	Adults with obstructive sleep apnea*
Sleep	Adults at home
Sleep - apnea	Older adults with Alzheimer's disease*
Sleep	Older adults with Lewy body dementia or Parkinson's Disease at a hospital
Sleep - apnea	Adults*
Sleep	No participants. The manuscript reports the development of an algorism.
Sleep	Older adults with insomnia at a laboratory
Sleep - apnea	Adults with or without obstructive sleep apnea at a hospital
Sleep - hypoxemia	Adults with advanced cancer in a specialist palliative care unit

eTable 3 Manuscripts in which the clinimetrics, acceptability or feasibility of the technologies that monitor distress and discomfort were not reported (the technology is either used as standard measurement or is newly developed) (continued)

First author	Year	Country	Monitoring technology (model and brand)
Xun	2019	China	Model not reported (Weinmann, Germany)
Zhang	2017	China, Germany	Alice 5 Diagnostic Sleep System (Philips Healthcare, Andover, USA)
Tateishi	1994	Japan	Fukuda SM28 (Fukuda, Tokyo, Japan)
Multi-modal systems – with environmental sensors			
Hoehn-Saric	2004	USA	Developed by other researchers, monitoring EDA, heart rate, activity level and ambient temperature
Multi-modal systems – other multi-model systems			
Hassan	2020	Pakistan, Saudi Arabia, Korea	Developed by the authors, including sEMG, EEG, and ECG
Non-contact monitoring systems - pressure mats			
Fukuda	2022	Japan	Nemuri Scan (Paramount Bed, Tokyo, Japan)
Higami	2019	Japan	Nemuri Scan (Paramount Bed, Tokyo, Japan)
Tong	2015	China	RS-611 (Beijing Xinxing Yangsheng Technology Co., Ltd.)
Peterson	2013	USA	Pressure mapping system (XSENSOR Technology Corporation, Calgary, Canada)
Sofronova	2021	Bulgaria	Developed by the authors

Note: Adults = mean age between 18 and 65; Older adults = mean age over 65; ICU = intensive care unit

References can be found in Supplement IV.

* The setting was not reported.

° This study aimed to test the feasibility, but did not report about it in the results or discussions.

Symptom monitored	Participant population and setting
Sleep – structure and hypoxia	Adults with obstructive sleep apnea monitored in the laboratory
Sleep – apnea and structure	Adults with snoring, with or without stroke history at a hospital
Sleep - apnea	Adults with coronary artery problems monitored in their normal daily life
Anxiety	Adults with panic disorder or general anxiety disorder and healthy controls in their own environment
Pain	No participants. The manuscript proposed a fog computer architecture for remote pain monitoring.
Sleep	Older adults with Lewy body dementia in nursing homes
Sleep	Older adults with Alzheimer's disease in nursing homes
Sleep – apnea and structure	Adults and older adults with obstructive sleep apnea-hypopnea syndrome*
Risk of pressure ulcers	Adults in intensive care and intermediate care units
Risk of pressure ulcers	One healthy adult. The manuscript reported the development of a an e-textile mat.

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Search strategy for "Noninvasive monitoring technologies to identify discomfort and distressing symptoms in persons with limited communication at the end of life: a scoping review"

Main topics: Non-invasive monitoring AND distressing symptoms.

Other topics: Dementia OR palliative care OR critically ill OR profound intellectual and multiple disability OR bedridden

Details of the search strategies for each database:

PubMed: 179
MEDLINE (OVID) 182
Embase (OVID) 184
Web of Science 186
Cochrane Library 188
Emcare (OVID) 191
PsycINFO (IEbscoHOST) 192
Academic Search Premier (EbscoHOST) 197
Google Scholar 201

PubMed:

(("Dementia"[Mesh] OR "Dementia"[tw] OR "dement*"[tw] OR "Alzheimer Disease"[tw] OR "Alzheimer*"[tw] OR "CADASIL"[tw] OR "Creutzfeldt-Jakob"[tw] OR "Creutzfeldt-Jakob Syndrome"[tw] OR "Diffuse Neurofibrillary Tangles with Calcification"[tw] OR "Frontotemporal Lobar Degeneration"[tw] OR "Huntington Disease"[tw] OR "Huntington*"[tw] OR "Kluver-Bucy"[tw] OR "Kluver-Bucy Syndrome"[tw] OR "Lewy Body"[tw] OR "Lewy Body Disease"[tw] OR "Pick Disease of the Brain"[tw] OR "Primary Progressive Aphasia"[tw] OR "Primary Progressive Nonfluent Aphasia"[tw] OR "Death"[Mesh] OR "dying"[tw] OR "end of life phase"[tw] OR "end of life"[tw] OR "end-of-life phase"[tw] OR "endoflife"[tw] OR "end-of-life"[tw] OR "Hospice and Palliative Care Nursing"[mesh] OR "Hospice Care"[Mesh] OR "Hospice Care"[tw] OR "Hospice Care"[tw] OR "Hospice"[tw] OR "Hospices"[Mesh] OR "Hospices"[tw] OR "palliat*"[tw] OR "Palliative Care"[Mesh] OR "Palliative Care"[tw] OR "Palliative Medicine"[mesh] OR "Palliative Phase"[tw] OR "Palliative Phases"[tw] OR "Palliative Stage"[tw] OR "Palliative Stages"[tw] OR "Palliative Supportive Care"[tw] OR "Palliative Surgery"[tw] OR "Palliative Therapy"[tw] OR "Palliative Treatment"[tw] OR "Palliative Treatments"[tw] OR "Terminal Care"[Mesh] OR "Terminal Care"[tw] OR "terminal stage"[tw] OR "elderly"[ti] OR "critical care"[mesh] OR "critical care"[tw] OR "intensive care"[tw] OR "Critical Illness"[Mesh] OR "Critical Illness"[tw] OR "critically ill"[tw] OR (("profound"[tw] OR "profound*"[tw]) AND ("Disabled Persons"[Mesh] OR "Intellectual Disability"[Mesh])) OR (("profound"[tw] OR "profound*"[tw]) AND ("intellectual"[tw] OR "intellectualism"[tw] OR "intellectually"[tw]

