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PRESSURE ULCERS

PREDICTING FACTORS, PREVENTION AND COSTS

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“Onze grootste overwinning is niet dat we nooit falen,
maar dat we telkens als we struikelen weer opstaan”

(Analecta Boek II, XXIV, Confucius, 551 v.C. – 479 v.C)

Voor mijn ouders

Voor Kim, Brecht en Dries

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION AND RESEARCH AIMS

1. PRESSURE ULCER DEFINITION AND AETIOLOGY

Pressure ulcers are defined as “localized injuries to the skin and/or underlying tissue, usually over a bony prominence, caused by pressure, or pressure in combination with shear” (National Pressure Ulcer Advisory Panel and European Pressure Ulcer Advisory Panel (NPUAP & EPUAP), 2009). Pressure ulcers develop as a result of the applied external mechanical load, which comprises all types of external forces applied to a patients’ skin and underlying tissue due to the contact with a support surface (NPUAP & EPUAP, 2009). The extent of the skin and/or tissue damage will depend on the duration and magnitude of the applied load (pressure and shear). A high mechanical load for a short period, as well as a low mechanical load applied for a long period can lead to tissue damage (Loerakker et al., 2011; NPUAP & EPUAP, 2009; Stekelenburg et al., 2008)

Pressure ulcer development is a complex and multi-factorial process that is still not fully understood. When the skin and/or underlying tissue are exposed to pressure and shear, a combination of several mechanisms can result in tissue damage. The primary mechanisms include oxygen deprivation (NPUAP & EPUAP, 2009), direct cell deformation (Ceelen et al., 2008; Gawlitta et al., 2007a; Stekelenburg et al., 2007), ischemic reperfusion injury (Peirce et al., 2000; Reid et al., 2004; Tsuji et al., 2005), and impaired lymphatic drainage (Miller and Seale, 1981).

Oxygen deprivation or ischemia was recognised as one of the primary etiological factors in pressure ulcer development. Pressure and shear cause occlusion of the capillary blood vessels, which leads to a decrease or absence of nutrient supply and the accumulation of metabolic waste products. Furthermore, the capillary permeability will increase, and oedema and cellular infiltration will occur, leading to tissue damage and necrosis (Coleman et al., 2014; Daniel et al., 1981; Kosiak, 1961; Kottner et al., 2009a; Loerakker et al., 2011). The role and effects of oxygen deprivation become more important when there is a prolonged exposure to pressure and shear (Loerakker et al., 2011).

Direct cell deformation assumes that a mechanical load results in a variety of effects, such as local membrane stresses, and cytoskeletal reorganisation. These changes of the mechanical and chemical environment of the cell induce tissue damage. This tissue damage only occurs if a deformation threshold is exceeded. Cell death can occur rapidly (Gefen et al., 2008; Loerakker et al., 2011). Furthermore, the amount of tissue damage is correlated with the level of the deformation (Loerakker et al., 2011). In contrast to oxygen deprivation, the effect of direct cell deformation occurs immediately if the deformation threshold is exceeded (Gawlitta et al., 2007b; Gawlitta et al., 2007a; Loerakker et al., 2011).

Ischemic reperfusion injury can be defined as tissue and cellular injury resulting from the re-establishment of blood flow and oxygen to a previously ischemic tissue (Pretto, 1991). Ischemic reperfusion injury was found to be a causal factor for several post-ischemic pathologies, such as myocardial infarction, but their role in the development of pressure ulcers is less known and only recently discussed (Bosboom et al., 2001; Peirce et al., 2000; Tsuji et al., 2005).
The role of ischemic reperfusion refers to the activation of damaging processes as a result of re-introduction of oxygen generating reactive oxygen species, such as unstable and highly reactive free radicals (Peirce et al., 2000; Tsuji et al., 2005). Gradual reperfusion of ischemic tissue is reported as a possible method to prevent an ischemic reperfusion injury (Okamoto et al., 1986). An in-vitro study in animals by Unal et al. (2001) found that gradual reperfusion of ischemic tissue resulted in a reduction of ischemic reperfusion injury (Unal et al., 2001).

Impaired lymphatic drainage can contribute to pressure ulcer development due to the accumulation of anaerobic metabolic waste products as a result of occluded and/or ischemic lymph vessels. This accumulation of waste products causes tissue necrosis, thereby contributing to the development of pressure ulcers (Krouskop et al., 1978).
Pressure ulcers can develop both superficially (involving the epidermis and dermis), or in the deep tissues (affecting fat, muscle and bone) (Bouten et al.,

2005), and may occur from different pathways. Both, a bottom-up and top-down pathway lead to skin and tissue damage (Bouten et al., 2003; Gefen et al., 2008; Kottner et al., 2009a; Kottner and Gefen, 2012; Stekelenburg et al., 2008). In the bottom-up pathway, deep tissue pressure ulcers arise from the muscle layers over bony prominences. These pressure ulcers progress towards the skin, and are difficult to identify, although considerable damage of the muscle, fascia, and subcutaneous fat may be present (Bouten et al., 2003). In the top-down pathway, detachment of the superficial skin layers sometimes progress into deeper tissue damage. The detachment of the superficial skin is predominantly caused by shearing stress (Bouten et al., 2003; Reuler and Cooney, 1981). Pressure ulcers that occur from this top-down pathway are relatively easily detectable (Bouten et al., 2003). Furthermore, the threshold for tissue to resist or recover from periods of pressure and shear, and hence for tissue damage to develop, differs for skin, fat and muscle (Daniel et al., 1981; Stekelenburg et al., 2006; Bouten et al., 2003). Skin and subcutaneous fat are more resistant to pressure than muscle tissue. Furthermore, Lahmann and Kottner (2011) have deducted that the aetiology of superficial and severe pressure ulcers may differ, because severe pressure ulcers were associated with other risk factors compared to superficial pressure ulcers (Lahmann and Kottner, 2011).

Specific risk factors can be used to identify patients at risk for pressure ulcer development. These factors influence the susceptibility and tolerance of the individual for pressure ulcer development, as well as what Coleman et al. (2014) referred to as the effects of the mechanical boundary conditions. These mechanical boundary conditions represents *"the mechanical load applied to the skin at the interface with the supporting surface"* (Coleman et al. 2014, p. 4), and includes the type, duration and magnitude of the mechanical load (Coleman et al., 2013; NPUAP & EPUAP, 2009; Coleman et al., 2014). Nine risk factors, including impaired mobility and activity, poor perfusion and nutrition, skin and pressure ulcer status, moisture, impaired sensory perception and response, diabetes and low albumin, were identified as key risk factors (Figure 1)

(Coleman et al., 2014). These risk factors were classified as direct and indirect causal factors and identified as key elements in a newly proposed pressure ulcer conceptual framework (Figure 1) (Coleman et al., 2014).

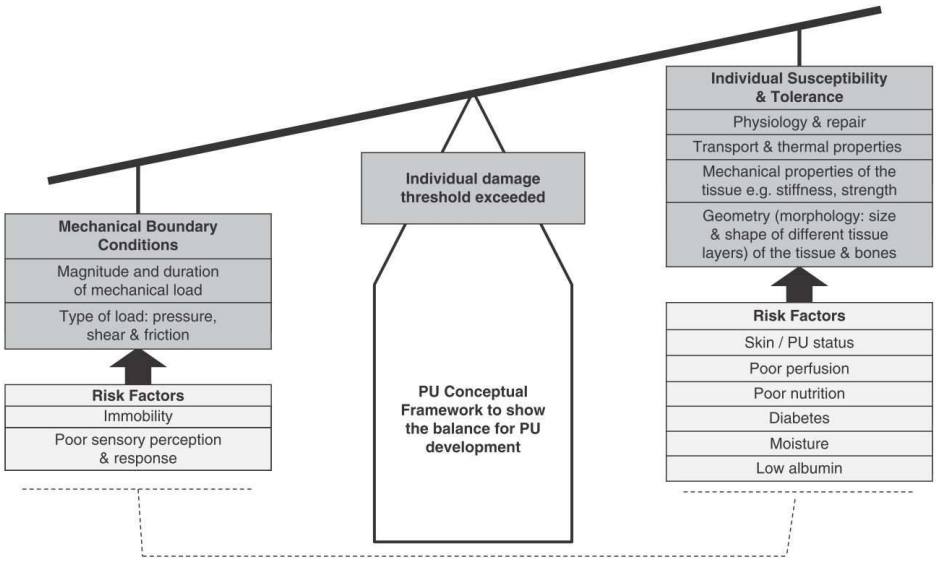

Figure 1 New pressure ulcer conceptual framework by Coleman et al. (2014, p.11)

2. PROBLEM DEFINITION AND IMPACT OF PRESSURE ULCERS ON HEALTH, FUNCTIONING AND WELL-BEING

Pressure ulcers are a common and debilitating health care problem. They occur in all healthcare services and can affect patients or residents that are subjected to prolonged pressure and shear (Bouten et al., 2003). Pressure ulcer prevalence (category I–IV) ranges from 8.8% to 29.9% in nursing homes (Gunningberg 2004, Lahmann et al. 2005, Tannen et al. 2006, Muurinen et al. 2009) and between 7.3% and 23% in hospitals throughout Europe and North-America (Hurd and Posnett, 2009; Kottner et al., 2009c; Vanderwee et al., 2007a; Whittington and Briones, 2004). The 2008 Belgian pressure ulcer prevalence study revealed that 12.1 % of the patients admitted to hospital had a pressure ulcer (category I-IV). Most pressure ulcers occurred at the sacrum (48.1%) and heels (38.4%) (Vanderwee et al., 2011). A study conducted in

Flemish nursing homes, reported a pressure ulcer prevalence of 14.6% (Demarré et al., 2012b).
In hospitals, incidences varied between 0.78 % for pressure ulcers category I-IV during the length of stay in Germany and a weekly incidence of pressure ulcers category II-IV of 6.2% in the Netherlands (Petzold et al., 2014; Schoonhoven et al., 2002). In North American hospitals, pressure ulcer incidence figures during the length of stay ranged between 7.0% and 9.0% (Whittington and Briones, 2004; Bergstrom et al., 1998). In nursing homes, pressure ulcer incidence figures between 11.4% and 29% were observed using a follow-up period between one week and 21 months (Bergstrom et al., 1998; Horn et al., 2004; Ooi et al., 1999).

Pressure ulcers have a profound impact on residents' and patients' overall well-being (Hopkins et al., 2006; Langemo et al., 2000), including a physical, social, and financial burden (Hopkins et al., 2006; Langemo et al., 2000).

Studies exploring experiences of living with a pressure ulcer have described their impact on a person's life and well-being (Hopkins et al., 2006; Langemo et al., 2000). Accepting compulsory bedrest, immobility, the loss of independence and the loss of control were found very tough to deal with (Hopkins et al., 2006; Langemo et al., 2000). Moreover, pressure ulcers can initiate a changed body image, and create important restrictions for the person and others. Emotions like powerlessness, worry, depression and worthlessness have been experienced (Hopkins et al., 2006). Furthermore, pressure ulcers have created a feeling of dependence from others, and the fear to be a burden to others. Pressure ulcers also resulted in restricted interaction with others and has created a feeling of social isolation (Gorecki et al., 2009).
Pain, complications and prolonged hospitalisation have been described as additional consequences for patients (Gorecki et al., 2009; Gorecki et al., 2011; Hopkins et al., 2006; Langemo et al., 2000). Pain as a result of pressure ulcers or related to the treatment of pressure ulcers is a serious and frequent problem with a profound impact on the patients well-being (Gorecki et al., 2009; Gorecki

et al., 2011; Hopkins et al., 2006; Langemo et al., 2000). The pain contributes to sleep disturbance, it negatively impacts mood, and creates feelings of anxiety. Furthermore, it interferes with daily living activities and social life (Gorecki et al., 2011).

Prolonged length of stay attributable to pressure ulcer development has been examined in several studies, with an extra length of stay varying between 4 and 26 days (Allman et al., 1999; Berthier et al., 2005; Graves et al., 2005). Although it has been argued that pressure ulcers are a cause of increased length of stay (Allman, 1998), pressure ulcers occur more often in patients with increased age, comorbidities and underlying conditions or diseases (Brown, 2003; Moore, 2009). The length of stay attributable to pressure ulcers, controlled for the primary diagnosis or other comorbidities, is less well examined. Furthermore, Graves et al. (2005) reported that the distribution of the extra length of stay due to pressure ulcers was positively skewed and therefore averages presented in some studies, such as 16.3 days by Berthier et al. (2005) and 17.6 days by Allman et al. (1999), cannot be compared with the median extra length of stay reported by Graves et al. (2005) (4.31 days).

Evidence on mortality attributable to pressure ulcers remains unclear. As said before, pressure ulcers occur more often in patients and residents with another primary condition or disease (Brown, 2003; Moore, 2009). Likewise, it has been argued that death may be more related to organ failure and underlying conditions and diseases (such as spinal cord injury or multiple sclerosis) than to the presence of a pressure ulcer alone (Berlowitz and Wilking, 1990; Brown, 2003; Graves et al., 2005; Berlowitz and Wilking, 1990; Redelings et al., 2005).

Besides their impact on the patients' overall well-being, pain, and length of stay, pressure ulcers also impose a substantial financial burden on all involved parties (Gorecki et al., 2009; Hopkins et al., 2006; Langemo et al., 2000). Several studies calculated the cost of pressure ulcer prevention and treatment in different countries, using different methodologies, and including different healthcare services. The development of, mostly avoidable, pressure ulcers is causing a considerable extra cost leading to an overall cost ranging between 1%

of the health care budget in the Netherlands up to 4% of the health care budget in the United Kingdom (Bennett et al., 2004; Severens et al., 2002).

3. PRESSURE ULCER CLASSIFICATION

The first pressure ulcer classification was proposed in 1975 by Shea (Shea, 1975). It was primarily used to describe the degree of tissue damage (Dealey and Lindholm, 2006). Since then, several pressure ulcer classifications have been developed (Ankrom et al., 2005; Dealey and Lindholm, 2006). The best known and most used classification is the NPUAP/EPUAP classification system, using four stages or categories of pressure ulcers (NPUAP & EPUAP, 2009) (Table 1). This system defines non-blanchable erythema of the intact skin as a pressure ulcer category I, and partial thickness loss of dermis as a pressure ulcer category II. If full thickness tissue loss is present, this is defined as a pressure ulcer category III. A full thickness tissue loss with exposed bone, tendon or muscle is categorised as a pressure ulcer category IV (NPUAP & EPUAP, 2009).

Observation of non-blanchable erythema (category I pressure ulcer) is considered to be an important sign of risk for pressure ulcer development (Defloor et al., 2004; Vanderwee et al., 2007b; Schoonhoven et al., 2002). Non-blanchable erythema is differentiated from blanchable erythema if the blanching remains despite pressure being removed. To differentiate non-blanchable from blanchable erythema, two methods are frequently used. In the first method a finger is pressed on the skin. In the second method a transparent plastic disc is used to apply pressure to the skin (Halfens et al., 2001).

The occurrence of a pressure ulcer category II-IV (skin breakdown) is considered as a primary endpoint in effectiveness studies (Defloor et al., 2004; Nixon et al., 2006a; Vanderwee et al., 2005). Two additional categories, Unstageable/Unclassified and Suspected Deep Tissue injury, are used in the United States. Unstageable or unclassifiable pressure ulcers are defined as full thickness tissue loss, but the severity cannot be determined because of the presence of slough and/or eschar in the wound bed. After removal of the slough

Table 1 Pressure ulcer classification (NPUAP & EPUAP, 2009)

Pressure ulcer category	Definition
Category I	Intact skin with non-blanchable erythema of a localised area usually over a bony prominence. A darkly pigmented skin may not have visible blanching, but the colour of the skin can differ from the surrounding area, which can be painful, firm, soft, warmer or cooler compared to adjacent tissue
Category II	Partial thickness loss of dermis. A category II pressure ulcer presents as a shallow open ulcer with a red pink wound bed without slough, or as an intact or open blister. The blister can be filled with serum or sanguineous serum
Category III	Full thickness tissue loss. Subcutaneous fat may be visible in a Category III pressure ulcer, but bone, tendon or muscles are not exposed. Slough can be present and the depth of the tissue loss can be assessed. Undermining and tunnelling of the wound may be present. The depth of a Category III pressure ulcer depends on presence and thickness of the subcutaneous tissue, which varies by anatomical location. Category III ulcers will be shallow on the nose bridge, the ear, occiput and malleolus, whereas they can be extremely deep at the sacrum. The bone or tendon should not visible or directly palpable
Category IV	Full thickness tissue loss with visible or palpable bone, tendon or muscle. Slough or eschar can be present, as well as undermining and tunnelling. The depth of a Category IV pressure ulcer varies by anatomical location. Category IV ulcer can be shallow at the nose bridge, ear, occiput, or malleolus, due to the absence of subcutaneous tissue. Category IV ulcers may be complicated with osteomyelitis or osteitis

and/or eschar, the pressure ulcer will be classified as a category III or category IV pressure ulcer (NPUAP & EPUAP, 2009).

The differentiation between pressure ulcers and other lesions, especially incontinence-associated dermatitis (IAD) and friction lesions, has been found difficult (Beeckman et al., 2007; Parish et al., 2007; Defloor et al., 2006). IAD can be defined as a reactive response of the skin due to chronic exposure to urine and faecal material (Gray et al., 2012). To differentiate pressure ulcers from IAD, wound-related characteristics (causes, location, shape, depth, edges,

and colour), along with patients related characteristics should be considered (Defloor et al., 2005b). Friction lesions can be defined as damage caused by "*rubbing a part of the body against another part or the force that resists relative motion between two bodies in contact and/or material elements sliding against each other*" (Antokal et al., 2012, p.1). Skills to improve pressure ulcer classification and the accurate differentiation from other lesions in clinical practice can be improved by education (Beeckman et al., 2008; Beeckman et al., 2010).

4. PRESSURE ULCER PREVENTION

An important proportion of the patients in hospitals, nursing homes and in community care are at risk for pressure ulcer development. As healthcare resources are scarce, risk assessment is essential to establish a pressure ulcer prevention policy. Following risk assessment, preventive measures need to be allocated striving for a minimal pressure ulcer incidence, as well as limiting the associated expenditures. The identification of patients in need of prevention needs to be accurate (Defloor and Grypdonck, 2004; Moore, 2009). In this section, an overview of risk assessment methods and preventive strategies is provided.

4.1 RISK ASSESSMENT

Risk assessment aims to consistently and correctly distinguish patients who are at risk to develop a pressure ulcer, from those not at risk (Defloor and Grypdonck, 2004; Moore and Cowman, 2014). Conflicting evidence exists on the merits of different risk assessment methods. (Balzer et al., 2013; Balzer et al., 2014; Schoonhoven et al., 2006).

Current national and international guidelines advise to include structured risk assessment for each patient including the use of a risk assessment scale, the nurses' clinical judgement, and a head to toe skin assessment (Beeckman et al., 2013a; National Institute for Clinical Excellence, 2005; NPUAP & EPUAP, 2009).

Risk assessment scales have been developed to facilitate the identification of patients at risk. A risk assessment scale is of interest if it enables a quick, easy and valid representation of risk, and if risk can be measured reliably (Kottner and Balzer, 2010; Papanikolaou et al., 2007). For research purposes, a risk assessment scale is also frequently used to compare baseline patient characteristics between studies.

The first scale, developed in 1962, was the Norton scale (Norton et al., 1975). The Norton scale includes five items: mobility, continence, mental status, general health and activity (Norton et al., 1975). Out of more than 40 instruments, developed to assess pressure ulcer risk, the Norton and Braden scale (Braden and Bergstrom, 1989) are the most commonly used risk assessment scales (Papanikolaou et al. 2007). The Braden scale was published for the first time in 1985 and consists of 6 subscales (nutrition, mobility, sensory perception, moisture, activity, and friction and shear). Sum scores count up between 6 and 23, and here as well lower scores correspond to higher risk (Bergstrom et al., 1987; Braden and Bergstrom, 1987; Braden and Bergstrom, 1994).

A risk assessment scale has a (population-) specific cut-off point. Below this point a patient is assumed to be at-risk. There is, however, little and conflicting evidence concerning these cut-off points, and no threshold was found to outperform another (Beeckman et al., 2013a; Papanikolaou et al., 2007). For the Braden scale, a cut-off score of 17 is commonly used in international research (Baumgarten et al., 2010; Defloor et al., 2005a; Vanderwee et al., 2005; Vanderwee et al., 2007a).