OR "intellectuals"[tw]) AND ("multiple"[tw] OR "multiples"[tw]) AND ("disabilities"[tw] OR "disability"[tw] OR "disabled persons"[MeSH Terms] OR "disabled persons"[tw] OR "disabled"[tw] OR "disablement"[tw] OR "disablements"[tw] OR "disabling"[tw] OR "disablity"[tw])) OR "Bedridden Persons"[Mesh] OR "Bedridden"[tw] OR "Non-Mobile Person"[tw] OR "Non-Mobile Persons"[tw]) AND ("activity monitor"[ti] OR "activity monitors"[ti] OR "activity monitoring"[ti] OR "activity tracker"[ti] OR "activity trackers"[ti] OR "activity tracking"[ti] OR "Ambulatory Monitor*"[ti] OR "Ambulatory Monitoring"[ti] OR "Electronic Skin"[ti] OR (("monitor*"[ti] OR "monitoring"[ti]) AND ("Telemedicine"[majr] OR "telemed*"[ti] OR "telehealth*"[ti] OR "technol*"[ti])) OR "monitoring app"[ti] OR "monitoring application"[ti] OR "monitoring applications"[ti] OR "monitoring apps"[ti] OR "monitoring device"[ti] OR "monitoring devices"[ti] OR "monitoring technologies"[ti] OR "monitoring technology"[ti] OR "Monitoring, Ambulatory"[majr] OR "Monitoring, Physiologic"[majr] OR "Monitoring, Physiologicinstrumentation"[majr] OR "Noninvasive device"[ti] OR "Non-invasive device"[ti] OR "Noninvasive devices"[ti] OR "Non-invasive devices"[ti] OR "Noninvasive monitoring device"[ti] OR "Noninvasive monitoring device"[ti] OR "Non-invasive monitoring device"[ti] OR "Noninvasive monitoring devices"[ti] OR "Noninvasive monitoring devices"[ti] OR "Non-invasive monitoring devices"[ti] OR "Noninvasive monitoring technologies"[ti] OR "Noninvasive monitoring technologies"[ti] OR "Non-invasive monitoring technologies"[ti] OR "Noninvasive monitoring technology"[ti] OR "Noninvasive monitoring technology"[ti] OR "Non-invasive monitoring technology"[ti] OR "Noninvasive monitoring"[ti] OR "Non-invasive monitoring"[ti] OR "Noninvasive technologies"[ti] OR "Non-invasive technologies"[ti] OR "Noninvasive technology"[ti] OR "Non-invasive technology"[ti] OR "Outpatient Monitor*"[ti] OR "Outpatient Monitoring"[ti] OR "Portable Electronic Application"[ti] OR "Portable Electronic Applications"[ti] OR "Portable Software Application"[ti] OR "Portable Software Applications"[ti] OR "Smart watch"[ti] OR "Smart watches"[ti] OR "Smartwatch"[ti] OR "Smartwatches"[ti] OR "tracker"[ti] OR "trackers"[ti] OR "wearab*"[ti] OR "wearable activity tracker"[ti] OR "wearable activity trackers"[ti] OR "wearable activity tracking"[ti] OR "Wearable Device"[ti] OR "Wearable Devices"[ti] OR "Wearable Electronic Device"[ti] OR "Wearable Electronic Devices"[majr] OR "Wearable Electronic Devices"[ti] OR "Wearable Technologies"[ti] OR "Wearable Technology"[ti] OR "wearable"[ti] OR "wearables"[ti] OR "noninvasive body sensor"[ti] OR "noninvasive body sensors"[ti] OR "non invasive body sensor"[ti] OR "non invasive body sensors"[ti] OR "body sensor"[ti] OR "body sensors"[ti] OR "wristband sensor"[ti] OR "wristband sensors"[ti] OR "wearable computing"[ti] OR "wearable computer"[ti] OR "wearable computers"[ti] OR "point-of-care App"[ti] OR "point-of-care Apps"[ti] OR "point-of-care Application"[ti] OR "point-of-care Applications"[ti] OR "facial recognition technology"[ti] OR "face recognition technology"[ti] OR "Point-of-Care Technology"[ti] OR "Point-of-Care Techn*"[ti] OR "HUME"[ti] OR "ePAT"[ti] OR " electronic pain assessment"[ti] OR ("BIS"[ti] AND "bispectral"[ti]) OR "bispectral index"[ti] OR "Consciousness Monitors"[majr] OR "Biosensing Techniques"[majr] OR ("Facial Expression"[majr] AND "Point-of-Care Systems"[majr]) OR (("noninvasiv*"[ti] OR "non invasiv*"[ti] OR "unobtrusiv*"[ti] OR "portable"[ti] OR "Mobile Applications"[Mesh]) AND "monitor*"[ti]) OR "Painchek"[tw] OR "Paincheck"[tw] OR "automated facial analysis"[tw] OR "automated facial recognition"[tw] OR "automated facial expression analysis"[tw]) AND ("discomfort"[ti] OR "discomfort*"[ti] OR "Psychological Distress"[majr] OR "distressing symptoms"[ti] OR "distressing symptom"[ti] OR "distressing"[ti] OR "distress"[ti]

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MEDLINE (OVID)

(exp "Dementia"/ OR "Dementia".mp OR "dement*".mp OR "Alzheimer Disease".mp OR "Alzheimer*".mp OR "CADASIL".mp OR "Creutzfeldt-Jakob".mp OR "Creutzfeldt-Jakob Syndrome".mp OR "Diffuse Neurofibrillary Tangles with Calcification".mp OR "Frontotemporal Lobar Degeneration".mp OR "Huntington Disease".mp OR "Huntington*". mp OR "Kluver-Bucy".mp OR "Kluver-Bucy Syndrome".mp OR "Lewy Body".mp OR "Lewy Body Disease".mp OR "Pick Disease of the Brain".mp OR "Primary Progressive Aphasia". mp OR "Primary Progressive Nonfluent Aphasia".mp OR exp "Death"/ OR "dying".mp OR "end of life phase".mp OR "end of life".mp OR "end-of-life phase".mp OR "endoflife".mp OR "end-of-life".mp OR exp "Hospice AND Palliative Care Nursing"/ OR exp "Hospice Care"/ OR "Hospice Care".mp OR "Hospice Care".mp OR "Hospice".mp OR exp "Hospices"/ OR "Hospices".mp OR "palliat*".mp OR exp "Palliative Care"/ OR "Palliative Care".mp OR exp "Palliative Medicine"/ OR "Palliative Phase".mp OR "Palliative Phases".mp OR "Palliative Stage".mp OR "Palliative Stages".mp OR "Palliative Supportive Care".mp OR "Palliative Surgery".mp OR "Palliative Therapy".mp OR "Palliative Treatment".mp OR "Palliative Treatments".mp OR exp "Terminal Care"/ OR "Terminal Care".mp OR "terminal stage". mp OR "elderly".ti. OR exp "critical care"/ OR "critical care".mp OR "intensive care".mp OR exp "Critical Illness"/ OR "Critical Illness".mp OR "critically ill".mp OR (("profound" OR "profound*").mp AND (exp "Disabled Persons"/ OR exp "Intellectual Disability"/)) OR (((("profound" OR "profound*") AND ("intellectual" OR "intellectualism" OR "intellectually" OR "intellectuals") AND ("multiple" OR "multiples")).mp AND (("disabilities" OR "disability").mp OR exp "disabled persons"/ OR "disabled persons".mp OR "disabled".mp OR "disablement".mp OR "disablements".mp OR "disabling".mp OR "disablity".mp)) OR exp "Bedridden Persons"/ OR "Bedridden".mp OR "Non-Mobile Person".mp OR "Non-Mobile Persons".mp) AND (("activity monitor" OR "activity monitors" OR "activity monitoring" OR "activity tracker" OR "activity trackers" OR "activity tracking" OR "Ambulatory Monitor*" OR "Ambulatory Monitoring" OR "Electronic Skin").ti. OR (("monitor*" OR "monitoring"). ti. AND (exp *"Telemedicine"/ OR "telemed*".ti. OR "telehealth*".ti. OR "technol*".ti.)) OR "monitoring app".ti. OR "monitoring application".ti. OR "monitoring applications".ti. OR "monitoring apps".ti. OR "monitoring device".ti. OR "monitoring devices".ti. OR "monitoring