Numerous studies focussed on the validity and reliability of risk assessment scales, but these studies support the validity and reliability only to a limited extent (Beeckman et al., 2013a; Moore and Cowman, 2014; Papanikolaou et al., 2007; Kottner and Balzer, 2010; Schoonhoven et al., 2002). Critical concerns about the use of risk assessment scales are related to the limited utility of equal-

weighting scoring of the items (Papanikolaou et al., 2007) and the items included in the scales. This has led to problems in sensitivity and specificity of the scales, and a lack of evidence that risk assessment scales can decreases pressure ulcer incidence (Beeckman et al., 2013a; Moore and Cowman, 2014; Papanikolaou et al., 2007; Kottner and Balzer, 2010; Schoonhoven et al., 2002).

Clinical judgement can be defined as the *"interpretation or conclusion on a patient's needs, concerns, or health problems and/or judgement to take action"* (Tanner, 2006). Balzer et al. (2014) found that assessing the risk for pressure ulcer development by using clinical judgement was based on a combination of multiple patient characteristics. Risk enhancing factors (such as mobility, activity, vulnerability enhancing conditions, and care dependency), and protective conditions (such as mental capabilities, motivation, and expected duration of immobility) were included in clinical judgement (Balzer et al., 2014).
Clinical judgement is a commonly used approach for risk assessment in care as usual, but the prognostic accuracy remains debatable (Saleh et al., 2009; Beeckman et al., 2013a). According to Saleh et al. (2009) clinical judgement is not less effective than the use of a risk assessment scale in reducing pressure ulcer incidence, but neither showed sufficient specificity and sensitivity (Saleh et al., 2009).

The skin status, and more specifically the presence of non-blanchable erythema, has been identified as a risk factor for the development of pressure ulcers category II-IV (Allman et al., 1995; Nixon et al., 2007; Vanderwee et al., 2007b). According to Vanderwee et al. (2007b), the number of patients receiving preventive measures could be reduced with 50% if prevention is postponed until non-blanchable erythema occurs compared to the number of patients assessed at risk using the Braden scale. This was achieved without increasing pressure ulcer incidence (Vanderwee et al. 2007b). However, pressure ulcers can also develop from within the deep tissue and become visible later. Therefore, only relying on the presence of non-blanchable erythema for risk assessment is insufficient. Nonetheless, when non-blanchable erythema is observed,

preventive measures should be started immediately (Vanderwee et al., 2007b). Therefore, head to toe skin assessment is recommended as part of a structured risk assessment policy in all health care settings (NPUAP & EPUAP, 2009).

4.2 PREVENTION

Adequate prevention focuses on reducing the amount and the duration of pressure and shear (Figure 2).

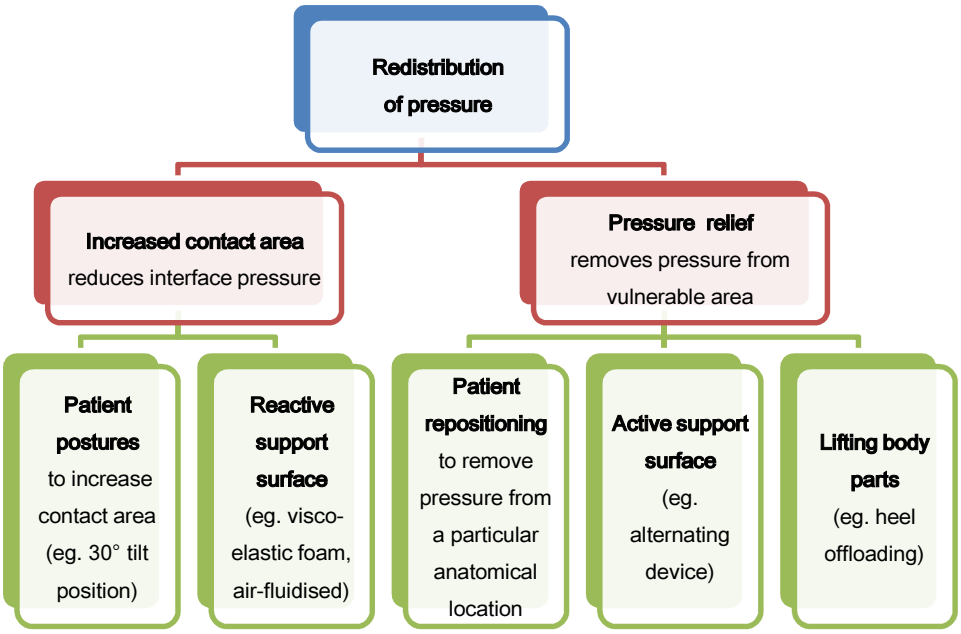

Figure 2 Methods of pressure redistribution (NPUAP & EPUAP, 2010)

A support surface is "*a specialised device for pressure redistribution designed for management of tissue loads*" (NPUAP, 2007, p. 1). The contact area can be increased by using reactive support surfaces, such as viscoelastic foam mattresses and air-fluidised devices (Figure 3). Increase of the contact area in reactive support surfaces is provided by immersion and envelopment (NPUAP & EPUAP, 2010). Immersion refers to the ability of the support surfaces to allow a patient to sink in the mattress or cushion. The deeper the patient sinks in the support surface, the more the patient's weight is redistributed and the lower the

pressures will be. Envelopment refers to the moulding of the support surface to the patient's body. The more the patient's body is enfolded by the support surface the larger the contact area and the lower the pressures will be (NPUAP & EPUAP, 2010).

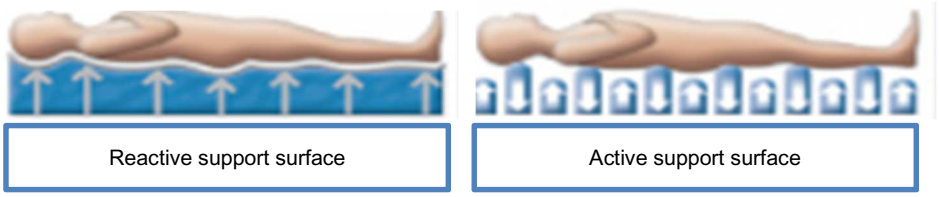

Figure 3 Active and reactive support surfaces (Phillips et al., 2012)

Another method to increase the contact area is the use of positions that decrease pressure over bony prominences. Positions such as the 30° tilt position, prone position, or lateral 30° position enables the preservation of perfusion and lymph drainage, and minimises cell deformation of the weight bearing areas (Figure 4) (Defloor, 2000; Moore, 2009; NPUAP & EPUAP, 2009).

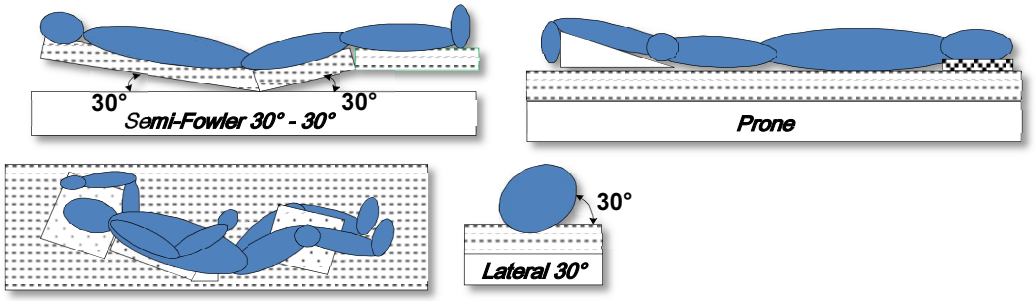

Figure 4 Patient postures (Defloor, 2000)

Pressure redistribution can also be achieved by removing pressure and shear from vulnerable areas, defined as pressure relief (NPUAP & EPUAP, 2010) (Figure 2). Pressure relief can be established through patient repositioning, the application of active support surfaces, and lifting body parts.

Patient repositioning is defined as relieving pressure and shear on particular body parts at risk for pressure ulcer development (Beeckman et al., 2013a). Providing repositioning for each patient at risk for pressure ulcer development is recommended (NPUAP & EPUAP, 2009). Repositioning may vary in terms of frequency and positions. Although evidence on the most effective repositioning frequency is inconclusive, the repositioning frequency and the posture should be determined and adapted based on an individual assessment and should take into account patient-related factors as medical condition, skin condition, level of activity and mobility, comfort, and plan of care, as well as support surface characteristics (Beeckman et al., 2013a; Moore et al., 2013).

Another method to intermittently remove pressure from vulnerable areas is the use of an active support surface (NPUAP & EPUAP, 2010). An active support surface is a powered surface that can change load distribution properties, with or without body weight of the patient resting on the surface. It provides pressure relief via cyclic inflating and deflating air cells (NPUAP, 2007). Differences between several types of active support surfaces can be related to differences in surface characteristics, such as cycle time, air cell inflation sequence, and pressure amplitude.

The pressure amplitude is the difference between the highest and lowest interface pressure (Tissue Viability Society, 2010). An example of an active support surface is an alternating pressure air mattress (APAM), available as APAM overlays and APAM replacement mattresses. The inflation and deflation of the air cells of an APAM are characterised by a steep, one-stage inflation or deflation.

Alternating Low Air Pressure Mattresses (ALPAMs) are designed to generate lower pressures compared to APAMs. Besides shifting pressure or shear to other areas of the body, ALPAMs are assumed to improve envelopment and immersion of the body in the underlying support surface due to these lower

pressures. The ALPAM air cells are also characterized by a steep inflation and deflation, and are therefore defined as one-stage ALPAMs.

Recently modified designs have changed this steep transition into a gradual, multi-staged inflation and deflation in response to the hypothesis of decreasing tissue damage by gradual reperfusion of ischemic tissue (Unal et al., 2001). These modified devices are defined as multi-stage ALPAMs.

Both APAMs and ALPAMs are frequently used throughout European health care services (Manzano et al., 2013; Nixon et al., 2006a). In Belgium, one third (33.3%) of all patients at risk (Bradenscore <17 or pressure ulcer) are allocated to such an alternating device (Vanderwee et al., 2011). The use of alternating devices is more technical and less labour intensive than repositioning (Moore, 2009; Schuurman et al., 2009). Furthermore, the use of these alternating devices is especially recommended when regular repositioning is contra-indicated (Vanderwee et al., 2005). The incidence of pressure ulcers (category II-IV) on APAM overlays ranged between 10.7% (Nixon et al., 2006b) and 15.3% (Vanderwee et al., 2005) in adult populations at risk. Cavicchioli and Carella (2007) found an incidence of pressure ulcers (category I-IV) on one-stage ALPAMs of 2.9 %.

Insufficient evidence is available to guide decision making as to which type of alternating device is most effective or the best choice for a specific patient (McInnes et al., 2012). Neither systematic reviews nor guidelines could conclude on the superiority of a specific alternating pressure device over another (Beeckman et al., 2013a; McInnes et al., 2012).

Heel prevention

Independently of the support surface being used, heel offloading needs to be provided. If pressure ulcers occur, heels are frequently affected (Demarré et al., 2012b; Vanderwee et al., 2011). Due to little adipose subcutaneous tissue at the heel, tissue damage may develop quickly and become serious as a result of the

mechanical loading (Gefen, 2010; Wong and Stotts, 2003; NPUAP & EPUAP, 2009). Evidence on pressure ulcer prevention at the heels is scarce and generally not provided by high-quality Randomised Controlled Trials (RCT's) (McGinnis and Stubbs, 2011; Wong and Stotts, 2003). Heel offloading that can realise pressures of 0mmHg at the heel area is the most appropriate and effective way to prevent heel pressure ulcers.

A pillow has been recommended to provide heel offloading (NPUAP & EPUAP 2009). Vanderwee et al. (2005) questioned if the use of a regular pillow to offload the heel from the mattress can be provided in a correct way. Some patients tend to push away or relocate the cushion under their legs (Vanderwee et al., 2005). Bottoming out of the pillow is another possible disadvantage of the use of a regular pillow. When bottoming out occurs, the heels will contact the support surface underneath. When using a pillow, efforts must be made to educate the patient and health care workers to provide correct heel offloading.

In a comparative study of Heyneman et al. (2009), based on a pooled database, the use of a wedge-shaped cushion was found to be more effective to offload the heels than a regular pillow (Heyneman et al., 2009).

Prevention when seated

Prevention should be provided on a continuous basis during the time an individual is at risk (Bergstrom 2005, NPUAP & EPUAP, 2009; Vanderwee et al., 2009). Besides pressure ulcer prevention while lying in bed, pressure ulcer prevention must also be provided when seated. Preventive measures when seated are founded on the same principles as pressure ulcer prevention in bed. Due to the decreased contact area between the ischium and the underlying support surface, pressure and shear will be higher than when lying (Defloor and Grypdonck, 1999; Linder-Ganz et al., 2007; Linder-Ganz and Gefen, 2009). Therefore the use of a pressure redistributing seat cushion, such as a static air cushion or viscoelastic foam cushion is recommended for patients at risk (Defloor, 2000; NPUAP & EPUAP, 2009). Little is known about the frequency of repositioning while seated in a chair, but as a result of increased mechanical load, repositioning must be more frequently provided than when lying in bed

(Defloor, 2000; Defloor et al., 2004). When positioning the patient in a chair a posture minimizing the pressure and shear to the skin and underlying tissue must be applied. In reclined position, the pelvis should be brought in a slightly flex forward and the footrest should be adjusted to position the thighs slightly lower than horizontal. When sitting upright in a chair, the feet should rest on the ground or on a footrest to avoid sliding down (Defloor, 2000; NPUAP & EPUAP, 2009).

Problems to successfully implement international guidelines in daily practice still lead to inadequate and/or incomplete pressure ulcer prevention for (the majority of) patients at risk (Baumgarten et al., 2010; Beeckman et al., 2013b; Gunningberg, 2005; van Gaal et al., 2011; Vanderwee et al., 2011; Defloor, 2000; Pieper et al., 1997). In Belgian hospitals only 10.8% of the patients at risk (Bradenscore < 17 or pressure ulcer) received prevention that is fully compliant to guidelines in bed and when seated. Correspondingly, 6.9% of nursing home residents at risk received prevention fully compliant to guidelines (Demarré et al., 2012b; Vanderwee et al., 2011).

Moreover, even when standardised prevention is provided, patients still develop new pressure ulcers (McInnes et al., 2012; Nixon et al., 2006a; Theaker et al., 2005). This indicates that the current preventive measures may still be insufficient for some patients that have an increased risk to develop a pressure ulcer notwithstanding the preventive measures they receive.

5 PRESSURE ULCERS AND HEALTH ECONOMICS

Pressure ulcers have, besides an impact on the patients' overall well-being as described above, also a financial impact on all involved parties (Bennett et al., 2004; Severens et al., 2002).

Health economics is the discipline which deals with the application of economic principles and theories to health and the health sector (Annemans, 2008). Different approaches in health economics can be perceived. A frequently used approach is the analysis of the cost of illness/injury. With this, the economic

burden of an injury or illness is calculated by quantifying the (direct) medical costs (Hodgson and Meiners, 1982). A second approach is the budget impact analysis. This approach analyses the financial impact of an intervention. A third approach consists of health economic evaluations (Ackaert et al., 2010). A health economic evaluation can be defined as a comparative analysis of both the costs and health effects of two or more alternative health interventions (Annemans, 2008). Three characteristics need to be fulfilled: (1) a systematic measurement of costs and health effects, (2) a comparison with alternative approaches and, (3) a combination of both costs and effects in the analysis to examine the cost-effectiveness (Ackaert et al., 2010). For example, the cost-effectiveness of pressure ulcer prevention can be calculated by balancing the costs of prevention with the achieved patient outcomes.

A growing awareness of the economic impact of pressure ulcers is partly related to constrained public and healthcare finances. Insight in the cost related to the treatment of mainly avoidable events, such as pressure ulcers is an obvious need. Cost-of-illness studies provide insight in the economic burden of pressure ulcers for society, healthcare services, insurances, and patients (Larg and Moss, 2011). These insights can help policymakers and health service management to identify the cost drivers for pressure ulcer prevention and treatment. Furthermore, it may guide decision making about allocating healthcare resources such as materials and nursing staff.

5.1 PERSPECTIVES

The health economic perspective specifies the chosen focus of the group that are bearing the costs (Larg and Moss, 2011). Different health economic perspectives can be perceived, such as the societal perspective, government perspective, organisational or institutional perspective, insurance perspective and patients' perspective. The terminology to describe health care perspectives used is diverse, and the choice of perspective is often not (clearly) reported. Besides this heterogeneity in used terminology, the terminology is often not or not clearly defined (Larg and Moss 2011). The choice of perspective should be

determined based on the research goal and the disease under study, but also the available cost data will influence the chosen perspective (Larg and Moss, 2011). Generally, the societal perspective is preferred as it provides the cost for the overall population, including costs outside the health care sector (Byford & Raftery 1998, Cleemput et al., 2011; Larg and Moss, 2011). The broader the perspective the less chance cost shifts between sectors will affect the outcome, thereby minimising the potential biases of more narrow views (Byford & Raftery 1998, Cleemput et al., 2011; Larg and Moss, 2011).

5.2 COST ITEMS

Health economic evaluations can comprise direct and indirect costs, as well as medical and non-medical costs (Larg and Moss, 2011). Direct medical costs are defined as disease related costs, such as prevention, detection, treatment, and rehabilitation, which are paid by the patient, healthcare institution, insurances, and/or government (Annemans, 2008; Larg and Moss, 2011, Rice, 1967).

Direct medical costs in the field of pressure ulcers can consist of labour cost and cost for materials (Dealey et al., 2012; Haalboom, 1991; Schuurman et al., 2009). Bennet et al. (2004) and Schuurman et al. (2009) found that most of the cost of pressure ulcer prevention and treatment is due to nursing time. In the study of Bennet et al. (2004) nursing time accounted for 90% of the overall cost of pressure ulcer treatment. For pressure ulcers Category I and II this percentage increased to 96% of the overall costs. No information was given in how nursing time was estimated or calculated. Schuurman et al. (2009) found that a more technical approach (such as the use of alternating devices) of pressure ulcer prevention was associated with lower costs, compared to a more human approach (such as providing repositioning at regular time intervals). When using alternating devices, the cost of pressure ulcer prevention was 13 euro compared to 24 euro when using a turning protocol in the prevention of pressure ulcers. The reported nursing time estimates were calculated based on the self-registration of nursing time by the nursing staff. The data on nursing

times were part of a standardised case report, which was filled out at during prevention or treatment of the patients (Schuurman et al., 2009).
Direct non-medical costs are disease related costs, which are not part of the healthcare service, such as travel costs to the health care provider, or costs related to the time that significant others spend to provide care for the patient. Indirect medical costs are future costs of general healthcare, such as the healthcare costs arising from living longer (Annemans, 2008).

Finally, indirect non-medical costs include costs related to reduced work productivity due to morbidity or premature death because of illness (Annemans, 2008). In general, indirect costs are often more difficult to measure objectively, and less easy to attribute to a specific disease (Larg and Moss, 2011). A number of published studies have described the cost of illness associated with pressure ulcer prevention and treatment. Summarising the costs of pressure ulcer prevention can be important for government and health care services to assess the impact of prevention on their budget (Schuurman et al., 2009; Severens et al., 2002) or when considering the expenditures of new preventive strategies (Xakellis et al., 1996b; Makai et al., 2010). A systematic review summarising the available evidence on the cost of pressure ulcer prevention and treatment is lacking.

As pressure ulcers represent a serious clinical and economical problem, pressure ulcer prevention is important in decreasing the human and also the financial burden for all parties involved. The calculation of the cost of illness of current pressure ulcer prevention can stimulate the government, the health care organisations, and the health care workers in the implementation and execution of a pressure ulcer prevention policies compliant to guidelines. Data on the cost of pressure ulcer prevention and treatment in Belgium are lacking.

The aim of this thesis is to fill some of the gaps in the current body of evidence related to pressure ulcer prevention.

6 OUTLINE OF THIS THESIS

The research questions in this thesis were grouped in three areas. The first area is the effectiveness of support surfaces in the prevention of pressure ulcers, more specifically the effectiveness of alternating devices. The aim of a first trial is to compare the effectiveness of two types of ALPAMs in an RCT. The central goal of this study is to examine the effect of a multi-stage inflation and deflation cycle versus a one-stage inflation and deflation cycle in ALPAMs.
Studies reported pressure ulcer incidences ranging between 10.7% (Nixon et al., 2006b) and 15.3% (Vanderwee et al., 2005) on APAM overlays in adult at risk-populations, compared to an incidence of 2.9 % on ALPAMs (Cavicchioli and Carella, 2007). The use of APAM overlays is widespread in Europe. In a second study, data from the ALPAM study are pooled with data from an RCT by Vanderwee et al. (2005). The aim of this study is to compare the effectiveness of an APAM overlay with a one-stage ALPAM and a multi-stage ALPAM in terms of cumulative pressure ulcer incidence and the time to develop a pressure ulcer.

The second area in this thesis relates to the identification of patients at risk for pressure ulcer development while receiving standardised preventive measures. Once patients are identified as being at risk and preventive measures are provided, some patients still develop pressure ulcers. Insight in specific predictive factors in this population may help to successfully target preventive measures. The aim of the third study is to identify such predictive factors based on secondary data analyses performed on the ALPAM database.

The third area relates to the cost of pressure ulcer prevention and treatment. Insight in these costs are needed to assist government and institutions to assess the impact of prevention and treatment on their budget. Furthermore, it can guide the decision process regarding the expenditures for the implementation of (new) preventive and treatment strategies. A systematic review is performed to summarise the available evidence on cost of pressure ulcer prevention and treatment. A subsequent study aims to provide insight into the cost of pressure ulcer prevention and treatment in an adult hospital and nursing home population

in Flanders. A mixed perspective is applied and data are collected to estimate the cost for pressure ulcer prevention and treatment per patient per day, per hospitalisation, as well as the annual national cost of prevention and treatment.
The structure of this thesis is based on the following research aims:

1) To compare the effectiveness of an ALPAM with a multi-stage inflation and deflation cycle of the air cells with an ALPAM with a one-stage inflation and deflation cycle of the air cells (Chapter 2).
2) To compare the effectiveness of an APAM overlay with a one-stage ALPAM and a multi-stage ALPAM (Chapter 3).
3) To examine predictive factors associated with the development of pressure ulcers in patients at risk while receiving standardised preventive measures (Chapter 4).
4) To provide insight in the available evidence on cost of pressure ulcer prevention and treatment in an adult patient population (Chapter 5).
5) To provide insight in the cost of pressure ulcer prevention and treatment in an adult hospital and nursing home population in Flanders using a mixed perspective (Chapter 6).

The current chapter addresses the general introduction into the study topic of pressure ulcer prevention and health economics. Chapters 2 to 6 include papers which have been published, accepted or submitted for publication in peer-reviewed journals. With respect to the content, some overlap between the chapters is present. Finally, Chapter 7 provides an overview of the key findings, a general discussion on the results reported in this thesis, a methodological discussion, and an overview of the implications for clinical practice and research.

CHAPTER 2

MULTI-STAGE VERSUS ONE-STAGE INFLATION AND DEFLATION CYCLE FOR ALTERNATING LOW PRESSURE AIR MATTRESSES TO PREVENT PRESSURE ULCERS IN HOSPITALISED PATIENTS: A RANDOMISED-CONTROLLED CLINICAL TRIAL

Based on the article of Demarré L, Beeckman D, Vanderwee K, Defloor T, Grypdonck M & Verhaeghe S (2012) Multi-stage versus one-stage inflation and deflation cycle for alternating low pressure air mattresses to prevent pressure ulcers in hospitalised patients: A randomised-controlled clinical trial. *International Journal of Nursing Studies* 49 (4), 416-426.

ABSTRACT

Introduction: The duration and the amount of pressure and shear must be reduced in order to minimise the risk of pressure ulcer development. Alternating low pressure air mattresses with multi-stage inflation and deflation cycle of the air cells have been developed to relieve pressure by sequentially inflating and deflating the air cells. Evidence about the effectiveness of this type of mattress in clinical practice is lacking.

Aim: This study aimed to compare the effectiveness of an alternating low pressure air mattress that has a standard one-stage inflation and deflation cycle of the air cells with an alternating low pressure air mattress with multi-stage inflation and deflation cycle of the air cells.

Methods and materials: A randomised controlled trial was performed in a convenience sample of 25 wards in five hospitals in Belgium. In total, 610 patients were included and randomly assigned to the experimental group (n = 298) or the control group (n = 312). In the experimental group, patients were allocated to an alternating low pressure air mattress with multi-stage inflation and deflation cycle of the air cells. In the control group, patients were allocated to an alternating low pressure air mattress with a standard one stage inflation and deflation cycle of the air cells. The outcome was defined as cumulative pressure ulcer incidence (Grade II–IV). An intention-to-treat analysis was performed.

Results: There was no significant difference in cumulative pressure ulcer incidence (Grade II–IV) between both groups (Exp. = 5.7%, Contr. = 5.8%, p = 0.97). When patients developed a pressure ulcer, the median time was 5.0 days in the experimental group (IQR = 3.0–8.5) and 8.0 days in the control group (IQR = 3.0–8.5) (Mann–Whitney U-test = 113, p = 0.182). The probability to remain pressure ulcer free during the observation period in this trial did not differ significantly between the experimental group and the control group (log-rank χ^2 = 0.013, df = 1, p = 0.911).

Conclusion: An alternating low pressure air mattress with multi-stage inflation and deflation of the air cells does not result in a significantly lower pressure ulcer incidence compared to an alternating low pressure air mattress with a standard

one-stage inflation and deflation cycle of the air cells. Both alternating mattress types are equally effective to prevent pressure ulcer development.

1. INTRODUCTION

Pressure ulcers are defined as ‘‘localised injuries to the skin and/or underlying tissue, usually over a bony prominence, caused by pressure, or pressure in combination with shear’’ (NPUAP & EPUAP, 2009).
Pressure ulcer development is multi-factorial, with applied pressure, or pressure in combination with shear being among the primary aetiological factors. Pressure and shear result in oxygen deprivation to the affected area (NPUAP & EPUAP, 2009). However, the importance of different mechanisms that lead to tissue damage, such as impaired lymphatic drainage (Miller and Seale, 1981), direct cell deformation (Ceelen et al., 2008; Gawlitta et al., 2007a; Stekelenburg et al., 2008), sustained tissue deformation (Daniel et al., 1981; Gawlitta et al., 2007b; Kosiak, 1961), and ischemic reperfusion injury (Peirce et al., 2000; Reid et al., 2004; Tsuji et al., 2005) has not been fully established (Bouten et al., 2003; NPUAP & EPUAP, 2009).

In European hospitals, pressure ulcer prevalence (Grade I–IV) varies between 7.3% and 23% (Gunningberg, 2004; Kottner et al., 2009c; Vanderwee et al., 2007a). In US acute care facilities, Whittington and Briones (2004) found a pressure ulcer prevalence (Grade I–IV) of 16% (Whittington and Briones, 2004). Pressure ulcers are a burden for the patient as they are painful and negatively affect the patient’s quality of life (Gorecki et al., 2009; Hopkins et al., 2006). Furthermore, pressure ulcers have an important financial impact for both, patients and society (Schuurman et al., 2009; Severens et al., 2002; Xakellis and Frantz, 1996).

Adequate pressure ulcer prevention needs to focus on the reduction of the duration (removal of pressure) and/or the amount of pressure and shear. The removal of pressure and shear on the tissue is defined as pressure relief (NPUAP & EPUAP, 2010). Pressure relief can be established through patient repositioning, lifting body parts and the application of active support surfaces, which are designed for the management of tissue loads (NPUAP & EPUAP, 2009; NPUAP & EPUAP, 2010). These are powered support surfaces, with the

capability to change their load distribution properties (NPUAP, 2007). Alternating Pressure Air Mattresses (APAMs) provide pressure relief by sequentially inflating and deflating air-filled sacs (McInnes et al., 2008). Incidence figures between 10.5% (Nixon et al., 2006a) and 15.3% (Vanderwee et al., 2005) were found on APAMs in a hospital setting.

More recently, alternating low pressure air mattresses (ALPAMs) have been developed. These support surfaces are supposed to differ from APAMs by generating lower pressure amplitudes, which is the difference between the highest and lowest interface pressure (Tissue Viability Society, 2010). APAMs and ALPAMs both have an alternating cycle, characterised by a steep transition during inflation and deflation of the air cells. Studies examining the effectiveness of ALPAMs are scarce. Two randomised controlled trials examined pressure ulcer incidence on ALPAMs (Cavicchioli and Carella, 2007; Theaker et al., 2005). Subsequently, ALPAMs have been modified so that the transition from deflated air cell to inflated air cell is more gradual or multi-staged. The purpose of this trial was to examine the influence of a longer multi-stage inflation and deflation cycle, combined with low pressures in the inflated air, on the development of pressure ulcers. To date, no clinical studies on the effectiveness of ALPAMs with a multistage inflation and deflation cycle of the air cells have been reported. Hence, the aim of the current trial was to compare the effectiveness of an ALPAM with multi-stage inflation and deflation cycle of the air cells with an ALPAM with one stage inflation and deflation cycle of the air cells.

2. METHODS AND DESIGN

2.1 DESIGN

A multicentre RCT (allocation ratio 1:1) was conducted between December 2007 and January 2010.

2.2 PARTICIPANTS

A convenience selection of 25 wards from five Belgian hospitals participated. The selection of hospitals was based on geographical proximity and their

willingness to participate. Seven hospitals were invited of whom five consented to participate. Per included hospital, a minimum of 4 wards and maximum of 6 wards were asked to participate in the study. The selection included 8 geriatric wards and 17 medical wards in one teaching and four general hospitals. The participating medical wards were neurology (n = 6), rehabilitation (n = 3), cardiology (n = 2), dermatology (n = 1), pneumology (n = 1), oncology (n = 1), and chronic care (n = 1) or a combination of different types of medical conditions (n = 2). A consecutive sample was used in this trial. All patients admitted to the participating wards were screened for eligibility. Patients were eligible for inclusion if they were at risk for pressure ulcer development according to the Braden scale. Risk assessment was evaluated by a ward nurse in each patient on admission and twice a week during the inclusion period. Patients with a Braden score of less than 17 were considered at risk (Defloor et al., 2004; Vanderwee et al., 2007a). The Braden scale consists of six subscales: sensory perception, moisture, activity, mobility, nutrition and friction and shear (Braden and Bergstrom, 1994). Patients having non-blanchable erythema (Grade I pressure ulcer) were eligible to be included in the study. Pressure ulcers were classified according to the four grades of the European Pressure Ulcer Advisory Panel (1999). A pressure ulcer Grade I was defined as non-blanchable erythema of the intact skin, a pressure ulcer Grade II as an abrasion or a blister, a pressure ulcer Grade III as a superficial ulcer and, a pressure ulcer Grade IV was classified as a deep ulcer (European Pressure Ulcer Advisory Panel, 1999). Patients were excluded if (1) they had a pressure ulcer Grade II–IV on admission, (2) the expected admission time in the hospital was < 3 days, (3) they were aged < 18 years, (4) there was a ‘‘do not resuscitate code’’ specifying ending all therapeutic interventions, (5) weight was less than 30 kg or more than 160 kg (mattress specification) and, (6) informed consent could not be obtained from the patient or his/her legal representative (Fig. 1).

Both mattresses were covered with an identical mattress cover. No standard repositioning protocol was used in bed. An identical seating protocol was used in both groups. All patients were seated on a static air cushion (Hill-Rom Reflex™).

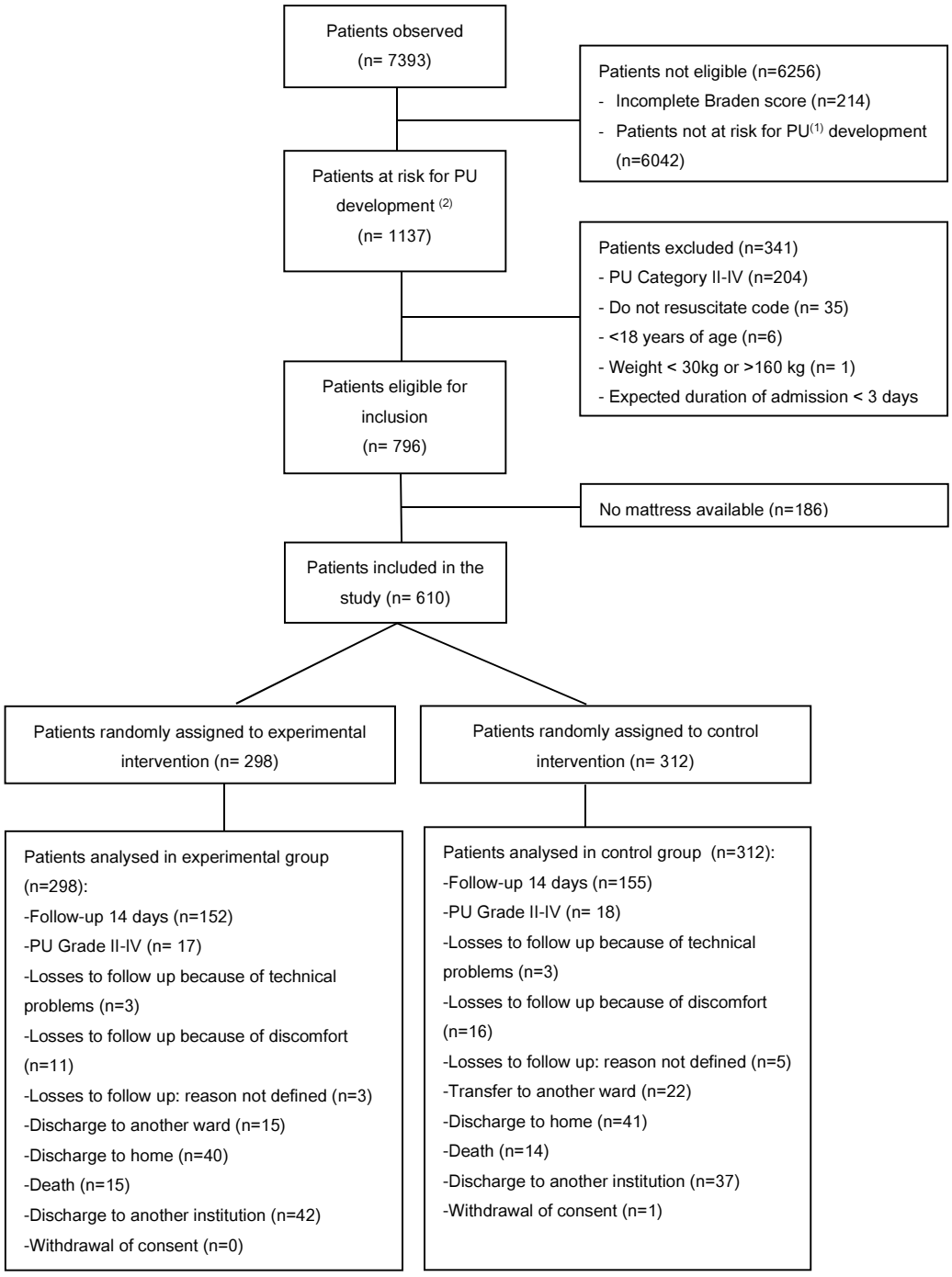

Figure 1 Flowchart Sample: Included and excluded patients ALPAM study

(1) PU: Pressure ulcer; (2) Bradenscore < 17

Table 1 Specifications and characteristics of experimental and control group

	Experimental group	Control group
Cycle amplitude	Multi-stage inflation and deflation of air cells	One-stage inflation and deflation of air cells
Cycle Time	10 minutes	10 minutes
Air cell inflation sequence	1/1 (one air cell is inflated/one air cell is deflated)	1/1 (one air cell is inflated/one air cell is deflated)
Width air cells (diameter)	10 cm	10 cm
Alternating sequence	- Back and sacrum: 10 cells alternating low pressure (1/1= one air cell is inflated/one air cell is deflated) - Head zone: 3 cells continuous low pressure (not alternating) - Heel zone: 7 cells continuous ultra-low pressure (not alternating)	All cells alternate (1/1= one air cell is inflated/one air cell is deflated)
Sensor	Yes Continuously measuring the load applied at sacral zone	No. Manually adjustable for weight.

The control unit was disconnected during transport of the patient, resulting in an inflated mattress for 2 h without alternating of the air cells.

2.3 OUTCOMES

Patient baseline characteristics were collected by the researcher on admission in the study: age, weight, length, Body Mass Index, primary diagnosis, comorbidities (diabetes, paralysis, cerebrovascular accident), the use of tranquilisers/corticosteroids, and nutritional status (using the Mini Nutritional Assessment). Data about mobility and activity of each patient were collected as part of the Braden risk assessment tool. The primary end point was the development of a new pressure ulcer Grade II–IV on any location during the period of observation. Daily skin assessment was performed by the ward nurses

(qualified nurses and nursing assistants under the supervision of a qualified nurse), in each patient, in the morning.

Pressure ulcers were classified according to the EPUAP classification system (European Pressure Ulcer Advisory Panel, 1999). The transparent plastic disc method was used to observe non-blanchable erythema (Grade I) (Halfens et al., 2001). Furthermore, a differentiation was made between pressure ulcers and incontinence-associated dermatitis (IAD), which was defined as a reactive response of the skin to chronic exposure to urine and faecal material (Gray et al., 2007). To differentiate pressure ulcers from IAD, wound-related characteristics (causes, location, shape, depth, edges, and colour), along with patients related characteristics were considered (Defloor et al., 2005b). The secondary outcome was the time to develop a pressure ulcer Grade II–IV. Data on this outcome were collected between patient inclusion and trial completion. Patient acceptability was assessed indirectly by the number of participants withdrawing their consent to participate during the period of observation. The daily skin observations and the risk assessments were registered by the ward nurse in a study file which was attached to the patient chart of all participating patients. The study file consisted of a daily observation sheet, used to tick the status of the skin per location and on day 5, 10 and 15 a risk assessment was included. Each study document included information about pressure ulcer classification, differentiation between pressure ulcers and IAD, the standard protocol when the patient was seated, and practical instructions for the use of the study mattresses. Data on time seated in a chair and time on transport were collected.

2.4 SAMPLE SIZE

The study was powered on the assumption that a 15% pressure ulcer incidence (Grade II–IV) (Vanderwee et al., 2005) would be present in the control arm of the study and the assumption that a 50% reduction (Nixon et al. 2006; Vanderwee et al. 2005) in pressure ulcer incidence (Grade II–IV) in the experimental arm would

be present (α = 0.05; β = 0.20; two sided). A sample size of 600 patients (300 in each group) was determined.

2.5 Randomisation

Included patients were randomly assigned to the study groups using simple randomisation. The random allocation sequence was based on a computer-generated list of random numbers. Patients were enrolled by the ward nurses after completing the pressure ulcer risk assessment form (Braden scale). When the patient was eligible, and a study mattress was available, they were assigned to one of the mattresses by contacting the researcher (24 h telephone accessibility). The ward nurse received a number of the type of allocated mattress (first available on the computer generated list). In total, 610 patients were included, of which 298 were allocated to the experimental and 312 to the control group (Fig. 1).

2.6 Blinding

The study could not be blinded, because of the visible differences of the external control unit of the study mattresses. No information was provided to the ward nurses about the differences between the experimental and control study device. Both were presented as alternating pressure air mattresses. The data-analysis was not blinded.

2.7 Procedure

Prior to the study, all nurses (qualified nurses and nursing assistants) attended a theoretical training on (1) pressure ulcer prevention (pathology, classification, differentiation between IAD and the use of the Braden scale for risk assessment), (2) an introduction to the study aims and protocol, (3) and the use of the data collection instrument. The purpose of this training was to certify the precision and uniformity of the data collection. Trial completion was defined as: (1) development of a pressure ulcer Grade II–IV, (2) 14 days of attending the trial (follow up period), (3) transfer to a non-participating ward, (4) discharge from the hospital, (5) death or (6) withdrawal of the initial consent to participate.

The inter-rater reliability of the observations of the skin at the pressure areas and the Braden scores were monitored by the researcher and the study nurse, who performed observations weekly, independently of each other. These observations and Braden scores were performed unannounced in a random sample of patients included in the study. The inter-rater reliability between researcher, study nurse and ward nurse was sufficient to very good (Landis and Koch, 1977). The inter-rater reliability for the classification of pressure ulcers ranged from k = 0.71 (95% CI 0.63 – 0.79) to k = 0.81 (95% CI 0.78 – 0.85). The inter-rater reliability for risk assessment based on the Braden scale varied from k = 0.64 (95% CI 0.01 – 0.1.28) to k = 0.90 (95% CI 0.81 – 0.99).