technologies".ti. OR "monitoring technology".ti. OR exp *"Monitoring, Ambulatory"/ OR exp *"Monitoring, Physiologic"/ OR "Noninvasive device".ti. OR "Non-invasive device".ti. OR "Noninvasive devices".ti. OR "Non-invasive devices".ti. OR "Noninvasive monitoring device".ti. OR "Noninvasive monitoring device".ti. OR "Non-invasive monitoring device". ti. OR "Noninvasive monitoring devices".ti. OR "Noninvasive monitoring devices".ti. OR "Non-invasive monitoring devices".ti. OR "Noninvasive monitoring technologies".ti. OR "Noninvasive monitoring technologies".ti. OR "Non-invasive monitoring technologies".ti. OR "Noninvasive monitoring technology".ti. OR "Noninvasive monitoring technology".ti. OR "Non-invasive monitoring technology".ti. OR "Noninvasive monitoring".ti. OR "Non-invasive monitoring".ti. OR "Noninvasive technologies".ti. OR "Non-invasive technologies". ti. OR "Noninvasive technology".ti. OR "Non-invasive technology".ti. OR "Outpatient Monitor*".ti. OR "Outpatient Monitoring".ti. OR "Portable Electronic Application". ti. OR "Portable Electronic Applications".ti. OR "Portable Software Application".ti. OR "Portable Software Applications".ti. OR "Smart watch".ti. OR "Smart watches".ti. OR "Smartwatch".ti. OR "Smartwatches".ti. OR "tracker".ti. OR "trackers".ti. OR "wearab*".ti. OR "wearable activity tracker".ti. OR "wearable activity trackers".ti. OR "wearable activity tracking".ti. OR "Wearable Device".ti. OR "Wearable Devices".ti. OR "Wearable Electronic Device".ti. OR exp *"Wearable Electronic Devices"/ OR "Wearable Electronic Devices". ti. OR "Wearable Technologies".ti. OR "Wearable Technology".ti. OR "wearable".ti. OR "wearables".ti. OR "noninvasive body sensor".ti. OR "noninvasive body sensors".ti. OR "non invasive body sensor".ti. OR "non invasive body sensors".ti. OR "body sensor".ti. OR "body sensors".ti. OR "wristband sensor".ti. OR "wristband sensors".ti. OR "wearable computing". ti. OR "wearable computer".ti. OR "wearable computers".ti. OR "point-of-care App".ti. OR "point-of-care Apps".ti. OR "point-of-care Application".ti. OR "point-of-care Applications". ti. OR "facial recognition technology".ti. OR "face recognition technology".ti. OR "Point-of-Care Technology".ti. OR "Point-of-Care Techn*".ti. OR "HUME".ti. OR "ePAT". ti. OR " electronic pain assessment".ti. OR ("BIS" AND "bispectral").ti. OR "bispectral index".ti. OR exp *"Consciousness Monitors"/ OR exp *"Biosensing Techniques"/ OR (exp *"Facial Expression"/ AND exp *"Point-of-Care Systems"/) OR (((("noninvasiv*" OR "non invasiv*" OR "unobtrusiv*" OR "portable").ti. OR exp "Mobile Applications"/) AND "monitor*".ti.) OR "Painchek".mp OR "Paincheck".mp OR "automated facial analysis".mp OR "automated facial recognition".mp OR "automated facial expression analysis".mp) AND (("discomfort" OR "discomfort*").ti. OR exp *"Psychological Distress"/ OR "distressing symptoms".ti. OR "distressing symptom".ti. OR "distressing".ti. OR "distress".ti. OR exp *"Patient Comfort"/ OR "comfort".ti. OR "comfort*".ti. OR exp *"Psychomotor Agitation"/ OR "agitation".ti. OR "agitat*".ti. OR "restlessness".ti. OR "restless*".ti. OR "hyperactivity". ti. OR "hyperactiv*".ti. OR "akathisia".ti. OR exp *"Pain"/ OR "pain".ti. OR exp *"Pain Measurement"/ OR "pain assessment".ti. OR exp *"Stress, Psychological"/ OR "stress level". ti. OR "stress levels".ti. OR "pressure ulcer".ti. OR "pressure ulcer".ti. OR "life quality".ti. OR exp *"quality of life"/ OR "quality of life".ti. OR "breathing difficulty".ti. OR "difficulty breathing".ti. OR "difficult breathing".ti. OR "labored breathing".ti. OR "laboured breathing". ti. OR "Shortness of Breath".ti. OR "Breath Shortness".ti. OR "Breathlessness".ti. OR exp *"Dyspnea"/ OR "Dyspnea".ti. OR exp *"Anxiety"/ OR "Anxiety".ti. OR "Nervousness". ti. OR "Hypervigilance".ti. OR "Anxiousness".ti. OR exp *"Sleep Wake Disorders"/ OR "sleep disturbances".ti. OR "sleep disturbance".ti. OR exp *"Fatigue"/ OR "fatigue".ti. OR exp *"Nausea"/ OR "nausea".ti. OR "nauseous".ti. OR exp *"Delirium"/ OR "delirium".ti.

OR "delirious".ti. OR exp *"Fever"/ OR "fever".ti. OR exp *"Urinary Incontinence"/ OR "Incontinence".ti. OR "incontinen*".ti. OR "Sedation depth".ti. OR "Sedation depths".ti. OR "Depth of sedation".ti.)

Embase (OVID)