2.8 STATISTICAL ANALYSES

Descriptive data are presented in frequencies (percentages) and means (standard deviation) if the data were distributed normally and medians (IQR) if data were not distributed normally. Independent sample t-tests were used in normally distributed continuous data, Mann–Whitney U-tests were used in not normally distributed continuous data, and chi-square and Fisher's exact tests were used in categorical variables. The primary end point was the cumulative incidence of a pressure ulcer Grade II–IV, which is the percentage of patients developing a new pressure ulcer (Grade II–IV) in the population at risk during data collection (Defloor et al., 2005a). Cumulative pressure ulcer incidence allows inferences to be made concerning the effectiveness of preventive measures (Defloor et al., 2005a). Pressure ulcer Grade II or more was chosen as end point, whereas the presence of a pressure ulcer Grade I is commonly used as a method for risk assessment for patients in need of pressure ulcer prevention in Belgian hospitals (Defloor et al., 2004; Vanderwee et al., 2007b; Schoonhoven et al., 2002). This primary end point was compared between groups using a chi-square test. Chi-square tests were also used to compare the proportions of participants between groups with an existing pressure ulcer Grade I and with newly developed pressure ulcers Grade I. Univariate binary logistic regression analysis was used to calculate the odds ratio and related 95% confidence interval for each variable. To evaluate the independence of the effect

of support surfaces on the pressure ulcer incidence, the variables with a value $p < 0.20$ in the univariate analyses were simultaneously entered in a multivariate binary logistic regression analysis combined with variables included on theoretical grounds. A correlation analysis was performed to test for multicollinearity of all independent variables. There was no multicollinearity observed between these variables, using a cut-off correlation coefficient < 0.60. Intraclass correlation coefficients were assessed to calculate the proportion of variance as a result of clustering on ward level and hospital level. Clustering on ward and hospital level was not accountable for any variance in pressure ulcer incidence, for the group in total and separately for the experimental and control group. To examine differences in the secondary outcome, the time needed to develop a pressure ulcer Grade II–IV, a survival analysis with Kaplan Meier plot and log rank test was used. A chi-square test was performed to compare the proportions of participants between groups of withdrawing consent due to dissatisfaction with the support surface under study. Statistical analyses were conducted using SPSS1 15.0 (IBM1 Corporation, Route 100 Somers, NY 10589, USA). A significance level of $p < 0.05$ was used. Intention to treat analysis was performed.

3. RESULTS

During recruitment period of 20 months (14 weeks of risk assessment and a two-week fade-out period for every participating hospital) 7393 patients were screened using the Braden scale. Of the patients considered at risk for pressure ulcer development (n = 1137), 341 were excluded because of (1) the presence of a pressure ulcer Grade II–IV (n = 204), (2) a presumable hospital length of stay of less than 3 days (n = 43), (3) the decision to end all therapeutic measures (DNR code 3) (n = 35), (4) an age of less than 18 years (n = 6), (5) a weight of less than 30 kg or higher than 160 kg (n = 1) and (6) the refusal of consent to participate (n = 52). In 186 patients eligible for inclusion there was no study surface available.

In total, 610 patients were randomised to the control (n = 312) and the experimental (n = 298) ALPAM group. Approximately 60% of the patients were female and the mean age of the participants was 76.3 years (SD = 14.00). Almost half of the patients were incontinent for urine and faeces. The median Braden score of the participating patients was 14.0 (IQR = 12.0–15.0). In both groups, 15.4% of the patients were admitted in the study having a pressure ulcer Grade I (χ^2 = 0.00; df = 1, p = 0.99). Experimental and control group were comparable for all baseline characteristics (Table 2).

In the total group, the cumulative incidence of pressure ulcers Grade II–IV was 5.7%. The pressure ulcer incidence density (Grade II–IV) was 0.54/100 observed days (35 pressure ulcers/6453 observed days) (CI 95% = 0.39–0.75). Most pressure ulcers Grade II–IV occurred at the sacral zone (cumulative incidence = 3.4%) and nine patients developed a heel pressure ulcer (cumulative incidence = 1.7%). The incidence of IAD was 11.1% (Table 3).
In the experimental group, 5.7% of the patients developed a pressure ulcer Grade II–IV, compared to 5.8% in the control group. Univariate analysis showed no significant difference between the two groups (χ^2 = 0.001; df = 1, p = 0.97). In the experimental group, newly developed non-blanchable erythema (pressure ulcer Grade I), was observed in 17.1% of the patients compared to 12.2% in the control group (χ^2 = 2.98; df = 1, p = 0.08).

Theoretically, pressure ulcers observed before day 4 could have been caused by tissue damage prior to the start of the study, as the time between the onset of pressure ulcer development and the external appearance can be 3 days (Reddy, 1990). When excluding pressure ulcers (Grade II–IV) occurring in the first 3 days after admission in the study, the results remained comparable, 3.4% incidence in the experimental group versus 4.2% in the control group (χ^2 = 0.257; df = 1, p = 0.61). Based on univariate analysis, Braden score, non-blanchable erythema at the start of the study and corticosteroids were included in the binary logistic regression analysis. This was completed with variables included on theoretical

grounds, as gender, paralysis, diabetes, tranquilisers, incontinence (urine and faeces), and the maximum time seated in a chair or on transport.

The analysis revealed no significant difference in the development of pressure ulcers Grade II–IV between the groups (OR = 1.17; 95% CI 0.553–2.455; Wald $\chi^2 = 0.16$, df = 1; p = 0.687) (Table 4). An equal number of patients developed a pressure ulcer Grade II–IV at the pelvic area (hip and sacral) in the experimental group (3.7%) compared to the control group (3.5%) ($\chi^2 = 0.01$; df = 1, p = 0.91). No significant difference in pressure ulcer incidence at the heel/ankle was found between the experimental (1.3%) and the control group (1.9%) ($\chi^2 = 0.32$; df = 1, p = 0.57). Seven severe pressure ulcers (Grade III and IV) occurred in the control group (2.2%), compared to four in the experimental group (1.3%) ($\chi^2 = 0.70$; df = 1, p = 0.40). At the heel area, one Grade III–IV pressure ulcer occurred in the experimental group (0.3%), compared to five (1.6%) in the control group (Fisher Exact; df = 1, p = 0.22). In the experimental group, no Grade IV pressure ulcers at the heel area occurred at all, compared to 4 (1.3%) patients in the control group (Fisher Exact; df = 1, p = 0.12). However, none of those differences in severe pressure ulcers between the experimental and the control group were significant.

When patients developed a pressure ulcer, the median time was 5.0 days (IQR = 3.0–8.5) in the experimental group and 8.0 days in the control group (IQR = 3.0–8.5) (Mann–Whitney U-test = 113, p = 0.182). The probability to remain pressure ulcer free during the observation period in this trial did not differ significantly between the experimental group and the control group (log-rank $\chi^2 = 0.013$, df = 1, p = 0.911, Fig. 2). The acceptability of the devices was comparable for both groups. Eleven patients in the experimental group withdrew their consent to participate in the study due to discomfort, compared to seventeen in the control group (1.8 versus 2.6%; $\chi^2 = 3.85$; df = 9, p = 0.92). In both groups, an equal number of patients were lost to follow-up due to technical problems of the study device (Figure 1).

Table 2 Baseline characteristics of included patients

	Total (n=610) mean (SD)[1]	**Control group (n=312) mean (SD)**	**Experimental group (n= 298) mean (SD)**	**t [2]**	**p[3]**
Age	76.3 (14.00)	76.50 (13.20)	76.15 (14.82)	- 0.31	0.76
Weight (kg)	65.8 (15.00)	66.50 (15.16)	65.08 (15.38)	- 1.16	0.25
Length (m)	1.7 (0.095)	1.66 (0.09)	1.65 (0.1)	- 1.36	0.17
BMI [4]	23.8 (4.65)	23.95 (4.66)	23.70 (4.64)	- 0.65	0.51
Braden score					
Median (IQR)	14.0 (12.0-15.0)	14.0 (12.0-15.0)	14.0 (12.0-15.0)	*	0.66
Maximum time sitting &/or transport (hours) [5]	2.4 (3.13)	2.3 (3.18)	2.5 (3.08)	0.73	0.46
	Total (n=610) % (n)	**Control group (n=312) % (n)**	**Experimental group (n= 298) % (n)**	**X^2[6]**	**p**
Gender					
Male	39.4 (241)	41.7 (130)	37.2 (111)	1.24	0.26
Female	60.6 (369)	58.3 (182)	62.8 (187)		
Wards					
Geriatric	32.3 (197)	14.4 (88)	17.9 (109)	6.53	0.59
Neurology	28.2 (172)	15.7 (96)	12.5 (76)		
Pneumology	4.6 (28)	2.5 (15)	2.1 (13)		
Dermatology	5.2 (32)	2.8 (17)	2.5 (15)		
Rehabilitation	7.4 (45)	3.8 (23)	3.6 (22)		
Chronic Care	4.1 (25)	2.1 (13)	2.0 (12)		
Internal medicine	8.5 (52)	5.1 (31)	3.4 (21)		
(combination)	4.3 (26)	2.1 (13)	2.1 (13)		
Oncology	5.4 (33)	2.6 (16)	2.8 (17)		
Cardiology					
Incontinence					
Urinary	66.3 (389)	65.9 (197)	66.7 (192)	0.04	0.84
Fecal	53.9 (318)	54.7 (164)	53.1 (154)	1.14	0.70
Urinary/Fecal	49.5 (302)	50.6 (158)	48.3 (144)	0.33	0.57
Braden- activity					
Bedfast	27.6 (165)	14.4 (86)	13.2 (79)	5.55	0.14
Chairfast 61.3 (366)	30.0 (179)	31.3 (187)			

Table 2 Baseline characteristics of included patients

	Total (n=610) % (n)	**Control group (n=312) % (n)**	**Experimental group (n= 298) % (n)**	**$X^{2(6)}$**	**p**
Braden- Moisture					
Always moistures	13.6 (81)	14.4 (44)	12.7 (37)	2.44	0.49
Mostly moistures	31.0 (185)	29.1 (89)	33.0 (96)		
Diabetes	22.1 (135)	22.8 (71)	21.5 (64)	0.15	0.70
Cerebrovascular disorder	12.5 (76)	11.9 (37)	13.1 (39)	0.21	0.65
Paralysis	11.6 (71)	10.9 (34)	12.4 (37)	0.34	0.56
Medication					
Tranquilizers	46.4 (283)	48.5 (142)	47.5 (141)	0.05	0.81
Corticosteroids(7)	12.5 (76)	10.9 (34)	14.1 (42)	1.43	0.23
PU(8) Grade I present at start	15.4 (94)	15.4 (48)	15.4 (46)	0.00	0.99
IAD(9) present at start	6.4 (39)	7.7 (24)	5.0 (15)	1.80	0.18

(1) SD= standard deviation; (2) t= t-value, unless mentioned else; (3) p= p-value; (4) BMI= Body Mass Index; (5) Maximum time sitting &/or transport= maximum time seated in a chair on a static air cushion and the time the power of the mattress was switched off because of transport; (6) χ^2: Chi-square; (7) Corticosteroids= systemic use of corticosteroids; (8) PU: pressure ulcer present at the start of the study; (9) IAD= Incontinence associated dermatitis present at the start of the study; * Mann-Whitney U-test.

Table 3 Overview of the incidence of pressure ulcers (Grade I-IV) and incontinence-associated dermatitis[5]

	Total (n=610) % (n)	Control (n= 312) % (n)	Experimental (n=298) % (n)	Test	X^2 (df=1)[1]	p[2]
PU Grade I [4]						
(Newly developed)	14.6 (89)	12.2 (38)	17.1 (51)	X^2	2.98	0.08
PU Grade II	3.9 (24)	3.5 (11)	4.4 (13)	X^2	0.28	0.60
Pelvic Area	3 (18)	3.2 (10)	2.7 (8)	X^2	0.14	0.70
Sacral	2.8 (17)	2.9 (9)	2.7 (8)	X^2	0.02	0.88
Hip	0.2 (1)	0.3 (1)	0 (0)	F.E. [3]	_	1.00
Heel Area	0.7 (4)	0.3 (1)	1 (3)	F.E.	_	0.36
Heel	0.7 (4)	0.3 (1)	1 (3)	F.E.	_	0.36
Ankle	0 (0)	0 (0)	0(0)	_	_	_
Other	0.3 (2)	0 (0)	0.7 (2)	F.E.	_	0.24
PU Grade III	1.0(6)	0.6 (2)	1.3 (4)	F.E.	_	0.44
Pelvic Area	0.7 (4)	0.3 (1)	(3)	F.E.	_	0.36
Sacral	0.7 (4)	0.3 (1)	(3)	F.E.	_	0.36
Hip	0 (0)	0 (0)	0 (0)	_	_	_
Heel Area	0.3 (2)	0.3 (1)	0.3 (1)	F.E.	_	1.00
Heel	0.2 (1)	0 (0)	0.3 (1)	F.E.	_	0.49
Ankle	0.2 (1)	0.3 (1)	0 (0)	F.E.	_	1.00
Other	0.0 (0)	0.0 (0)	0.0 (0)	_	_	_
PU Grade IV	0.8 (5)	1.6 (5)	0.0 (0)	F.E.	_	0.06
Pelvic Area	(0)	0.0 (0)	0.0 (0)	_	_	_
Sacral	0.0 (0)	0.0 (0)	0.0 (0)	_	_	_
Hip	0.0 (0)	0.0 (0)	0.0 (0)	_	_	_
Heel Area	0.7 (4)	1.3 (4)	0.0 (0)	F.E.	_	0.12
Heel	0.7 (4)	1.3 (4)	0.0 (0)	F.E.	_	0.12
Ankle	0.0 (0)	0.0 (0)	0.0 (0)	_	_	_
Other	0.2 (1)	0.3 (1)	0.0 (0)	F.E.	_	1.00
PU Grade II-IV	5.7 (35)	5.8 (18)	5.7 (17)	X^2	0.001	0.97
Pelvic Area	3.6 (22)	3.5 (11)	3.7 (11)	X^2	0.01	0.91
Heel Area	1.7 (10)	1.9 (6)	1.3 (4)	F.E.	_	0.75
Other	0.4 (3)	0.3 (1)	0.7 (2)	F.E.	_	0.62
PU Grade III-IV	1.8 (11)	2.2 (7)	1.3 (4)	X^2	0.70	0.40
Pelvic Area	0.7 (4)	0.3 (1)	1.0 (3)	F.E.	_	0.36
Heel Area	1 (6)	1.6 (5)	0.3 (1)	F.E.	_	0.22
Other	0.2 (1)	0.3 (1)	0 (0)	F.E	_	1.00
IAD[5] (newly developed)	11.1 (68)	13.5 (42)	8.7 (26)	X^2	3.45	0.063

[1] X^2 (df=1): Chi-square (degrees of freedom); [2] p: p-value; [3] Fisher Exact test; [4] PU: Pressure Ulcer; [5] IAD: Incontinence-Associated Dermatitis

Table 4 Binary Logistic regression with pressure ulcer Category II-IV as dependent variable and risk factors as independent variables

	B (s.e.) [1]	Wald	OR [2]	95% CI	p-value
Standard ALPAM[3]	0.15 (0.38)	0.16	1.17	(0.553-2.455)	0.687
NBE* [4]	1.53 (0.40)	14.50	4.63	(2.103-10.173)	<0.001
Braden score*	-0.22 (0.08)	7.74	0.80	(0.684-0.936)	0.005
Corticosteroids* [5]	-1.76 (1.04)	2.85	0.17	(0.022-1.329)	0.092
Diabetes [6]	0.49 (0.42)	1.31	1.63	(0.708-3.731)	0.252
Tranquillizers[7]	0.20 (0.39)	0.27	1.22	(0.574-2.593)	0.606
Paralysis [8]	0.21 (0.53)	0.16	1.23	(0.440-3.451)	0.691
Maximum time sitting &/or transport [9]	0.04(0.06)	0.42	1.04	(0.921-1.178)	0.518
Incontinence (urine & faeces) [10]	-0.11(0.39)	0.08	0.90	(0.418-1.922)	0.779
Gender [11]	-0.39 (0.40)	0.98	0.68	(0.311-1.468)	0.322

[1] B(s.e.): regression coefficient (standard error); [2] OR: odds ratio; [3] Standard ALPAM: control group is reference category; [4] NBE at the start of the study: absence of Non- Blanchable Erythema is reference category; [5] Corticosteroids (systemic): absence of corticosteroids is reference category; [6] Diabetes: absence of diabetes is reference category; [7] Tranquillizers: absence of tranquillizers is reference category; [8] paralysis: absence of paralysis is reference category; [9] Maximum time sitting and/or transport= maximum time seated in a chair on a static air cushion and the time the power of the mattress was switched off because of transport; [10] Incontinence: absence of double incontinence is reference category; [11]Gender: male is reference category;

*Variables in Univariate analysis p<0.2

4. DISCUSSION

The aim of this clinical trial was to compare the effectiveness of an ALPAM with multi-stage inflation and deflation cycle of the air cells (experimental mattress) with the effectiveness of an ALPAM with a standard one-stage inflation and deflation cycle of the air cells (control mattress). The primary outcome was the cumulative incidence of pressure ulcers Grade II–IV. Both mattresses resulted in a low pressure ulcer incidence. The experimental mattress did not result in a significantly lower pressure ulcer incidence compared to the control mattress. Both mattresses were equally effective to prevent pressure ulcers. The time to develop a pressure ulcer was comparable in both groups. This discussion will

compare the results of this study with those from similar trials and will account for possible explanations for the observed effects.

4.1 COMPARISON WITH SIMILAR TRIALS

Clinical trials on the effectiveness of APAMs (using a similar design and methodology) reported incidence figures between 10.5% (Nixon et al., 2006b) and 15.3% (Vanderwee et al., 2005). Those results are considerably higher than the results found in the current trial (cumulative pressure ulcer incidence = 5.7%). The incidence density was found to be lower [0.54/100 observed days (95% CI = 0.39–0.75)], compared to the APAM study by Vanderwee et al. (2005) [1.46/100 observation days (95% CI = 0.98–1.97)]. These findings are supported by the study of Cavicchioli and Carella (2007) on pressure ulcer incidence on ALPAMs, using a comparable patient population and study methodology. In the trial of Cavicchioli and Carella (2007), with a smaller sample size, even a lower pressure ulcer incidence was found (cumulative pressure ulcer incidence including Grade I = 2.9%). Different reasons may account for the differences found in pressure ulcer incidence between APAMs studies and the current ALPAM study.

A first reason might be related to the use of different inclusion criteria in the trials. In the study by Nixon et al. (2006a), a large proportion of the patients (79%) were bedbound, compared to 27.6% in this trial (61.3% was chairbound). No reference was made to the use of a standardised protocol for patients at risk when they were sitting in a chair. The fact that the patients were less mobile and the possible lack of a standardised protocol when seated in a chair may have resulted in these considerably higher pressure ulcer incidences. Compared to Vanderwee et al. (2005), considerably fewer patients entered the study with non-blanchable erythema (15.4% versus 33.6%). As non-blanchable erythema is considered as an independent risk factor for pressure ulcer development (Nixon et al., 2007) the population in the current study was probably less at risk for pressure ulcer development compared to the trial by Vanderwee et al. (2005).

A second reason may be related to the differences in observer training regarding the clinical differences between pressure ulcers and IAD. Difficulties related to

pressure ulcer observation and differentiation between pressure ulcers and IAD have been reported in multiple studies (Beeckman et al., 2007; Kottner et al., 2009b). Beeckman et al. (2007) found that only 22% of the nurses correctly assessed IAD, which were often misclassified as a pressure ulcer Grade II or Grade III. Although a considerable proportion of the included patients in the Nixon trial (15%) had a moist skin according to the Braden scale (Nixon et al., 2006a), the researchers did not mention the organisation of a training to observe the difference between pressure ulcers and IAD. This lack of training may have caused an overestimation of pressure ulcers in their study. In this trial, all observers were intensively trained to correctly differentiate between pressure ulcers and IAD. Furthermore, the correctness of the skin observations was regularly assessed by introducing inter-observer checks between the observations of the ward nurses, the study nurses and the researcher. The inter-rater reliability was sufficient to good (Landis and Koch, 1977).

A third reason for the difference in pressure ulcer incidence between the APAM studies and this ALPAM study may be the lower interface pressure and the higher pressure redistribution index of the ALPAM, which suggests a hypothetical advantage of this support surface. Large and methodological sound clinical trials are needed to confirm the existence of a clinical advantage.

4.2 POSSIBLE EXPLANATIONS FOR THE OBSERVED EFFECTS

No differences in pressure ulcer development were found between the experimental and the control mattress. A first possible explanation may be related to the gradual inflation and deflation cycle of the experimental mattress. The possible role of this gradual inflation and deflation cycle of the air cells, in pressure ulcer development is not yet clear and needs to be clarified. It is possible that this modification of the inflation/deflation cycle only is not able to impact pressure ulcer incidence significantly.

Secondly, despite the fact that this is one of the largest trials of this kind, the lack of effect may also be related to the power of the study. The study was powered on the assumption of a pressure ulcer incidence of 15% on an APAM (Vanderwee et al., 2005), because there were no data available on incidence on

ALPAMs at the start of the study. In the current study, only 5.7% of the included patients developed a pressure ulcer. These lower incidence figures resulted in a decrease in power. Moreover, with the minimal differences in pressure ulcer incidence found between both groups, it is likely that significance could not be achieved by the recruitment of more patients. An assessment based on the figures found in this study suggest the need of an unrealistic, not feasible sample size to find a significant result between the two groups, if this difference would even exist.