((exp *"Dementia"/ OR ("Dementia" OR "dement*" OR "Alzheimer Disease" OR "Alzheimer*" OR "CADASIL" OR "Creutzfeldt-Jakob" OR "Creutzfeldt-Jakob Syndrome" OR "Diffuse Neurofibrillary Tangles with Calcification" OR "Frontotemporal Lobar Degeneration" OR "Huntington Disease" OR "Huntington*" OR "Kluver-Bucy" OR "Kluver-Bucy Syndrome" OR "Lewy Body" OR "Lewy Body Disease" OR "Pick Disease of the Brain" OR "Primary Progressive Aphasia" OR "Primary Progressive Nonfluent Aphasia").ti,ab OR exp *"Death"/ OR exp *"Terminal Care"/ OR exp *"Hospice"/ OR exp *"Palliative Therapy"/ OR ("dying" OR "end of life phase" OR "end of life" OR "end-of-life phase" OR "endoflife" OR "end-of-life" OR "Hospice and Palliative Care Nursing" OR "Hospice Care" OR "Hospice Care" OR "Hospice Care" OR "Hospice" OR "Hospices" OR "Hospices" OR "palliat*" OR "Palliative Care" OR "Palliative Care" OR "Palliative Medicine" OR "Palliative Phase" OR "Palliative Phases" OR "Palliative Stage" OR "Palliative Stages" OR "Palliative Supportive Care" OR "Palliative Surgery" OR "Palliative Therapy" OR "Palliative Treatment" OR "Palliative Treatments" OR "Terminal Care" OR "Terminal Care" OR "terminal stage").ti,ab OR "elderly".ti OR exp *"Intensive Care"/ OR exp *"Critical Illness"/ OR exp *"critically ill patient"/ OR ("critical care" OR "critical care" OR "intensive care" OR "Critical Illness" OR "Critical Illness" OR "critically ill") OR (("profound" OR "profound*").ti,ab AND (exp *"Disabled Person"/ OR exp *"Intellectual Impairment"/)) OR (("profound" OR "profound*") AND ("intellectual" OR "intellectualism" OR "intellectually" OR "intellectuals") AND ("multiple" OR "multiples") AND ("disabilities" OR "disability" OR "disabled persons" OR "disabled persons" OR "disabled" OR "disablement" OR "disablements" OR "disabling" OR "disablity")).ti,ab OR exp *"Bedridden Patient"/ OR ("Bedridden" OR "Non-Mobile Person" OR "Non-Mobile Persons").ti,ab) AND (("activity monitor" OR "activity monitors" OR "activity monitoring" OR "activity tracker" OR "activity trackers" OR "activity tracking" OR "Ambulatory Monitor*" OR "Ambulatory Monitoring" OR "Electronic Skin").ti. OR (("monitor*" OR "monitoring").ti. AND (exp *"Telemedicine"/ OR "telemed*".ti. OR "telehealth*".ti. OR "technol*".ti.)) OR "monitoring app".ti. OR "monitoring application".ti. OR "monitoring applications".ti. OR "monitoring apps".ti. OR "monitoring device".ti. OR "monitoring devices".ti. OR "monitoring technologies".ti. OR "monitoring technology".ti. OR exp *"Monitoring, Ambulatory"/ OR exp *"Monitoring, Physiologic"/ OR exp *"Ambulatory Monitoring"/ OR exp *"Physiologic Monitoring"/ OR "Noninvasive device".ti. OR "Non-invasive device".ti. OR "Noninvasive devices".ti. OR "Non-invasive devices".ti. OR "Noninvasive monitoring device".ti. OR "Noninvasive monitoring device".ti. OR "Non-invasive monitoring device".ti. OR "Noninvasive monitoring devices". ti. OR "Noninvasive monitoring devices".ti. OR "Non-invasive monitoring devices".ti. OR "Noninvasive monitoring technologies".ti. OR "Noninvasive monitoring technologies".ti. OR "Non-invasive monitoring technologies".ti. OR "Noninvasive monitoring technology". ti. OR "Noninvasive monitoring technology".ti. OR "Non-invasive monitoring technology". ti. OR "Noninvasive monitoring".ti. OR "Non-invasive monitoring".ti. OR "Noninvasive technologies".ti. OR "Non-invasive technologies".ti. OR "Noninvasive technology".ti. OR "Non-invasive technology".ti. OR "Outpatient Monitor*".ti. OR "Outpatient Monitoring".

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Web of Science

(TS=("Dementia" OR "Dementia" OR "dement*" OR "Alzheimer Disease" OR "Alzheimer*" OR "CADASIL" OR "Creutzfeldt-Jakob" OR "Creutzfeldt-Jakob Syndrome" OR "Diffuse Neurofibrillary Tangles with Calcification" OR "Frontotemporal Lobar Degeneration" OR