Thirdly, the lack of difference found between the two study groups can be due to the fact that the control group performed better than expected. A pressure ulcer incidence on ALPAMs with a one-stage inflation and deflation cycle was assumed to be comparable with the incidence on APAMs, which was not found in this study. As mentioned above, there are several possible explanations for this difference.

At the heel area the experimental mattress included an ultra-low continuous pressure zone and the control mattress included an alternating low pressure zone. Pressure ulcers Grade II–IV still occurred on both devices with an incidence of 1.7% at the heel area. However, no differences in heel pressure ulcers were observed between both mattresses and we observed a non-significant difference in the severity of heel pressure ulcers between the mattresses. More patients developed a severe pressure ulcer (Grade III–IV) the heel area in the control group compared to the experimental group. However, this is based on a small number of pressure ulcers. Continuous ultra-low pressure at the heel zone is not adequate to prevent the development of heel pressure ulcers, but can have an additional role in the effective prevention. Nevertheless, offloading the heels in accordance with the latest NPUAP/EPUAP guidelines (2009) remains the most appropriate and effective way to prevent heel pressure ulcers. Further research needs to clarify the possible additional value of continuous very low pressure at the heel area when combined with offloading the heels.

5. LIMITATIONS

The lack of a blinded outcome assessment is a first limitation of this study. However, the nurses were not informed about the differences in the mattresses in order to minimise the effect of non-blinding. Furthermore, inter-rater observations were conducted to assure the reliability of the observations. A second limitation is related to the limited predictive value of the Braden scale to assess risk for pressure ulcer development. Risk assessment, and particularly the use of risk assessment scales, has always been a controversial issue in practice and in scientific debates. This controversy is linked to the limited predictive validity of the available risk assessment scales. In 2002, Schoonhoven and co-workers concluded that the Braden scale is only able to predict the development of pressure ulcers to some extent. This issue might have resulted in the inclusion of patients who were thought as being at risk, but who were not.

Although the cumulative pressure ulcer incidence on ALPAMs found in this study can be seen as representative for a population of geriatric and medical patients, these results cannot be generalized to other patient populations.

6. CONCLUSION

Based on the results of this study, we can conclude that ALPAMs with multi-stage inflation and deflation cycle of the air cells and standard ALPAMs are equally effective in pressure ulcer prevention. Both ALPAMs generate a low pressure ulcer incidence and consequently seem to be good and effective preventive measures.

CONFLICT OF INTEREST

There are no conflicts of interest.

FUNDING

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ROLE OF THE FUNDING SOURCE

Hill-rom™ did not influence the study design, data collection, interpretation of the results, and the decision to publish.

ETHICAL APPROVAL

The study received approval from the Ethical Committee of Ghent University Hospital (B/67020071976) and of the Ethical Committee of each participating hospital. Informed consent was obtained from the participating patients or their legal representative by the researcher or the ward nurse.

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CHAPTER 3

THE EFFECTIVENESS OF THREE TYPES OF ALTERNATING PRESSURE AIR MATTRESSES IN THE PREVENTION OF PRESSURE ULCERS IN BELGIAN HOSPITALS

Based on the article of Demarré L, Verhaeghe S, Van Hecke A, Grypdonck M, Clays E, Vanderwee K & Beeckman D (2013) The effectiveness of three types of alternating pressure air mattresses in the prevention of pressure ulcers in Belgian hospitals.
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ABSTRACT

To compare the effectiveness of multi-stage and one-stage alternating low-pressure air mattresses (ALPAM) and alternating pressure air mattress (APAM) overlays in preventing pressure ulcers among hospitalised patients, data were pooled (N=617) from a study of patients allocated to multi-stage ALPAM (n=252) or one-stage ALPAM (n=264), and another study of patients allocated to APAM overlay (n=101). Cumulative pressure ulcer incidence was 4.9% (n=30) over 14 days. Fewer ulcers developed on multi-stage ALPAM compared with APAM overlay (OR=0.33; 95% CI [0.11, 0.97]), but no difference was found between one-stage ALPAM and APAM overlay (OR=0.40; 95% CI [0.14, 1.10]). Time to develop ulcers did not differ by mattress type.

1. INTRODUCTION

Pressure ulcers remain a significant health problem for patients and healthcare providers. Pressure ulcer development is a complex phenomenon. Exposure to pressure and/or shear, a combination of ischemia, direct cell deformation, ischemic reperfusion injury, and impaired lymphatic drainage may lead to damage to the skin or the underlying tissues and structures (Ceelen et al., 2008; Loerakker et al., 2011; NPUAP & EPUAP, 2009; Reed, et al., 2003; Tsuji, et al., 2005).

In 2004, the prevalence of pressure ulcers in US hospitals was 16.0% (Whittington & Briones, 2004), and similar results (prevalence of 18.1%) were found across Europe (Vanderwee, et al., 2007a). In 2009, pressure ulcer prevalence in US hospitals was reduced to 6.7% (Gunningberg, et al., 2012). Changes in reimbursement policy, hospital staffing, and increased awareness of the negative patient outcomes of hospital-acquired pressure ulcers may have prompted more systematic risk assessment and timely start of preventive measures.

Paramount to the prevention of pressure ulcers is reducing the amount and duration of pressure or shear, which can be achieved by the use of patient repositioning or by a support surface, “a specialized device for pressure redistribution designed for management of tissue loads” (NPUAP, 2007, p. 1). Pressure redistribution can be achieved by temporarily shifting contact between the support surface and vulnerable areas or pressure points to other areas (NPUAP, 2007), either by repositioning the patient or by using an active support surface (NPUAP 2007; NPUAP & EPUAP, 2010).

An active support surface is a powered surface that achieves load distribution by cyclic inflation and deflation of air cells, with or without body weight of the patient resting on the surface (NPUAP, 2007). Active support surfaces differ in their duration of cycle time, rate of change of air cell inflation, and pressure amplitude (NPUAP, 2007). Pressure amplitude is defined as the difference between the

highest and the lowest interface pressure (Tissue Viability Society, 2010). An example of an active support surface is an alternating pressure air mattress (APAM), available as APAM overlays (used atop a standard bed mattress) and APAM replacement mattresses. The inflation and deflation of the air cells of an APAM are characterized by a steep, one-stage inflation or deflation.

Pressure redistribution also can be achieved with a support surface that enables the patient to sink into the mattress, thereby increasing the contact area between the patient and the support surface. Alternating low pressure air mattresses (ALPAMs) generate lower pressures than APAMs, enabling them not only to shift pressure or shear to other areas of the body but to better envelop the body in the underlying support surface. One-stage ALPAMs have air cells that inflate and deflate in a single step. The air cells of more recent multi-stage ALPAMs have gradual, stepwise inflation and deflation, in response to the hypothesis that tissue damage is decreased by gradual reperfusion of ischemic tissue (Unal et al., 2001).

The use of different types of pressure redistributing surfaces varies internationally. Based on limited reports, in US acute care settings, 57% of patients with a hip fracture, a population of patients considered at risk for pressure ulcers, are placed on pressure-redistributing surfaces (Baumgarten et al., 2010). The absence of studies of APAM overlays from the United States suggests that these devices may be less common in US healthcare institutions. However, their use is widespread in Europe (Manzano et al., 2013; Nixon et al., 2006b), where the incidence of pressure ulcers on APAM overlays ranged between 10.7% (Nixon et al., 2006b) and 15.3% (Vanderwee, et al., 2005) in adult populations at risk. The incidence of pressure ulcers on one-stage ALPAMs has ranged between 2.9% and 5.8% (Cavicchioli & Carella, 2007; Demarré et al., 2012; Theaker, et al., 2005). Pressure ulcer incidence on multi-stage ALPAMs was 5.7% (Demarré et al., 2012a). Demarré et al. (2012a) found one-stage and multi-stage ALPAMs equally effective in terms of pressure ulcer incidence and time to develop a pressure ulcer.

Costs for purchase and maintenance of support surfaces vary widely. The purchase price for an APAM overlay is estimated at $1,500 (Nixon et al., 2006). Estimated purchase costs for a one-stage ALPAM range from $2,500 to $3,500, and from $6,000 to $7,000 for a multi-stage ALPAM. Given these cost differences, health systems may take an interest in their comparative effectiveness. In a systematic review and meta-analysis, McInnes et al. (2012) did not find any one specific alternating pressure device more effective than others, but no comparisons of the effectiveness of an APAM overlay with a one-stage or multi-stage ALPAM have been reported.

To help determine whether more complex technology leads to more effective devices, data from two previously conducted randomised controlled trials (RCTs) were pooled to compare the effectiveness of the less expensive APAM overlay with one-stage and multi-stage ALPAMs. The main outcome was cumulative incidence of all pressure ulcers (Category/ Stages II–IV). Subgroup analyses examined predictors of superficial (Category/Stage II) and severe (Category/Stages III–IV) pressure ulcers. The secondary outcome was the time to develop a pressure ulcer.

2. METHODS

2.1 DESIGN

A comparative design was used to pool the data from two RCTs (Demarré et al., 2012a; Vanderwee et al., 2005). In the study by Vanderwee et al. (2005) (hereafter referred to as “APAM overlay study”), data were collected from May 2000 until August 2002. In the study by Demarré et al. (2012a) (hereafter referred to as “ALPAM study”), data were collected from December 2007 until January 2010.

2.2 Randomized Controlled Trials Used for the Pooled Database

APAM overlay study.

The APAM overlay study included 447 patients admitted to 1 of 19 surgical, medical, and geriatric wards in a convenience sample of seven Belgian hospitals. Risk assessment was conducted in consecutive patients admitted to the participating wards during the study period. The Braden score was assessed on admission and every 3 days, and the presence or absences of non-blanchable erythema was assessed daily. The Braden scale is a risk assessment scale that consists of six items: sensory perception, mobility, activity, nutrition, friction, and shear. The lowest score on the Braden scale is 6 (high risk) and the highest is 23 (no risk). A patient was classified as at risk for pressure ulcer development if the Braden score was less than 17 or when non-blanchable erythema was present. This cut-off score is commonly used in Belgian health care institutions (Defloor, et al., 2004; Vanderwee et al., 2005) and was chosen to enhance comparability with other studies (Baumgarten et al., 2010; Defloor, et al., 2005; Vanderwee et al., 2005, Vanderwee et al., 2007). Patients at risk were randomly assigned to an APAM overlay with no repositioning protocol or to a viscoelastic polyethylene-urethane foam mattress with a standardised repositioning protocol every 4 hours. In both groups, a pillow supporting the calf of the leg was used for heel offloading. All patients used a static air cushion for pressure redistribution when seated (Vanderwee et al., 2005).

ALPAM study. The ALPAM study included a consecutively identified sample of 610 patients from a convenience sample of five Belgian hospitals. Eight geriatric wards and 17 medical wards participated in the study, the latter consisting of neurology (6), rehabilitation (3), cardiology (2), dermatology (1), pulmonology (1), oncology (1), chronic care (1), or mixed medical conditions (2). Patients with Braden scores less than 17 were classified as at risk for pressure ulcer development (Baumgarten et al., 2010; Defloor et al., 2005; Vanderwee et al., 2005, 2007). The patients at risk were randomly assigned to a one-stage ALPAM (n=312) or to a multi-stage ALPAM (n=298). No standard protocol for

repositioning in bed was used in either group, and all patients used a static air cushion to redistribute pressure when seated (Demarré et al., 2012a). An equal number of one-stage and multi-stage ALPAMs were available during the study period. Further information on the two studies is available in previous publications (Demarré et al., 2012a; Vanderwee et al., 2005).

2.3 Inclusion Criteria Used for the Pooled Database

Patient data were pooled if the following criteria were met (see Figure 1):

- Allocation to an alternating pressure air device (APAM overlay, one-stage or multi-stage ALPAM).
- Braden score of less than 17 (Baumgarten et al., 2010; Defloor et al., 2005; Vanderwee et al., 2005, Vanderwee et al., 2007).
- No pressure ulcer of any category/stage at the start of the study. Patients with pressure ulcers Category/Stage I (n=175) were excluded for this pooled analysis, as the presence of a pressure ulcer Category/Stage I was only an inclusion criteria in the APAM overlay study.
- Admitted to a geriatric or internal medicine ward.

The first 14 observation days were examined. This 14-day period was chosen based on the mean length of stay in Belgian hospitals (6 days on medical wards to 18 days on geriatric wards) (Flemish Agency for Care and Health in Trybou, 2011).

2.4 Interventions: Alternating Pressure Support Surfaces

Table 1 provides an overview of the characteristics of the support surfaces in this study. The three support surfaces were comparable with respect to the diameter of the air cells (10 cm), rate of change of inflating/deflating air cells (sequence of one cell inflated/one cell deflated), and time needed to complete one cycle (between 10 and 12 minutes). No standard repositioning protocol was used for any patient. All patients used a static air cushion when seated in an armchair.

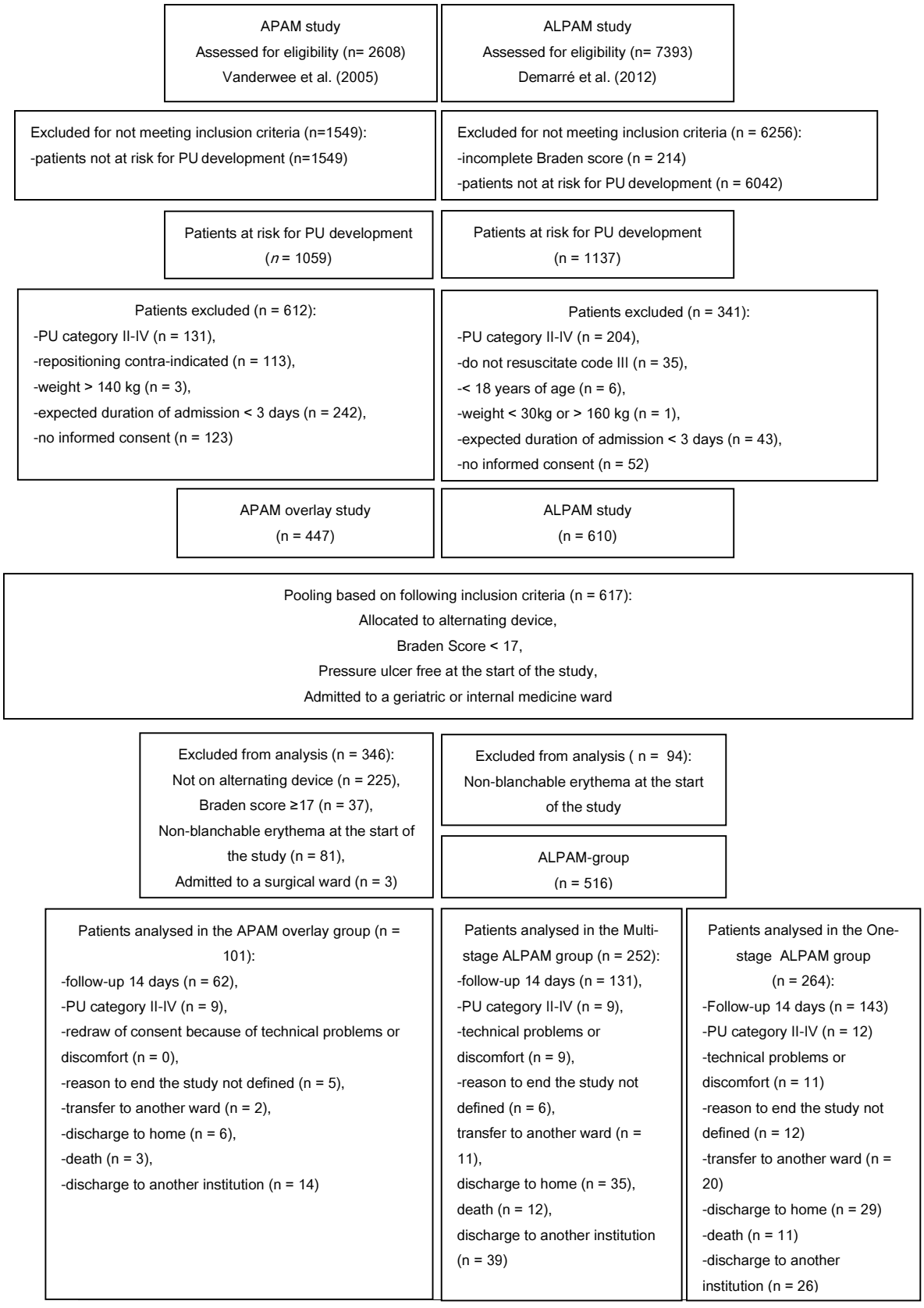

Figure 1 Flowchart of pooling process.

PU = Pressure ulcer; APAM = Alternating Pressure Air Mattress; ALPAM = Alternating Low-Pressure Air Mattress

The main differences among the three groups were: (1) the type of support surface (overlay vs. replacement), (2) the air cell pressures, (3) the method of inflating and deflating the air cells, (4) the use of a sensor, and (5) the preventive measures at the heels (Table 1).
A detailed description of these differences is provided below.

APAM overlay. The overlay was placed atop a standard mattress. The inflation and deflation of the APAM overlay air cells was steep and one-staged. All air cells except three at the head zone alternated inflation and deflation. The surface was manually adjusted to the patient's weight via an external control unit. The heels of the patients were offloaded, using a pillow supporting the calf of the leg.

One-stage ALPAM. The one-stage ALPAM replaced the standard mattress. The air cell cycle of the one-stage ALPAM was characterised by steep inflation and deflation. All air cells alternated. The mattress was manually adjusted to the patient's weight via an external control unit. No heel offloading was provided.

Multi-stage ALPAM. The multi-stage ALPAM was also a mattress replacement. The air cells of the multi-stage ALPAM were gradually inflated and deflated. The air cells at the spine and the sacrum alternated. A sensor at the sacrum continuously measured weight distribution and adjusted the pressure in the cells. The air cells at the head and heels did not alternate but had continuous low pressure. No heel offloading was provided.

2.5 Outcome Measures and Subgroup Analyses

Main and secondary outcomes were compared in APAM overlay, one-stage ALPAM, and multi-stage ALPAM groups. The primary outcome was cumulative pressure ulcer incidence of Category/Stages II–IV on any location of the body during the 14-day period of observation. The secondary outcome was the time in days to develop a pressure ulcer of Category/Stages II–IV.

Table 1 Specifications and Characteristics of Experimental and Control Group

	Support Surface		
	ALPAM		
Characteristic	Multi-stage	One-stage	APAM overlay
Cycle amplitude	Multi-stage inflation and deflation of air cells	One-stage inflation and deflation of air cells	One-stage inflation and deflation of air cells
Cycle Time	10-12 minutes	10 minutes	10 minutes
Air cell inflation sequence	1/1	1/1	1/1
Width air cells (diameter)	10 cm	10 cm	10 cm
Alternating sequence	(1) Head zone: 3 cells continuous low pressure (not alternating) (2) Back and sacrum: 10 cells alternating low pressure (1/1) (3) Heel zone: 7 cells continuous ultra low pressure (not alternating)	(1) All cells alternate, except from 3 cells at the head zone (1/1)	(1) All cells alternate, except from 3 cells at the head zone (1/1)
Heels	Continuous ultra low pressure zone	Alternating low pressure zone	Heel offloading using a pillow
Sensor	Yes Continuously measuring the load applied on sacral zone	No Manually adjustable for weight.	No
System	Mattress replacement	Mattress replacement	Mattress overlay

ALPAM = Alternating Low-Pressure Air Mattress; APAM = Alternating Pressure Air Mattress; 1/1 = one air cell is inflated/one air cell is deflated

Pressure ulcers were categorized according to the classification system of the NPUAP and EPUAP (2009), in which pressure ulcer severity ranges from non-blanchable erythema (Category/Stage I) and partial thickness skin loss (Category/Stage II) to full thickness skin loss (Category/Stage III) and full thickness tissue loss (Category/Stage IV). To differentiate between blanchable and non-blanchable erythema, a transparent plastic disc was used (Halfens, et al., 2001). Pressure ulcers were distinguished from incontinence-associated dermatitis (IAD) and friction lesions. An IAD was defined as a reactive response of the skin to chronic exposure to urine and faecal material (Beeckman, et al., 2009; Gray et al., 2012). No data were collected on the use of incontinence briefs or the prevention and treatment of IAD. A friction lesion was defined as damage caused by "the rubbing of one body against another or the force that resists relative motion between two bodies in contact and/or material elements sliding against each other" (Antokal et al., 2012, p. 1).

A subgroup analysis of patients who developed pressure ulcers was done to examine group differences in cumulative incidence of superficial versus severe pressure ulcers. In addition, because tissue damage could have developed in underlying tissue prior to the patients' inclusion in the study (Berlowitz & Brienza, 2007; Gefen, 2009), cumulative pressure ulcer incidence was analysed excluding patients who developed severe pressure ulcers in the first 3 days (Reddy, 1990).

2.6 PROCEDURE

Baseline variables from both studies were age, gender, diagnosis, type of ward (geriatric or medical), and Braden risk assessment score (Table 2). Both studies had an identical procedure. Skin assessment was performed by the ward nurses on a daily basis during morning care. To enhance the precision of the observations and the uniformity of data collection, all nurses attended a training session on aetiology, pressure ulcer classification, differentiation from IAD and friction lesions, differentiation of blanchable and non-blanchable erythema, and the use of the Braden scale. The training also clarified the aim of the study and the protocol.

The inter-rater reliability of the skin observations and the Braden score was assessed weekly. These observations and Braden scores were performed unannounced in a random sample of patients in the study. The inter-rater reliability among researcher, study nurse, and ward nurse ranged between k=0.71 (95% CI [0.63, 0.79]) to k=0.94 (95% CI [0.91, 0.97]) for skin observations, and between k=0.64 (95% CI [0.01, 1.28]) to k=0.90 (95% CI [0.81, 0.99]) for risk assessment (Demarré et al., 2012a; Vanderwee et al., 2005).

Data from the first 14 days after study inclusion were used in analysis. No data were collected after patients developed a pressure ulcer Category/Stages II–IV, or withdrew their consent, died, or were discharged to a non-participating ward, home, or nursing home (see Figure 1).

2.7 Statistical Analyses

The variables included in analyses in addition to group assignment were those that were identical in both studies: age, gender, diagnosis, type of ward (geriatric or medical), and the Braden risk assessment. Frequencies (percentages) and medians (interquartile range) were used to present descriptive data. To compare non-normally distributed continuous data, Kruskal–Wallis tests were conducted. For categorical variables, Chi-square and Fisher's exact tests were used. Univariate binary logistic regression analyses were conducted to calculate the odds ratio and related 95% CIs for each variable. Only Braden risk assessment and the age of the patient were associated with pressure ulcer development ($p<0.10$) in univariate analyses, and both variables were included as covariates in multivariate analyses. The total Braden score was entered in the multivariate analyses rather than the separate Braden items, as the total score had the lowest p-value in univariate analyses.

No multicollinearity was detected between the independent variables. Multivariate logistic regression was used to examine the influence of support surface type, risk category, and age on pressure ulcer development and pressure ulcer severity. A log-rank test analysis and a Kaplan–Meier survival plot were used to examine differences in time to develop pressure ulcers. Statistical

analyses were conducted using SPSS 15.0 (IBM Corporation, Somers, NY), and a significance level of $p<0.05$ was set.

3. Results

3.1 Baseline Characteristics

The data of 617 patients were analysed (multi-stage ALPAM: n=252, one-stage ALPAM: n=264, and APAM overlay: n=101). The median age of the patients was 80 years (IQR=71–86), and 60.1% (n=365) were female. Patients were most frequently admitted with neurological diagnoses (25.9%), rehabilitation disorders (23.4%), or pulmonary disorders (17.9%). The median Braden score was 14 (IQR=12–15). Baseline patient characteristics are presented in Table 2. Activity level, gender, primary diagnosis, and Braden score were comparable among groups. Patients were significantly older (p=0.03) in the APAM overlay group (Mdn=81), compared with the one-stage ALPAM (Mdn=79) and multi-stage ALPAM (Mdn=80). More patients in the APAM overlay group than in the one-stage and multi-stage ALPAM groups were cared for in geriatric wards ($p<0.001$).

3.2 Primary Outcome: Cumulative Incidence of Pressure Ulcers Outcomes in support surface groups.

In the sample as a whole, the cumulative pressure ulcer incidence was 4.9% (n=30). Pressure ulcer incidence was significantly lower in the multi-stage ALPAM group (3.6%) compared with the APAM overlay group (8.9%) (p=0.047). The difference between the APAM overlay group (8.9%) and the one-stage ALPAM group (4.5%) was not significant (p=0.126). More patients developed non-blanchable erythema in the APAM overlay group (23.8%) compared with the one-stage ALPAM group (14.4%) (p=0.045). Most pressure ulcers occurred in the pelvic area, either sacrum or hip (n=17, 2.7% of sample). No significant differences in pelvic area ulcer incidence were found between the multi-stage ALPAM (2.0%) and APAM overlay (5.8%) groups (Fisher's exact; p=.088), or

Table 2 Baseline characteristics of included patients

		Type of Support Surface				
		ALPAM				
	Total *Mdn (IQR)*	Multi-stage *Mdn (IQR)*	One-stage *Mdn (IQR)*	APAM overlay *Mdn (IQR)*	Kruskall Wallis-test	p
			Continuous Variables			
Age	80 (71-86)	80 (70-86)	79 (70-85)	81(75-89)	7.0	0.03
Braden score	14 (12-15)	14 (12-15)	14 (12-15)	15 (13-15.5)	5.8	0.05
		Type of Support Surface				
		ALPAM[2]				
	Total % (n)	Multi-stage % (n)	One-stage % (n)	APAM overlay[3] % (n)	χ^2	p
			Categorical variables			
Gender*						
Male	39.9 (242)	39.7 (100)	42.8 (113)	31.9 (29)	3.4	0.18
Female	60.1 (365)	60.3 (152)	57.2 (151)	68.1 (62)		
*10 missings						
Ward						
Geriatrics	37.4 (231)	34.1 (86)	29.2 (77)	67.3 (68)	47.4	<.001
Internal medicine	62.6 (386)	65.9 (166)	70.8 (187)	32.7 (33)		
Activity level					8.1	0.23
Bedfast	27.2 (167)	26.2 (66)	25.3 (66)	34.7 (35)		
Chair fast	62.4 (383)	65.1 (164)	61.7 (161)	57.4 (58)		
Ambulatory	10.5 (64)	8.7 (22)	13.0 (34)	7.9 (8)		
Diagnosis*					20.1	0.07
Neurologic	25.9 (155)	29.8 (75)	25.8 (67)	15.1 (13)		
Pneumologic	17.9 (107)	17.9 (45)	19.2 (50)	14.0 (12)		
Rehabilitation	23.4 (140)	24.6 (62)	21.5 (56)	25.6 (22)		
Cardiac	7.4 (44)	7.9 (20)	6.5 (17)	8.1 (7)		
Gastrologic	14.2 (85)	11.5 (29)	15.8 (41)	17.4 (15)		
Urogenital	4.2 (25)	4.4 (11)	3.1 (8)	7.0 (6)		
Other	7.0 (42)	4.0 (10)	8.1 (21)	12.8 (11)		
*19 missings						
Total	617	252	264	101		

IQR = Inter Quartile Range; ALPAM = alternating low pressure air mattress; APAM overlay = alternating pressure air mattress overlay; p = p-value; χ^2 = Chi-square test;

between the one-stage ALPAM (2.3%) and APAM overlay group (5.8%) (Fisher's exact; p=0.106). Seven (1.1%) patients developed pressure ulcers on the heel. Pressure ulcer incidence on the heel was comparable among the three groups (Fisher's exact for comparisons above; p=1.00; p=1.00) (Table 3).

3.3 Independent effects of support surface, age and risk category on incidence of pressure ulcers in multivariate analyses.

Multivariate analyses confirmed that pressure ulcer development was lower in the multi-stage ALPAM group compared with the APAM overlay group, when controlling for Braden score category and age (OR=0.33; 95% CI [0.11, 0.97]) (see Table 4). No significant differences in pressure ulcer development were found between patients on an APAM overlay and those on a one-stage ALPAM (OR=0.40; 95% CI [0.14, 1.10]). The results were similar when excluding severe pressure ulcers occurring in the first 3 days after admission to the study. Age was not associated with pressure ulcer incidence in multivariate analyses. Fewer severe pressure ulcers developed in the multi-stage ALPAM group compared with the APAM overlay group (OR=0.08; 95% CI [0.01, 0.83]). No difference in incidence of superficial pressure ulcers was found among the three study groups.

More pressure ulcers developed in higher risk patients, with Braden scores between 6 and 9, than those with Braden scores between 15 and 16 (OR=5.23; 95% CI [1.67, 16.32]), due to higher incidence of superficial pressure ulcers among the higher-risk patients (OR=6.89; 95% CI [1.84, 25.75]). Risk category based on the Braden scale was not associated with severe pressure ulcers (OR=2.28; 95% CI [0.22, 23.32]) (Table 4).

Table 3 Overview of the cumulative pressure ulcer incidences

Pressure ulcers	Total % (n)	Support Surface: ALPAM Multi-stage % (n)	Support Surface: ALPAM One-stage % (n)	Support Surface: APAM % (n)	Multi-stage ALPAM vs APAM p	One-stage ALPAM vs APAM p
Category I	18.3 (113)	20.2 (51)	14.4 (38)	23.8 (24)	0.550	**0.045**
Category II	3.2 (20)	3.2 (8)	2.7 (7)	5 (5)	0.532*	0.325*
Category III	1.0 (6)	.4 (1)	.4 (1)	4 (4)	**0.025***	**0.022***
Category IV	.6 (4)	0 (0)	1.5 (4)	0 (0)	-	0.579*
Category II-IV	4.9 (30)	3.6 (9)	4.5 (12)	8.9 (9)	**0.047**	0.126
Pelvic Area	2.7 (17)	2.0 (5)	2.3 (6)	5.8 (6)	0.088*	0.106*
Heels	1.1 (7)	0.8 (2)	1.5 (4)	1.0 (1)	1.000*	1.000*
Other	1.0 (6)	0.8 (2)	0.8 (2)	1.9 (2)	0.583*	0.317*

ALPAM = alternating low pressure air mattress; APAM = alternating pressure air, p = p-value, Pelvic Area = Sacrum and Hips; * Fisher-Exact test

Table 4 Multivariate analysis with pressure ulcer severity as dependent variable

Variable	Wald	OR	95% CI	p
Pressure ulcer category II-IV				
Multi-stage ALPAM [(1)]	4.10	0.33	[0.11,0 .97]	**0.043**
One-stage ALPAM [(1)]	3.18	0.40	[0.14, .1.10]	0.103
Braden moderate risk (13-14) [(2)]	0.01	0.96	[0.30, 3.00]	0.938
Braden high risk (10-12) [(2)]	2.09	2.13	[0.76, 5.93]	0.148
Braden very high risk (6-9) [(2)]	8.11	5.23	[1.67, 16.32]	**0.004**
Age	1.06	0.99	[0.96, 1.01]	0.303
Pressure ulcer category II				
Multi-stage ALPAM [(1)]	0.97	0.52	[0.15, 1.89]	0.324
One-stage ALPAM [(1)]	1.98	0.38	[0.10, 1.46]	0.159
Braden moderate risk (13-14) [(2)]	0.070	1.19	[0.31, 4.54]	0.799
Braden high risk (10-12) [(2)]	0.55	1.67	[0.43, 6.43]	0.458
Braden very high risk (6-9) [(2)]	8.23	6.89	[1.84, 25.75]	**0.004**
Age	0.24	0.99	[0.96, 1.02]	0.627
Pressure ulcer category III-IV				
Multi-stage ALPAM [(1)]	4.47	0.08	[0.01,0 .83]	**0.035**
One-stage ALPAM [(1)]	1.49	0.39	[0.08, 1.78]	0.223
Braden moderate risk (13-14) [(2)]	0.32	0.52	[0.05, 5.13]	0.574
Braden high risk (10-12) [(2)]	1.82	2.92	[0.62, 13.84]	0.174
Braden very high risk (6-9) [(2)]	0.49	2.28	[0.22, 23.32]	0.486
Age	1.27	0.98	[0.93, 1.02]	0.259

OR = odds ratio; CI = Confidence Interval; ALPAM = alternating low pressure air mattress;
[(1)] APAM overlay group is reference category, [(2)] Braden mild risk (15-17) is reference category; p = p-value.

3.4 SECONDARY OUTCOME: TIME TO DEVELOP A PRESSURE ULCER

Overall, the median time to develop a pressure ulcer was 8 days (IQR=4.00–12.25). No difference in time to ulcer was found among the three groups (multi-stage ALPAM=6 days [IQR= 3.50–8.50], one-stage ALPAM=11.5 days [IQR=4.0–14.0], and APAM overlay=8 days [IQR=4.50–8.50], Kruskal–Wallis test χ^2=5.749, p=0.056). The probability of remaining pressure ulcer-free did not differ among the three groups (log-rank X^2=3.167, df=2, p=0.205, Figure 2).

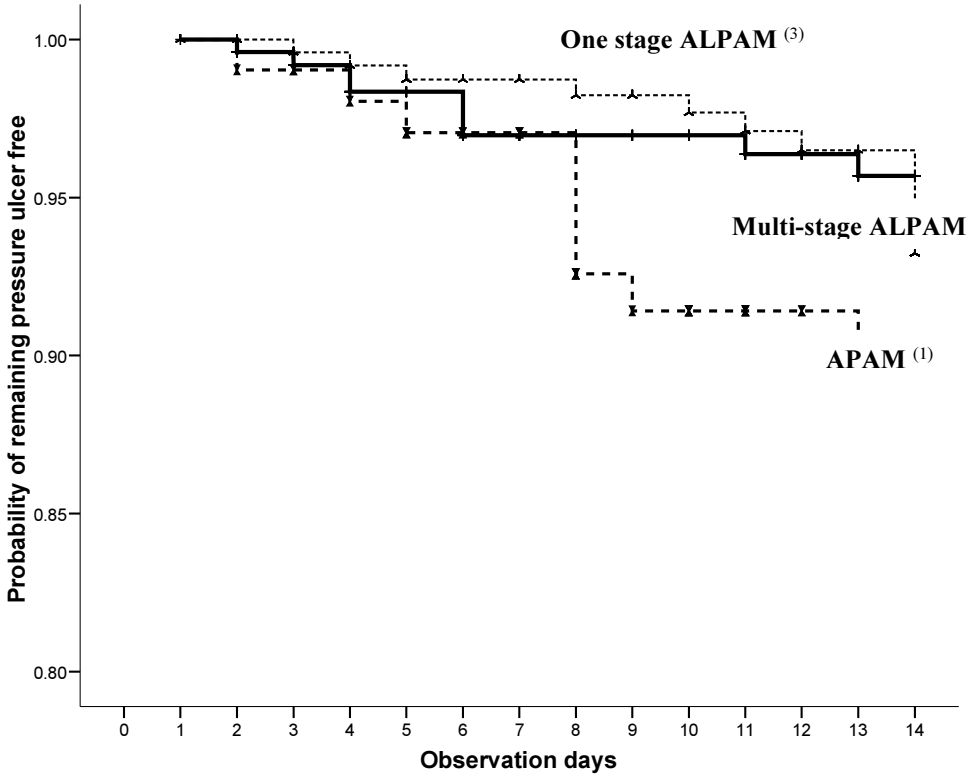

Figure 2 Kaplan Meier plot of the time to develop pressure ulcers Category II-IV.

(1) APAM = Alternating pressure air mattress; (2) Multi-stage ALPAM = Multi-stage Alternating low-pressure air mattress; (3) One-stage ALPAM = One-stage Alternating low-pressure air mattress

4. Discussion

4.1 Effect of Support Surface on Pressure Ulcer Incidence and Severity

In this comparison of the effectiveness of an APAM overlay with a one-stage and a multi-stage ALPAM, a reduced incidence of pressure ulcers was found in the multi-stage ALPAM group compared to the APAM overlay group. The median time to develop a pressure ulcer was similar among groups.

Pressure ulcer incidence on APAM overlays in this study was comparable with the incidence on APAM overlays found by Nixon et al. (2006b), who examined the effectiveness of various types of APAM overlays compared with various types of APAM replacements and found that they were equally effective (Nixon et al., 2006b). Similarly, our analyses did not identify differences in effectiveness between APAM overlays and one-stage ALPAMs. No studies were found comparing the effectiveness of one-stage and multi-stage ALPAMs with APAM overlays. A thorough comparison of our results with others was hampered by heterogeneity in type of support surfaces (Cavicchioli & Carella, 2007; Nixon et al., 2006; Theaker et al., 2005), study population (Theaker et al., 2005), inclusion criteria (Cavicchioli & Carella, 2007; Theaker et al.,2005), and outcomes (Cavicchioli & Carella, 2007; Theaker et al., 2005). The incidence of pressure ulcers was significantly lower in the multi-stage ALPAM group compared with the APAM overlay group. Others found that overlays and replacements (Nixon et al., 2006b), but also multi-stage and one-stage ALPAMs (Demarré et al., 2012a), were equally effective at preventing pressure ulcers. The contrasting findings of the current study may be due to the features of the two mattresses that had significantly different outcomes. The main characteristics that distinguish multi-stage ALPAMs from APAMs are: (1) lower pressures, (2) use of a sensor continuously adjusting the body weight applied to the mattress, and (3) gradual inflation and deflation of the air cells. The development of a pressure ulcer is thought to be caused by a combination of mechanisms (Loerakker et al., 2011; Nixon, et al., 2005). Similarly, the effectiveness of a multi-stage ALPAM at preventing pressure ulcers may be due

to the combined performance of several features, acting on different aetiological mechanisms.

Subgroup analyses showed that the incidence of severe pressure ulcers was lower on multi-stage ALPAMs compared to APAMs. Damage to the deeper tissue structures may be not visible because of intact skin, and therefore adequate treatment or secondary prevention may be delayed (Berlowitz & Brienza, 2007; Black, 2005; Gefen, 2009). This delay may lead to longer hospitalisations, more frequent need for surgery, and higher costs (Berlowitz & Brienza, 2007; Dealey, Posnett, & Walker, 2012; McNair et al., 2010). If multi-stage ALPAMs would be able to reduce the incidence of severe pressure ulcers, costs related to the purchase and maintenance of these sophisticated devices may be warranted by their benefits. An RCT is needed to confirm the advantages of multi-stage ALPAMs over other support surfaces, and a cost-effectiveness analysis would provide further insight on performance in relation to costs. An a priori sample size calculation needs to take into account the low event rate of severe pressure ulcers.

The median time to develop a pressure ulcer was 8 days and was comparable in all groups. A similar result was found by Theaker et al. (2005), who found the median time to develop a pressure ulcer in an intensive care population to be 7 days, but did not report separate results for each study mattress (a one-stage ALPAM and a low-air-loss bed). As is true for incidence rates, comparing the time to develop a pressure ulcer in our study with those of other studies was hampered by several factors. First, the time to develop pressure ulcers is not often reported in effectiveness studies (Cavicchioli & Carella, 2007), perhaps because preventing pressure ulcers is more important than delaying the onset of a pressure ulcer. Furthermore, an accurate analysis of the time to develop an ulcer demands reliable daily registration of skin observations, which is often difficult to achieve (Cavicchioli & Carella, 2007; Nixon et al., 2006).

4.2 Pressure Ulcer Prevention at the Heel Site

The one-stage ALPAM had low alternating pressure air cells at the heel site, whereas the multi-stage ALPAM had an ultra-low continuous pressure zone. In the APAM overlay group, a pillow was used to support the heel. Pressure ulcers at the heel occurred on all three devices. To prevent pressure ulcers at this body site, 0 mm/Hg is the ideal pressure, which can be achieved only by heel offloading (NPUAP & EPUAP, 2009). Vanderwee et al. (2005) suggested that the use of a regular pillow to offload the heel may be less effective because patients push away or relocate the cushion beneath their legs, or because the pillow flattens out, allowing the heels to rest on the support surface.

Studies of the effectiveness of devices to prevent heel pressure ulcers are scarce. In a comparative study by Heyneman et al. (2009) using a pooled database of patients positioned on viscoelastic foam mattresses, a wedge-shaped cushion was more effective than a regular pillow at offloading the heel. Well-conducted RCTs are needed, however, to confirm these findings. In the meantime, when using a pillow, continuous attention and education of both patients and nurses are needed to provide correct heel offloading. Further research should focus on the development of devices that are simultaneously effective and well tolerated by patients.

4.3 Strengths and Limitations

RCTs are the gold standard to compare the effectiveness of support surfaces, but they are also expensive and time-consuming. We used pooled data from two previous studies to compare the effectiveness of an APAM overlay, a one-stage, and a multi-stage ALPAM. The use of pooled databases of original patient data has clinical and statistical advantages, compared to meta-analyses based on reported data (Hudgens et al., 2013), such as the ability to correct for known covariates or differences in inclusion criteria, and the creation of a larger sample by combining several databases. The main limitation is the lack of randomisation within the pooled sample, which may lead to an unequal distribution of baseline characteristics. In spite of the similarities in inclusion criteria and settings of both studies from which our pool was drawn, patients were older in the APAM overlay

group than in the one-stage and multi-stage ALPAM groups. This difference may be due to the inclusion of more geriatric patients in the APAM group compared with the one-stage ALPAM or multi-stage ALPAM group. Furthermore, only a few characteristics were identical in both studies and available for analysis (age, gender, diagnosis, type of ward, and the Braden risk assessment). In a 2013 review, Coleman et al. (2013) identified other risk factors, including skin status, diabetes, haematological measures, and general health status, as predictors of pressure ulcer development. As we were unable to adjust for these, the results of this study must be interpreted with caution.