"Huntington Disease" OR "Huntington*" OR "Kluver-Bucy" OR "Kluver-Bucy Syndrome" OR "Lewy Body" OR "Lewy Body Disease" OR "Pick Disease of the Brain" OR "Primary Progressive Aphasia" OR "Primary Progressive Nonfluent Aphasia" OR "Death" OR "dying" OR "end of life phase" OR "end of life" OR "end-of-life phase" OR "endoflife" OR "end-of-life" OR "Hospice and Palliative Care Nursing" OR "Hospice Care" OR "Hospice Care" OR "Hospice Care" OR "Hospice" OR "Hospices" OR "Hospices" OR "palliat*" OR "Palliative Care" OR "Palliative Care" OR "Palliative Medicine" OR "Palliative Phase" OR "Palliative Phases" OR "Palliative Stage" OR "Palliative Stages" OR "Palliative Supportive Care" OR "Palliative Surgery" OR "Palliative Therapy" OR "Palliative Treatment" OR "Palliative Treatments" OR "Terminal Care" OR "Terminal Care" OR "terminal stage" OR "elderly" OR "critical care" OR "critical care" OR "intensive care" OR "Critical Illness" OR "Critical Illness" OR "critically ill" OR (("profound" OR "profound*") AND ("Disabled Persons" OR "Intellectual Disability")) OR (("profound" OR "profound*") AND ("intellectual" OR "intellectualism" OR "intellectually" OR "intellectuals") AND ("multiple" OR "multiples") AND ("disabilities" OR "disability" OR "disabled persons" OR "disabled persons" OR "disabled" OR "disablement" OR "disablements" OR "disabling" OR "disablity")) OR "Bedridden Persons" OR "Bedridden" OR "Non-Mobile Person" OR "Non-Mobile Persons") AND TS=("activity monitor" OR "activity monitors" OR "activity monitoring" OR "activity tracker" OR "activity trackers" OR "activity tracking" OR "Ambulatory Monitor*" OR "Ambulatory Monitoring" OR "Electronic Skin" OR (("monitor*" OR "monitoring") AND ("Telemedicine" OR "telemed*" OR "telehealth*" OR "technol*")) OR "monitoring app" OR "monitoring application" OR "monitoring applications" OR "monitoring apps" OR "monitoring device" OR "monitoring devices" OR "monitoring technologies" OR "monitoring technology" OR "Monitoring, Ambulatory" OR "Monitoring, Physiologic" OR "Noninvasive device" OR "Non-invasive device" OR "Noninvasive devices" OR "Non-invasive devices" OR "Noninvasive monitoring device" OR "Noninvasive monitoring device" OR "Non-invasive monitoring device" OR "Noninvasive monitoring devices" OR "Noninvasive monitoring devices" OR "Non-invasive monitoring devices" OR "Noninvasive monitoring technologies" OR "Noninvasive monitoring technologies" OR "Non-invasive monitoring technologies" OR "Noninvasive monitoring technology" OR "Noninvasive monitoring technology" OR "Non-invasive monitoring technology" OR "Noninvasive monitoring" OR "Non-invasive monitoring" OR "Noninvasive technologies" OR "Non-invasive technologies" OR "Noninvasive technology" OR "Non-invasive technology" OR "Outpatient Monitor*" OR "Outpatient Monitoring" OR "Portable Electronic Application" OR "Portable Electronic Applications" OR "Portable Software Application" OR "Portable Software Applications" OR "Smart watch" OR "Smart watches" OR "Smartwatch" OR "Smartwatches" OR "tracker" OR "trackers" OR "wearab*" OR "wearable activity tracker" OR "wearable activity trackers" OR "wearable activity tracking" OR "Wearable Device" OR "Wearable Devices" OR "Wearable Electronic Device" OR "Wearable Electronic Devices" OR "Wearable Electronic Devices" OR "Wearable Technologies" OR "Wearable Technology" OR "wearable" OR "wearables" OR "noninvasive body sensor" OR "noninvasive body sensors" OR "non invasive body sensor" OR "non invasive body sensors" OR "body sensor" OR "body sensors" OR "wristband sensor" OR "wristband sensors" OR "wearable computing" OR "wearable computer" OR "wearable computers" OR "point-of-care App" OR "point-of-care Apps" OR "point-of-care Application" OR "point-of-care Applications" OR "facial recognition technology" OR "face recognition technology" OR "Point-of-Care Technology" OR "Point-

of-Care Techn*" OR "HUME" OR "ePAT" OR " electronic pain assessment" OR ("BIS" AND "bispectral") OR "bispectral index" OR "Consciousness Monitors" OR "Biosensing Techniques" OR ("Facial Expression" AND "Point-of-Care Systems") OR (("noninvasiv*" OR "non invasiv*" OR "unobtrusiv*" OR "portable" OR "Mobile Applications") AND "monitor*") OR "Painchek" OR "Paincheck" OR "automated facial analysis" OR "automated facial recognition" OR "automated facial expression analysis") AND TI=("discomfort" OR "discomfort*" OR "Psychological Distress" OR "distressing symptoms" OR "distressing symptom" OR "distressing" OR "distress" OR "Patient Comfort" OR "comfort" OR "comfort*" OR "Psychomotor Agitation" OR "agitation" OR "agitat*" OR "restlessness" OR "restless*" OR "hyperactivity" OR "hyperactiv*" OR "akathisia" OR "Pain" OR "pain" OR "Pain Measurement" OR "pain assessment" OR "Stress, Psychological" OR "stress level" OR "stress levels" OR "pressure ulcer" OR "pressure ulcer" OR "life quality" OR "quality of life" OR "quality of life" OR "breathing difficulty" OR "difficulty breathing" OR "difficult breathing" OR "labored breathing" OR "laboured breathing" OR "Shortness of Breath" OR "Breath Shortness" OR "Breathlessness" OR "Dyspnea" OR "Dyspnea" OR "Anxiety" OR "Anxiety" OR "Nervousness" OR "Hypervigilance" OR "Anxiousness" OR "Sleep Wake Disorders" OR "sleep disturbances" OR "sleep disturbance" OR "Fatigue" OR "fatigue" OR "Nausea" OR "nausea" OR "nauseous" OR "Delirium" OR "delirium" OR "delirious" OR "Fever" OR "fever" OR "Urinary Incontinence" OR "Incontinence" OR "incontinen*" OR "Sedation depth" OR "Sedation depths" OR "Depth of sedation"))