A second limitation is the choice of the cut-off Braden score of 17 for inclusion. The score of 17 was chosen to enhance comparability with other studies (Baumgarten et al., 2010; Cavicchioli & Carella, 2007; Defloor et al., 2005; Gunningberg, 2004; Vanderwee et al., 2007), but some of the patients in the current study at the lower pressure ulcer risk levels of 15–16 may have been relatively mobile and therefore at less risk for pressure ulcer development. In a recent review by Beeckman et al. (2013), authors could not determine a clear cut-off point, as no Braden threshold outperformed another as a predictor of pressure ulcers.

A third limitation of the study is the time lapse of 7 years between the APAM overlay study and the ALPAM study. Patients admitted to hospitals more recently (ALPAM study, 2007–2010) may have been more care-dependent or more severely ill than a decade ago (APAM study, 2000–2002). The trend toward lower Braden risk scores (higher risk) in the ALPAM groups compared to the APAM overlay group may reflect a higher acuity level. Although pressure ulcer prevention protocols evolved over those 7 years, confounding due to updated prevention protocols was avoided by using a comparable and strict study protocol.

A fourth limitation was the absence of twice daily re-assessment of non-blanchable erythema. The release of pressure/shear from a vulnerable area produces an increased blood flow through hypoxic tissue, defined as reactive hyperaemia. As this reactive hyperaemia can continue for 1/2 to 3/4 of the observed arterial or capillary occlusion time (Khan, et al. 1991; Nixon, 2001), the

incidence of non-blanchable erythema may have been overestimated in the current study.

A final limitation was the lack of blinded skin assessment because of the visible differences in support surfaces. This is a well-known and common limitation in this type of study. Interrater reliability checks were conducted to minimise potential bias due to the lack of blind assessment and to enhance accuracy and reliability of the observations.

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CHAPTER 4

FACTORS PREDICTING THE DEVELOPMENT OF PRESSURE ULCERS IN AN AT RISK POPULATION WHO RECEIVE STANDARDISED PREVENTIVE CARE: SECONDARY ANALYSES OF A MULTICENTRE RANDOMISED CONTROLLED TRIAL

Based on the article of Demarré L, Verhaeghe S, Van Hecke A, Clays E, Grypdonck M & Beeckman D (2014). Factors predicting the development of pressure ulcers in an at risk population receiving standardised prevention: secondary analyses of a multicentre randomised controlled trial. *Journal of Advanced Nursing.* In Press. doi/10.1111/jan.12497

ABSTRACT

Aims: To identify predictive factors associated with the development of pressure ulcers in patients at risk who receive standardised preventive care.

Background: Numerous studies have examined factors that predict risk for pressure ulcer development. Only a few studies identified risk factors associated with pressure ulcer development in hospitalised patients receiving standardised preventive care.

Design: Secondary analyses of data collected in a multicentre randomised controlled trial.

Methods: The sample consisted of 610 consecutive patients at risk for pressure ulcer development (Braden Score < 17) receiving standardised preventive care measures. Patient demographic information, data on skin and risk assessment, medical history, and diagnosis were collected during a 20 month period. Predictive factors were identified using multivariate statistics.

Results: Pressure ulcers in category II-IV were significantly associated with non-blanchable erythema, urogenital disorders, and higher body temperature. Predictive factors significantly associated with superficial pressure ulcers were admission to an internal medicine ward, incontinence-associated dermatitis, non-blanchable erythema, and a lower Braden score. Superficial sacral pressure ulcers were significantly associated with incontinence-associated dermatitis.

Conclusions: Despite the standardised preventive measures they received, hospitalised patients with non-blanchable erythema, urogenital disorders, and a higher body temperature were at increased risk for developing pressure ulcers.

Relevance to clinical practice: Improved identification of at-risk patients can be achieved by taking into account specific predictive factors. Even if preventive measures are in place, continuous assessment and tailoring of interventions is necessary in all patients at risk. Daily skin observation can be used to continuously monitor the effectiveness of the intervention.

1. INTRODUCTION

Pressure ulcers are internationally accepted as an important indicator of the quality of care. They are considered to be a preventable adverse event (Gunningberg and Stotts, 2008; Van den Heede et al., 2007). Targeted prevention must consist of the identification of patients at risk and the introduction of tailored preventive care. A structured approach for risk assessment should include the use of a reliable and valid risk assessment scale (NPUAP & EPUAP, 2009), the observation of non-blanchable erythema (Defloor et al., 2004; Schoonhoven et al., 2002), and clinical judgment of the nurse based on a profound knowledge of key risk factors (National Institute for Clinical Excellence, 2005; NPUAP & EUAP, 2009). A risk factor can be defined as a variable associated with pressure ulcer development (Kraemer, 2010; Woodward, 2005). The identification of these risk factors allows a more accurate and precise judgment about the risk to develop pressure ulcers (Kottner et al., 2011).

2. BACKGROUND

Pressure ulcer development is a complex and multi-factorial process. Several mechanisms may lead to tissue damage as a result of exposure to pressure and/or shear. Oxygen deprivation, direct cell deformation (Ceelen et al., 2008; Gawlitta et al., 2007a; Stekelenburg et al., 2007), ischemic reperfusion injury (Peirce et al., 2000; Reid et al., 2004; Tsuji et al., 2005), and impaired lymphatic drainage (Miller and Seale, 1981) are mechanisms that might lead to pressure ulcer development. Pressure ulcers can develop both superficially or in the deep tissues (Bouten et al., 2005). Skin and subcutaneous fat are more resistant to pressure than muscle tissue. The threshold for tissue damage resulting from periods of pressure and shear differs for skin, fat, and muscle (Daniel et al., 1981; Stekelenburg et al., 2006; Bouten et al., 2003). Lahmann & Kottner (2011) suggested that the aetiology causing superficial (category II) and severe (category III-IV) pressure ulcers may differ. This hypothesis was based on findings that severe pressure ulcers were associated with complete immobility, whereas superficial pressure ulcers were associated with friction and shear,

both items on the Braden scale (Lahmann and Kottner, 2011). It is not yet clear if other risk factors for developing a superficial pressure ulcer are different from those for a severe ulcer.

Numerous studies identified risk factors predicting pressure ulcer development (Beeckman et al., 2013a; Coleman et al., 2013). Several studies considered preventive measures when examining risk factors in a population of hospitalised patients (Beeckman et al., 2013a; Coleman et al., 2013; Schoonhoven et al., 2006). Only a few studies examined specific predictive factors in a population of at-risk hospitalised patients who received preventive care (Manzano et al., 2013; Nixon et al., 2006a). These studies identified predictive factors such as non-blanchable erythema, existing wounds, diabetes, low haemoglobin level on admission or before surgery (Nixon et al., 2006a), and age in high-risk hospitalised patients (Manzano et al., 2013; Nixon et al., 2006a).

A first and necessary step for successful pressure ulcer prevention is the correct identification of patients who are at risk for pressure ulcer development. Identification using a structured approach that combines several risk assessment methods is recommended (Defloor and Grypdonck, 2004; NPUAP & EPUAP, 2009; Schoonhoven et al., 2002; Vanderwee et al., 2007b). When patients are assessed as being at risk, preventive care should be provided in accordance with international guidelines and institutional standards. However, even when standardised prevention is implemented, patients may develop new pressure ulcers (McInnes et al., 2012; Nixon et al., 2006a; Theaker et al., 2005). Knowledge about predictive factors identifying patients at risk of developing pressure ulcers even when preventive measures are applied may help to successfully tailor preventive measures to further decrease the development of pressure ulcers, thus improving patient outcomes.

3. THE STUDY

3.1 AIM

To examine predictive factors associated with the development of pressure ulcers in patients at risk while receiving standardised preventive care.

3.2 DESIGN

Secondary data analyses were performed on a cohort of 610 patients included in a multicentre Randomised Controlled Trial (RCT).

Data were collected as part of a larger study examining predictive factors for pressure ulcer development and the effectiveness of alternating low-pressure air mattresses (Demarré et al., 2012a).

3.3 SAMPLE

Data were collected in five Belgian hospitals. Patients were recruited in a convenience sample of 8 geriatric wards and 17 internal medical wards: neurology (n = 6), rehabilitation (n = 3), cardiology (n = 2), dermatology (n = 1), pneumology (n = 1), oncology (n = 1), chronic care (n = 1), and wards with combined internal medicine pathology (n = 2). All patients admitted to the participating wards (n = 7393) were screened for eligibility. Patients were eligible for inclusion if their Braden score was less than 17 (n = 1137). The reliability and validity of the Braden scale has been extensively studied (Braden and Bergstrom, 1994; Schoonhoven et al., 2002; Kottner et al., 2009b), and it is often used internationally as a tool for risk assessment (Baumgarten et al., 2010; Lahmann and Kottner, 2011; Vanderwee et al., 2011; NPUAP & EPUAP, 2009).

Exclusion criteria were the presence of a pressure ulcer category II-IV (n = 204), a presumed hospital length of stay of less than 3 days (n = 43), the decision to end all therapeutic interventions (Do Not Resuscitate code 3) (n = 35), age less than 18 years (n = 6), bodyweight less than 30kg or more than 160 kg (n= 1), no standardised preventive measures available (n = 186), and no consent to participate (n = 52). Patients with non-blanchable erythema were eligible for inclusion. If patients were excluded, they received preventive measures

compliant with the hospital protocol. In total, 610 patients comprised the sample (Figure 1).

3.4 VARIABLES

The selection of potential predictive variables was based on the PrePURSE study of Schoonhoven et al. (2006), including variables obtained from literature (Schoonhoven et al., 2006). Data were collected for the following potential predictive factors: patient characteristics (age, gender, weight, length, incontinence, presence of urinary catheter, body temperature, and blood pressure), items included on the Braden scale, medical characteristics (diabetes, paralysis, medication), primary diagnosis, ward type (internal medicine ward and geriatric ward), and skin status (non-blanchable erythema and incontinence-associated dermatitis (IAD)).

3.5 DATA COLLECTION

Prior to the start of the study, the researcher trained the ward nurses in pressure ulcer prevention (pathology, classification, differentiation between IAD, and the use of the Braden scale for risk assessment), and gave an introduction to the study aims, protocol, and the use of the data collection instrument. The purpose of this training was to ensure precision and uniformity of data collection.

Patient characteristics, medical history, and primary diagnosis were assessed at baseline by the researcher. Skin assessment, including specific assessment of the pressure points and IAD, was performed daily by the ward nurse during morning care. Pressure ulcers were classified according to the NPUAP/EPUAP classification system. Non-blanchable erythema was defined as a pressure ulcer category I, partial thickness skin loss as a pressure ulcer category II, full thickness skin loss as a pressure ulcer category III, and full thickness tissue loss was classified as a pressure ulcer category IV (NPUAP & EPUAP, 2009). The transparent plastic disc method was used to differentiate between non-blanchable erythema and blanchable erythema (Halfens et al., 2001). The reactive response of the skin to chronic exposure to urine and faecal material

was defined as IAD. Wound-related characteristics (causes, location, shape, depth, edges, and colour) and patient-related characteristics were evaluated to differentiate pressure ulcers from IAD (Defloor et al., 2005b). Data were collected between December 2007 and January 2010.

The researcher and a tissue viability nurse affiliated with the hospital (study nurse), performed skin assessments independently, unannounced and at least once a week, in a random sample of patients. The inter-rater reliability for pressure ulcer classification ranged between κ= 0.71 (95% CI 0.6 - 0.8) and κ= 0.81 (95% CI 0.8 - 0.9) among the researcher, the study nurse, and ward nurses.

3.6 Standardised Prevention

All patients received standardised preventive care when lying in bed and when seated. The patients were randomly allocated (allocation sequence of 1:1) to a one-stage or multi-stage alternating low-pressure air mattress when lying in bed. The two types of alternating low-pressure air mattresses were found to be equally effective in terms of pressure ulcer incidence (respectively 5.8% and 5.7%; p = 0.97), and probability to remain pressure ulcer free (log-rank X^2 = 0.013, p = 0.911) (Demarré et al., 2012a). A static air cushion was used in both groups to prevent pressure ulcer development when seated in an armchair. A standardised repositioning protocol was not used in any group. (Demarré et al., 2012a).

3.7 Ethical Aspects

The study was approved by the Ethical Committee of Ghent University Hospital (B/ 67020071976) and by the Ethical Committee of each participating hospital. Informed consent was obtained from the participating patients or their legal representatives.

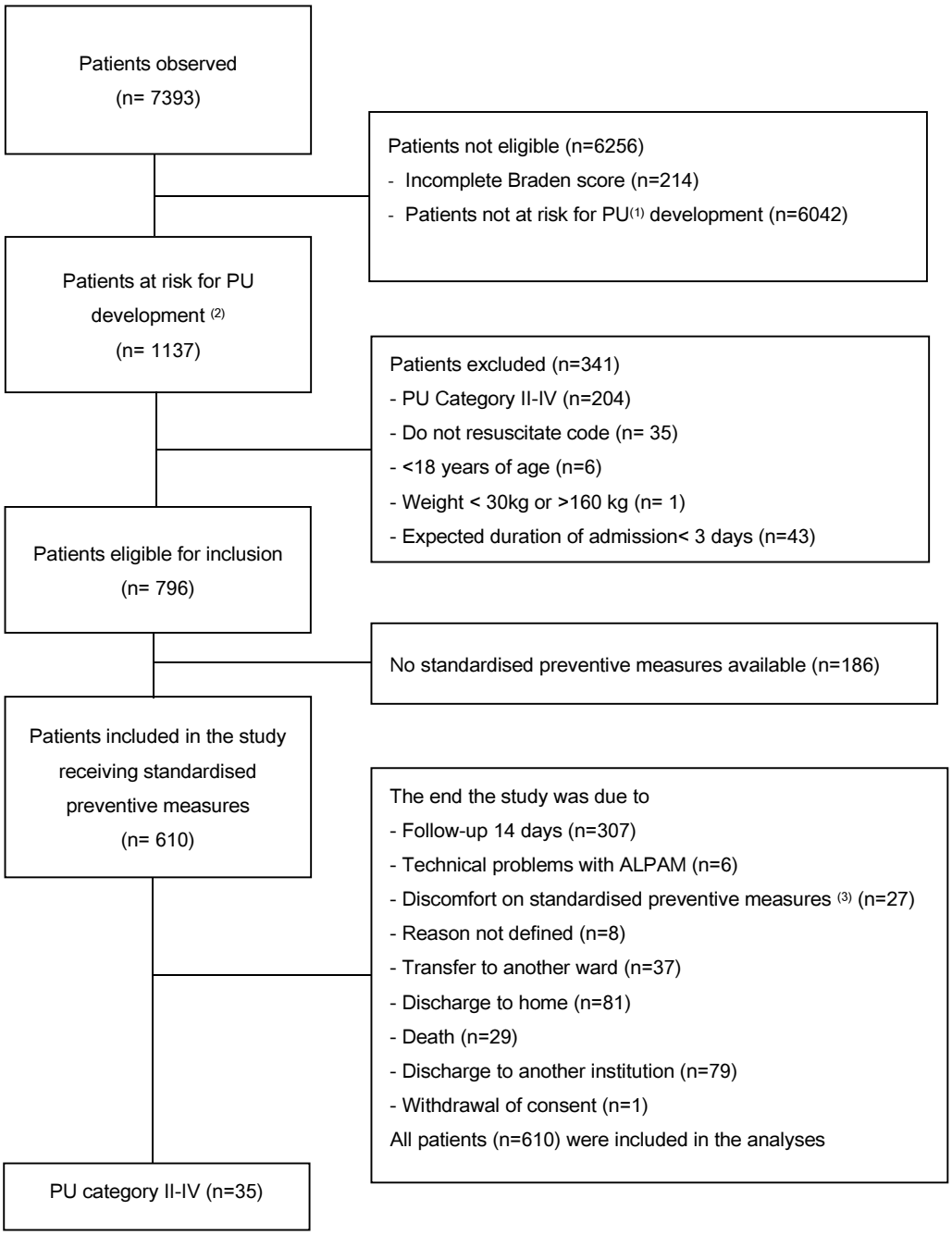

Figure 1 Flowchart Sample: Included and excluded patients

(1) PU: Pressure ulcer; (2) Bradenscore<17; (3) standardised preventive measures = an Alternating Low Pressure Air Mattress was used to provide standardised preventive measures in bed and a static air cushion to provide standardised prevention when seated in an armchair

3.8 DATA ANALYSES

Categorical variables were presented as frequencies (percentages). Continuous variables were described as medians (IQR). Mann-Whitney U-tests were used for continuous data; chi-square and Fisher's exact tests were used for the categorical variables. Purposeful selection of variables was used for the multiple binary logistic regression as described by Bursac *et al.* (2008). Univariate binary logistic regression analyses were performed on all potentially predictive factors using a cut-off point of $p < 0.25$ (Table 1). The retained variables were simultaneously entered in the multivariate binary logistic regression; variables were removed from the model if they were not significant (cut off point of $p < 0.10$) (Bursac *et al.* 2008). The odds ratios and 95% confidence intervals were calculated. No multicollinearity was observed among variables in the multivariate model. If the total score on the Braden scale and the items on the scale were significantly associated, the total score was included in the model. The variation in the development of pressure ulcers explained by the multivariate models was provided by the Nagelkerke R Square. Additional univariate and multivariate sub-analyses were performed to identify factors associated with the development of superficial pressure ulcers (category II) at the sacrum and heels, and severe pressure ulcers (category III-IV). Statistical interaction to assess whether the effect of IAD on the development of pressure ulcers was dependent on the presence of non-blanchable erythema was conducted using multivariate logistic regression. No statistical interaction was found. Statistical analyses were conducted using SPSS® 15.0 (IBM® Corporation, NY, USA). A significance level of $p < 0.05$ was applied.

4. RESULTS

4.1 CHARACTERISTICS OF THE PARTICIPANTS

The median age of the patients was 80 years (IQR = 71-86) and 60.5% of the patients were female. Almost half of the patients were incontinent for urine and faeces. The median Braden score was 14.0 (IQR = 12.0-15.0), 27.5% (n = 167) of the patients were bedbound and 61.3% (n = 373) were chairbound. Fifteen

percent (n = 94) were admitted with non-blanchable erythema, and 14.6% (n = 89) developed non-blanchable erythema during the study. The cumulative pressure ulcer incidence was 5.7% (n = 35), including 3.9% (n = 24) superficial (category II) and 1.8% (n = 11) severe (category III-IV) pressure ulcers.

Pressure ulcers occurred more frequently at the sacrum (3.4%, n = 22), compared to the heels (1.7%, n = 9). A pressure ulcer category II-IV developed in 13.7% (n = 25) of the patients with non-blanchable erythema (Table 2). IAD was present in 6.4% (n = 39) of the patients at the start of the study; another 6.7% (n = 49) developed IAD during the study.

4.2 Predictive factors for the development of pressure ulcers (category II-IV)

Patients developing pressure ulcers category II-IV had a higher body temperature (p = 0.041), had higher rates of urinary catheterisation (p = 0.006), and were more frequently admitted with a primary diagnosis of a urogenital disorder (p = 0.048), compared to patients who did not develop a pressure ulcer (Table 2).

In the multivariate analysis, non-blanchable erythema (OR = 5.36; 95% CI 2.4 – 12.0), having a urogenital disorder (OR = 3.76; 95% CI 1.0 - 13.7), and higher body temperature (OR = 1.65; 95% CI 1.0 - 2.7) were independent predictive factors for the development of pressure ulcers category II-IV (Table 3). The percent of variance explained for developing a category II – IV pressure ulcer by predictors included in this model was 23% (Nagelkerke $R^2 = 0.23$).