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(("Dementia" OR "Dementia" OR "dement*" OR "Alzheimer Disease" OR "Alzheimer*" OR "CADASIL" OR "Creutzfeldt Jakob" OR "Creutzfeldt Jakob Syndrome" OR "Diffuse Neurofibrillary Tangles with Calcification" OR "Frontotemporal Lobar Degeneration" OR "Huntington Disease" OR "Huntington*" OR "Kluver Bucy" OR "Kluver Bucy Syndrome" OR "Lewy Body" OR "Lewy Body Disease" OR "Pick Disease of the Brain" OR "Primary Progressive Aphasia" OR "Primary Progressive Nonfluent Aphasia" OR "Death" OR "dying" OR "end of life phase" OR "end of life" OR "end of life phase" OR "endoflife" OR "end of life" OR "Hospice and Palliative Care Nursing" OR "Hospice Care" OR "Hospice Care" OR "Hospice Care" OR "Hospice" OR "Hospices" OR "Hospices" OR "palliat*" OR "Palliative Care" OR "Palliative Care" OR "Palliative Medicine" OR "Palliative Phase" OR "Palliative Phases" OR "Palliative Stage" OR "Palliative Stages" OR "Palliative Supportive Care" OR "Palliative Surgery" OR "Palliative Therapy" OR "Palliative Treatment" OR "Palliative Treatments" OR "Terminal Care" OR "Terminal Care" OR "terminal stage" OR "elderly" OR "critical care" OR "critical care" OR "intensive care" OR "Critical Illness" OR "Critical Illness" OR "critically ill" OR (("profound" OR "profound*") AND ("Disabled Persons" OR "Intellectual Disability")) OR (("profound" OR "profound*") AND ("intellectual" OR "intellectualism" OR "intellectually" OR "intellectuals") AND ("multiple" OR "multiples") AND ("disabilities" OR "disability" OR "disabled persons" OR "disabled persons" OR "disabled" OR "disablement" OR "disablements" OR "disabling" OR "disablity")) OR "Bedridden Persons" OR "Bedridden" OR "Non Mobile Person" OR "Non Mobile Persons"):ti,ab,kw AND ("activity monitor" OR "activity monitors" OR "activity monitoring" OR "activity tracker" OR "activity trackers" OR "activity tracking" OR "Ambulatory Monitor*" OR "Ambulatory Monitoring" OR "Electronic Skin" OR (("monitor*" OR "monitoring") AND ("Telemedicine" OR "telemed*" OR "telehealth*" OR "technol*")) OR

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Emcare (OVID)

((exp *"Dementia"/ OR ("Dementia" OR "dement*" OR "Alzheimer Disease" OR "Alzheimer*" OR "CADASIL" OR "Creutzfeldt-Jakob" OR "Creutzfeldt-Jakob Syndrome" OR "Diffuse Neurofibrillary Tangles with Calcification" OR "Frontotemporal Lobar Degeneration" OR "Huntington Disease" OR "Huntington*" OR "Kluver-Bucy" OR "Kluver-Bucy Syndrome" OR "Lewy Body" OR "Lewy Body Disease" OR "Pick Disease of the Brain" OR "Primary Progressive Aphasia" OR "Primary Progressive Nonfluent Aphasia").ti,ab OR exp *"Death"/ OR exp *"Terminal Care"/ OR exp *"Hospice"/ OR exp *"Palliative Therapy"/ OR ("dying" OR "end of life phase" OR "end of life" OR "end-of-life phase" OR "endoflife" OR "end-of-life" OR "Hospice and Palliative Care Nursing" OR "Hospice Care" OR "Hospice Care" OR "Hospice Care" OR "Hospice" OR "Hospices" OR "Hospices" OR "palliat*" OR "Palliative Care" OR "Palliative Care" OR "Palliative Medicine" OR "Palliative Phase" OR "Palliative Phases" OR "Palliative Stage" OR "Palliative Stages" OR "Palliative Supportive Care" OR "Palliative Surgery" OR "Palliative Therapy" OR "Palliative Treatment" OR "Palliative Treatments" OR "Terminal Care" OR "Terminal Care" OR "terminal stage").ti,ab OR "elderly".ti OR exp *"Intensive Care"/ OR exp *"Critical Illness"/ OR exp *"critically ill patient"/ OR ("critical care" OR "critical care" OR "intensive care" OR "Critical Illness" OR "Critical Illness" OR "critically ill") OR (("profound" OR "profound*").ti,ab AND (exp *"Disabled Person"/ OR exp *"Intellectual Impairment"/)) OR (("profound" OR "profound*") AND ("intellectual" OR "intellectualism" OR "intellectually" OR "intellectuals") AND ("multiple" OR "multiples") AND ("disabilities" OR "disability" OR "disabled persons" OR "disabled persons" OR "disabled" OR "disablement" OR "disablements" OR "disabling" OR "disablity")).ti,ab OR exp *"Bedridden Patient"/ OR

("Bedridden" OR "Non-Mobile Person" OR "Non-Mobile Persons").ti,ab) AND (("activity monitor" OR "activity monitors" OR "activity monitoring" OR "activity tracker" OR "activity trackers" OR "activity tracking" OR "Ambulatory Monitor*" OR "Ambulatory Monitoring" OR "Electronic Skin").ti. OR (("monitor*" OR "monitoring").ti. AND (exp *"Telemedicine"/ OR "telemed*".ti. OR "telehealth*".ti. OR "technol*".ti.)) OR "monitoring app".ti. OR "monitoring application".ti. OR "monitoring applications".ti. OR "monitoring apps".ti. OR "monitoring device".ti. OR "monitoring devices".ti. OR "monitoring technologies".ti. OR "monitoring technology".ti. OR exp *"Monitoring, Ambulatory"/ OR exp *"Monitoring, Physiologic"/ OR exp *"Ambulatory Monitoring"/ OR exp *"Physiologic Monitoring"/ OR "Noninvasive device".ti. OR "Non-invasive device".ti. OR "Noninvasive devices".ti. OR "Non-invasive devices".ti. OR "Noninvasive monitoring device".ti. OR "Noninvasive monitoring device".ti. OR "Non-invasive monitoring device".ti. OR "Noninvasive monitoring devices". ti. OR "Noninvasive monitoring devices".ti. OR "Non-invasive monitoring devices".ti. OR "Noninvasive monitoring technologies".ti. OR "Noninvasive monitoring technologies".ti. OR "Non-invasive monitoring technologies".ti. OR "Noninvasive monitoring technology". ti. OR "Noninvasive monitoring technology".ti. OR "Non-invasive monitoring technology". ti. OR "Noninvasive monitoring".ti. OR "Non-invasive monitoring".ti. OR "Noninvasive technologies".ti. OR "Non-invasive technologies".ti. OR "Noninvasive technology".ti. OR "Non-invasive technology".ti. OR "Outpatient Monitor*".ti. OR "Outpatient Monitoring". ti. OR "Portable Electronic Application".ti. OR "Portable Electronic Applications".ti. OR "Portable Software Application".ti. OR "Portable Software Applications".ti. OR "Smart watch".ti. OR "Smart watches".ti. OR "Smartwatch".ti. OR "Smartwatches".ti. OR "tracker".ti. OR "trackers".ti. OR "wearab*".ti. OR "wearable activity tracker".ti. OR "wearable activity trackers".ti. OR "wearable activity tracking".ti. OR "Wearable Device". ti. OR "Wearable Devices".ti. OR "Wearable Electronic Device".ti. OR exp *"Wearable Electronic Devices"/ OR exp *"wearable computer"/ OR "Wearable Electronic Devices". ti. OR "Wearable Technologies".ti. OR "Wearable Technology".ti. OR "wearable".ti. OR "wearables".ti. OR "noninvasive body sensor".ti. OR "noninvasive body sensors".ti. OR "non invasive body sensor".ti. OR "non invasive body sensors".ti. OR "body sensor".ti. OR "body sensors".ti. OR "wristband sensor".ti. OR "wristband sensors".ti. OR "wearable computing". ti. OR "wearable computer".ti. OR "wearable computers".ti. OR "point-of-care App".ti. OR "point-of-care Apps".ti. OR "point-of-care Application".ti. OR "point-of-care Applications". ti. OR "facial recognition technology".ti. OR "face recognition technology".ti. OR "Point-of-Care Technology".ti. OR "Point-of-Care Techn*".ti. OR "HUME".ti. OR "ePAT".ti. OR " electronic pain assessment".ti. OR ("BIS" AND "bispectral").ti. OR "bispectral index".ti. OR exp *"Consciousness Monitor"/ OR exp *"Consciousness Monitors"/ OR exp *"Biosensing Techniques"/ OR (exp *"Facial Expression"/ AND (exp *"Point-of-Care Systems"/ OR exp *"Point of Care System"/)) OR ((("noninvasiv*" OR "non invasiv*" OR "unobtrusiv*" OR "portable").ti. OR exp "Mobile Applications"/ OR exp *"Mobile Application"/) AND "monitor*".ti.) OR "Painchek".mp OR "Paincheck".mp OR "automated facial analysis".mp OR "automated facial recognition".mp OR "automated facial expression analysis".mp) AND (("discomfort" OR "discomfort*").ti. OR exp *"Psychological Distress"/ OR exp *"distress syndrome"/ OR "distressing symptoms".ti. OR "distressing symptom".ti. OR "distressing". ti. OR "distress".ti. OR exp *"Patient Comfort"/ OR "comfort".ti. OR "comfort*".ti. OR exp *"Psychomotor Agitation"/ OR exp *"Restlessness"/ OR "agitation".ti. OR "agitat*". ti. OR "restlessness".ti. OR "restless*".ti. OR "hyperactivity".ti. OR "hyperactiv*".ti. OR

"akathisia".ti. OR exp *"Pain"/ OR "pain".ti. OR exp *"Pain Measurement"/ OR "pain assessment".ti. OR exp *"Stress, Psychological"/ OR exp *"Mental stress"/ OR "stress level".ti. OR "stress levels".ti. OR "pressure ulcer".ti. OR "pressure ulcer".ti. OR "life quality".ti. OR exp *"quality of life"/ OR "quality of life".ti. OR "breathing difficulty".ti. OR "difficulty breathing".ti. OR "difficult breathing".ti. OR "labored breathing".ti. OR "laboured breathing".ti. OR "Shortness of Breath".ti. OR "Breath Shortness".ti. OR "Breathlessness".ti. OR exp *"Dyspnea"/ OR "Dyspnea".ti. OR exp *"Anxiety"/ OR "Anxiety".ti. OR "Nervousness".ti. OR "Hypervigilance".ti. OR "Anxiousness".ti. OR exp *"Sleep Disorder"/ OR exp *"Sleep Wake Disorders"/ OR "sleep disturbances".ti. OR "sleep disturbance".ti. OR exp *"Fatigue"/ OR "fatigue".ti. OR exp *"Nausea"/ OR "nausea".ti. OR "nauseous".ti. OR exp *"Delirium"/ OR "delirium".ti. OR "delirious".ti. OR exp *"Fever"/ OR "fever".ti. OR exp *"Urinary Incontinence"/ OR exp *"Urine Incontinence"/ OR "Incontinence".ti. OR "incontinen*".ti. OR "Sedation depth".ti. OR "Sedation depths".ti. OR "Depth of sedation".ti. OR exp *"anesthesia level"/))

PsycINFO (EbscoHOST)

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"Dementia"|"dying"|"end of life"|"Palliative"|"Hospice"|"critical care"|"Bedridden" "activity monitor"|"activity tracker"|"monitoring app" "discomfort"|"Distress"|"comfort"|"pain"