Table 1 Univariate binary logistic regression analyses of potentially predictive factors

Variables		All PU [2] (n=35)			Superficial PU [3] (n=24)	
	OR[1]	95% CI	p-value	OR	95% CI	p-value
Patients' characteristics						
Age	0.99	0.97-1.02	0.769	0.99	0.97-1.02	0.577
Gender[4]	0.75	0.39-1.52	0.440	0.64	0.28-1.46	0.287
Weight	1.00	0.98-1.02	0.889	1.01	0.98-1.03	0.584
Length	1.04	1.00-1.07	0.046	1.04	1.00-1.09	0.051
BMI	0.96	0.89-1.04	0.348	0.98	0.89-1.07	0.576
Incontinence for urine[5]	1.30	0.63-2.66	0.480	1.53	0.66-3.57	0.316
Incontinence for faeces[5]	0.75	0.36-1.53	0.428	0.89	0.38-2.05	0.797
Double incontinence[5]	1.04	0.53-2.06	0.909	1.16	0.51-2.64	0.714
Presence of urinary catheter[5]	2.68	1.29-5.51	0.008	1.89	0.76-4.71	0.203
Body temperature	1.88	1.23-2.86	0.004	1.81	1.10-2.99	0.020
Fever (>38°Celcius) [5]	0.57	0.19-1.68	0.305	0.80	0.18-3.54	0.804
Systolic blood pressure	0.99	0.97-1.00	0.197	0.98	0.96-1.01	0.128
Diastolic blood pressure	0.99	0.97-1.02	0.566	0.98	0.95-1.01	0.246
Skin assessment						
Non-blanchable erythema[5]	4.12	2.02-8.44	<0.001	3.71	1.57-8.77	0.004
IAD[5]	1.44	0.67-3.08	0.002	4.40	1.86-10.44	0.001
Braden score	0.83	0.72-0.95	0.006	0.77	0.66-0.90	0.001
Sensory perception[6]	0.76	0.37-1.55	0.446	0.66	0.28-1.53	0.330
Activity[7]	0.47	0.11-1.99	0.301	0.69	0.16-3.04	0.653
Mobility[8]	0.71	0.25-2.06	0.531	0.79	0.23-2.69	0.703
Moisture[9]	0.95	0.48-1.89	0.889	0.95	0.42-2.15	0.899
Nutrition[10]	0.63	0.31-1.27	0.191	0.28	0.10-0.76	0.012
Friction and shear[11]	0.00	0.00-	0.998	0.00	0.00-	0.998
Medical characteristics						
Diabetes[5]	1.44	0.67-3.08	0.347	0.51	0.15-1.75	0.256
Paralysis[5]	1.29	0.48-3.43	0.616	0.70	0.16-3.05	0.636
Use of sleep medication and tranquilizers[5]	0.94	0.47-1.88	0.864	1.38	0.59-3.19	0.433
Systemic use of corticosteroids[5]	0.41	0.09-1.75	0.228	0.29	0.04-2.21	0.237

Table 1 Univariate binary logistic regression analyses of potentially predictive factors

Variables		**All PU** [2] **(n=35)**			**Superficial PU** [3] **(n=24)**	
	OR[1]	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
Primary diagnosis[5]						
Pulmonary diagnosis						
Hart and vascular disorders	1.10	0.49-2.48	0.818	1.53	0.62-3.77	0.357
Neurology	1.09	0.37-3.18	0.879	0.77	0.18-3.34	0.723
Physiology	1.14	0.55-2.38	0.729	1.24	0.52-2.96	0.624
Gastroenterology	0.66	0.27-1.61	0.357	0.83	0.31-2.27	0.722
Urogenital disorders	0.54	0.16-1.80	0.317	0.52	0.12-2.27	0.388
Endocrinology	3.40	1.10-10.53	0.033	2.39	0.53-10.88	0.257
Immunology	1.18	0.15-9.23	0.876	0.00	0.00-	0.999
Sensory diagnosis	0.00	0.00-	0.999	0.00	0.00-	0.999
Dermatology	-	0.00-	1.000	0.00	0.00-	1.000
	0.00	0.00-	0.999	0.00	0.00-	0.999
Characteristics related to the study						
Internal medicine ward[12]	0.51	0.22-1.18	0.115	3.46	1.02-11.73	0.047
Maximum time sitting &/or transport (hours)	0.99	0.88-1.11	0.839	0.99	0.87-1.13	0.876
Standardised preventive measures[13]	0.99	0.50-1.96	0.973	1.24	0.55-2.81	0.612

[1] OR: odds ratio; [2] All PU: pressure ulcers category II-IV; [3]Superficial PU: pressure ulcer category II; [4] Male is reference category; [5] The absence of the dichotomous variable is reference category; [6] Completely and very limited is reference category compared to slightly limited and no impairment; [7] Bedfast and chairfast is a reference category compared to walks occasionally and frequently [8] Completely immobile and very limited is reference category compared to slightly limited and no limitations [9] Constantly and often moist is reference category compared to occasionally and rarely moist; [10] Very poor and probably inadequate is reference category compared to adequate and excellent; [11] Problem and potential problem is reference category compared to no problem; [12] Geriatric ward is reference category; [13] One-stage ALPAM is reference category compared to Multi-stage ALPAM

Table 2 Potential predictive factors in all patients and comparison of predictive factors between patients developing a pressure ulcer category II-IV and remaining pressure ulcer free

	Total (n=610) median (IQR[1]) % (n)	**No PU** (n=575) median (IQR[1]) % (n)	**PU** (n=35) median (IQR[1]) % (n)	Mann-Whitney U/χ^2 ; p-value
Age	80 (71-86)	80 (71-86)	79 (73-84)	p=0.52
Weight (kg)	65 (55-76)	65 (55.0-75.7)	65 (56.0-78.0)	p=0.87
Length (cm)	165 (159-173)	165 (159-173)	168.5 (160-178)	p=0.08
BMI	23.6 (21.0-26.6)	23.6 (21.1-26.7)	23.2 (20.0-26.1)	p=0.39
Systolic blood pressure	130 (120-140)	130 (120-143.5)	130 (120-140)	p=0.54
Diastolic blood pressure	70 (61-80)	70 (60.5-80)	70 (64-77)	p=0.71
Braden	14 (12-15)	14.0 (12.0-15.0)	13.0 (10.0-15.0)	**p<0.05**
Braden-Mobility				
Completely immobile	14.5 (88)	14.1 (81)	20.0 (7)	X^2=1.17;
Very limited	70.4 (428)	70.5 (404)	68.6 (24)	p=0.76
Slightly limited & no impairment	15.1 (92)	15.4 (88)	11.4 (4)	
Braden-Activity				
Bedbound	27.5 (167)	26.7 (153)	40.0 (14)	X^2=3.44;
Chairbound	61.3 (373)	61.8 (354)	54.3 (19)	p=0.33
Walks occasionally/frequently	11.2 (68)	11.5 (66)	5.7 (2)	
Braden-Sensory perception				
Completely & very limited	28.6 (174)	28.3 (162)	34.3 (12)	X^2=0.58;
Slightly limited & no impairment	71.4 (434)	71.7 (411)	65.7 (23)	p=0.45
Braden-Moisture				
Constantly & often moist	44.6 (271)	44.5 (255)	45.7 (16)	X^2=0.02;
Occasionally & rarely moist	55.4 (337)	55.5 (318)	54.3 (19)	p=0.89
Braden-Nutrition				
Very poor & probably inadequate	52.1 (316)	51.4 (294)	62.9 (22)	X^2=1.74;
Adequate & excellent	47.9 (291)	48.6 (278)	37.1 (13)	p=0.19
Braden-Friction & Shear				
Problem & potential problem	96.2 (585)	96.0 (550)	6.0 (35)	X^2=1.46;
No problem	3.8 (23)	4.0 (23)	0.0 (0)	p=0.23

Table 2 Potential predictive factors in all patients and comparison of predictive factors between patients developing a pressure ulcer category II-IV and remaining pressure ulcer free

	Total (n=610) median (IQR[1]) % (n)	**No PU** (n=575) median (IQR[1]) % (n)	**PU** (n=35) median (IQR[1]) % (n)	Mann-Whitney U/χ^2 ; p-value
Body temperature	36.5 (36.1-36.9)	36.5 (36.1-36.9)	36.8 (36.4-37.3)	**p< 0.01**
Fever (>38°Celcius)	7.1 (44)	6.8 (39)	11.4 (4)	χ^2=1.08; p=0.30
Gender				
Male	39.5 (241)	39.1 (225)	45.7 (16)	X^2=0.60; p=0.44
Female	60.5 (369)	60.9 (350)	54.3 (19)	
Incontinence				
Urinary	66.3 (389)	66.6 (369)	60.6 (20)	χ^2=0.50.; p=0.48
Fecal	53.9 (318)	53.5 (298)	60.6 (20)	χ^2=0.63; p= 0.42
Urinary & fecal	49.5 (302)	49.6 (285)	48.5 (17)	χ^2=0.01; p=0.91
Urinary catheter	19.9 (119)	18.8 (106)	38.6 (13)	χ^2=7.60; **p <0.01**
Ward type				
Internal medicine	67.7 (413)	63.1 (385)	4.6 (28)	χ^2=2.57; p=0.11
Geriatrics	32.3 (197)	31.1 (190)	1.1 (7)	
Primary diagnosis				
Pulmonary disorder	21.3 (130)	21.2 (122)	22.9 (8)	χ^2=0.05; p=0.82
Cardiovascular disorder	10.7 (65)	10.6 (61)	11.4 (4)	χ^2=0.02; p=0.88
Neurological disorder	28.9 (176)	28.7 (165)	31.4 (11)	χ^2=0.12; p=0.73
Locomotor disorder	23.6 (144)	24.0 (138)	17.1 (6)	χ^2=0.86; p=0.35
Gastroenterological disorder	14.4 (88)	14.8 (85)	8.6 (3)	χ^2=1.03; p=0.31
Urogenital disorder	4.1 (25)	3.7 (21)	11.4 (4)	F.E.[4]; **p<0.05**
Endocrinological disorder	2.5 (15)	2.4 (14)	2.9 (1)	F.E.[4]; p=0.59
Immunological disorder	1.6 (10)	1.7 (10)	0 (0)	F.E.[4], p=1.00
Sensorial perception disorder	0.2 (1)	0.2 (1)	0 (0)	F.E.[4], p=1.00
Dermatological disorder	1.8 (11)	1.9 (11)	0 (0)	F.E.[4], p=1.00
Diabetes	22.1 (135)	21.7 (125)	28.6 (10)	χ^2=0.89.; p=0.34
Paralysis	11.6(71)	11.5 (66)	14.3 (5)	F.E.[4], p=0.59
Medication				
Sleep medication/ tranquilizers	48.5 (288)	48.6 (272)	47.1 (16)	χ^2=0.03; p=0.86
Corticosteroids (oral/IV)	12.5 (76)	12.9 (74)	5.7 (2)	χ^2=1.55 ; p=0.21

Table 2 Potential predictive factors in all patients and comparison of predictive factors between patients developing a pressure ulcer category II-IV and remaining pressure ulcer free

	Total (n=610) median (IQR[1]) % (n)	**No PU** (n=575) median (IQR[1]) % (n)	**PU** (n=35) median (IQR[1]) % (n)	Mann-Whitney U/χ^2 ; p-value
Preventive measures				
ALPAM Type 1[2]	48.9 (298)	48.9 (281)	48.6 (17)	χ^2=0.001; p=0.97
ALPAM Type 2[3]	51.1 (312)	51.1 (294)	51.4 (18)	
Non-blanchable erythema at the start of the study	15.4 (94)	13.9 (80)	40.0 (14)	χ^2=17.22; **p<0.001**
IAD at the start of the study[5]	6.4 (39)	5.9 (34)	14.3 (5)	F.E.[4]; p=0.064

[1] IQR= Interquartile Range; [2] ALPAM Type 1 = Alternating Low Pressure Air Mattress with gradual inflation and deflation of the air cells; [3] ALPAM Type 2 = Alternating Low Pressure Air Mattress with one steep inflation and deflation of the air cells; [4] F.E. = Fisher's Exact test; [5]IAD at the start of the study= Incontinence-associated Dermatitis at the start of the study

4.3 Predictive factors for the development of superficial (Category II) and severe pressure ulcers (Category III-IV)

Admission to an internal medicine ward (OR = 4.16; 95% CI 1.2 - 7.5), IAD (OR = 2.99; 95% CI 1.20- 7.5), non-blanchable erythema (OR = 3.73; 95% CI 1.5 - 9.1), and the Braden score (OR = 0.79; 95% CI 0.7 - 0.9) were independent predictive factors for the development of category II pressure ulcers. The predictors included in the model explained 18% of the variance for the development of superficial pressure ulcers (Nagelkerke R^2 = 0.18) (Table 3). For the patients on an internal medicine ward, a trend towards being bed- and chairbound (90.5%, n= 372) was found compared to patients on a geriatric ward (85.3%, n= 168), but the difference was not significant (p = 0.055). More patients on an internal medicine ward had paralysis (14.8%, n = 61) and had a urinary catheter (22.8%, n = 92), compared to the patients on a geriatric ward (5.19%, n = 10, p < 0.001 and 13.8%, n = 27, p = 0.012 respectively).

The development of superficial sacral pressure ulcers was significantly associated with the presence of IAD. It was present in 44.4% of the patients who developed a superficial sacral pressure ulcer compared to 12.2% of the patients who did not (Fisher's Exact, p = 0.001). The development of heel

pressure ulcers was not significantly associated with the presence of IAD (Fisher's Exact, p = 0.431).

Non-blanchable erythema (OR = 25.95; 95% CI 3.2 - 212.3), diabetes (OR = 7.62; 95% CI 2.0 - 28.8), and having a urinary catheter (OR = 3.72; 95% CI 1.0 - 13.7) were found to be significantly associated with the development of severe pressure ulcers. The predictors included in the model explained 34% of the variance for the development of severe pressure ulcers (Nagelkerke R^2 = 0.34), but the confidence intervals of the odds ratios indicated that this model was probably less reliable.

Table 3 Multivariate analysis with patients with pressure ulcers of varying severity as dependent variable and risk factors as independent variables

Patients with **pressure ulcer category II-IV** as dependent variable	**OR [1]**	**95% CI**	**p-value**
Non-blanchable erythema[2]	**5.36**	**(2.40-11.99)**	**<0.001**
Urogenital diagnosis [3]	**3.76**	**(1.03-13.70)**	**0.044**
Body temperature	**1.65**	**(1.02-2.66)**	**0.041**
Urinary catheter [4]	2.00	(0.92-4.37)	0.081
IAD[7]	2.15	(0.92-4.37)	0.079
Braden score	0.87	(0.75-1.01)	0.074
Patients with **superficial pressure ulcer[4]** as dependent variable	**OR [1]**	**95% CI**	**p-value**
Internal medicine ward[6]	**4.16**	**(1.20-7.52)**	**0.027**
IAD[7]	**2.99**	**(1.20-7.52)**	**0.019**
Non-blanchable erythema[2]	**3.73**	**(1.53-9.11)**	**0.004**
Braden score	**0.79**	**(0.67-0.94)**	**0.009**

[1] OR: odds ratio; [2] Absence of non blanchable erythema is reference category; [3] Absence of the diagnosis is reference category; [4] Urinary catheter; [5] superficial pressure ulcer: pressure ulcer category II; [6]Geriatrics is reference category; [7]Absence of IAD (Incontinence-associated dermatitis) is reference category.

5. DISCUSSION

Once patients are found to be at risk for pressure ulcer development, preventive care is needed. Despite preventive measures, a proportion of these patients still develop a pressure ulcer (Demarré et al., 2012a; Nixon et al., 2006b; Theaker et al., 2005; Vanderwee et al., 2005). The identification of these 'high risk' patients is crucial for improved quality of care. The aim of this study was to identify factors that independently predicted the development of a pressure ulcer in an at risk population who received standardised preventive care. All patients in this study were allocated to an alternating low-pressure device when lying in bed and they all had a static air cushion when seated. The presence of non-blanchable erythema, having a urogenital disorder, and higher body temperature were found to be predictive factors associated with the development of a pressure ulcer.

5.1 PREDICTIVE FACTORS FOR THE DEVELOPMENT OF PRESSURE ULCERS (CATEGORY II-IV)

Previous studies found that non-blanchable erythema was an independent predictive factor for developing pressure ulcers (Nixon et al., 2007; Reed et al., 2003; Vanderwee et al., 2009; Coleman et al., 2013; Allman et al., 1995; NPUAP & EPUAP, 2009). The findings of this study illustrate that non-blanchable erythema is a high-risk indicator, even when patients receive preventive care (Nixon et al., 2006a). Although it is not clear to what extent non-blanchable erythema would have been reversible, this predictive factor indicates the risk for pressure ulcer deterioration and signifies that current preventive measures must be further tailored.

In the present study, body temperature was also found to be an independent predictor of pressure ulcer development. Increased body temperature influences tissue metabolism (Maklebust *et al.* 1987 cited in Defloor *et al.* 1999, Patel *et al.* 1999), as well as tissue stiffness (Patel et al., 1999). Increased body temperature will lead to an increased metabolism (Maklebust *et al.* 1987 cited in Defloor *et al.* 1999) and subsequent increased oxygen need. If the oxygen

supply to the tissue no longer matches the needs, the risk of pressure ulcers increases (Defloor, 1999). Furthermore the effect of temperature may differ for muscle tissue, subcutaneous fat, and skin tissue (Lachenbruch et al., 2013). Lachenburg and colleagues suggested there is a need to manage skin temperature, as well as pressure, to reduce the risk of ischemia (Lachenbruch et al., 2013).

Increased body temperature also influences tissue stiffness (Patel et al., 1999). Tissue stiffness allows tissue to resist deformation (Arokoski et al., 2005; Iivarinen et al., 2011); stiffness depends on the type of tissue and is influenced by numerous factors including past or present injuries (Gefen et al., 2005; Gefen, 2007; Levy et al., 2013). For example, stiffness of different tissues influences overall tissue deformation and minimising tissue deformation decreases the chance of developing a deep tissue injury (Loerakker et al., 2013). However, the relation between temperature, tissue stiffness, and pressure ulcer development is complex, and requires further study.

Detailed information on the specific diagnosis of patients classified with a urogenital disorder was not collected. Further research should include data which is based on (inter)national diagnostic classification systems, such as the International Classification of Diseases (ICD), to enhance clarity and allow benchmarking with other studies.
Generally, patients admitted with a urogenital disorder on a geriatric or internal medicine ward have a diagnosis of (suspected) urinary tract infection or urosepsis. None of the baseline characteristics collected in this study could explain the increased risk for patients with a urogenital disorder to develop a pressure ulcer compared to those without. A possible reason for the finding may be, that as the urogenital disorders referred to a diagnosis of infection, they may be related to severe illness and/or organ failure. Severe illness may be insufficiently measured by the variables included in the present study, such as temperature and fever. Further research might collect data on the severity of

illness index, sepsis, and organ failure to examine their association with the process of pressure ulcer development.

5.2 Predictive factors for the development of superficial (Category II) and severe pressure ulcers (Category III-IV)

IAD was found to be associated with a higher risk of developing a superficial pressure ulcer. More specifically, IAD was significantly associated with the development of superficial sacral pressure ulcers, but not associated with superficial heel ulcers.

The presence of a skin lesion (Nonnemacher et al., 2009), as well as incontinence for urine and feces (Brandeis et al., 1994; Marchette et al., 1991; Ooi et al., 1999), and moist skin (Bates-Jensen et al., 2007; Compton et al., 2008; Sanada et al., 2007) have been described as factors associated with pressure ulcer development (Coleman et al., 2013). The association between IAD and pressure ulcers has not been previously examined. The skin may be more susceptible to shear and pressure when it is moist (Antokal et al., 2012). The strength of the stratum corneum is affected, thereby increasing the risk of skin damage (Hagisawa and Shimada, 2005).

Patients hospitalised on an internal medicine ward had a higher risk of developing a pressure ulcer compared to patients admitted to a geriatric ward. The reason for this finding could not be explained by the multivariate analyses. The most plausible explanation is that these patients were more severely ill and less mobile compared to patients admitted to a geriatric ward. Patients admitted to an internal medicine ward may be burdened with a combination of several potential risk factors which were not significantly associated when assessed separately.

5.3 Study limitations

The main limitation of this study was the low event rate, which mainly affected the multivariate analyses for severe pressure ulcers. Only 11 severe pressure ulcers occurred, leading to wide confidence intervals of the potentially predictive

factors for developing a severe pressure ulcer. Sample size calculation of this study was guided by the sample size calculation of the original study, an RCT to compare the effectiveness of two ALPAMs. Sample size calculations for multivariable analyses, as conducted in these risk factor analyses, can be informed by the 'rule of thumb'. This rule of thumb states that ten events or pressure ulcers per variable in the multivariate model are needed (Coleman et al. 2012; Peduzzi et al. 1995). Therefore, the results for superficial and severe pressure ulcers presented in the subanalyses, need to be interpreted with caution.

Due to ethical considerations, the participation of a patient in the study was ended when a pressure ulcer category II-IV developed, but superficial pressure ulcers may have evolved to a more severe lesion if follow-up had been continued.

Another limitation of the study is the length of the follow-up. A follow-up period of 14 days may have been too brief to observe the development of a pressure ulcer in patients during a lengthy hospital stay (Theisen et al., 2012). A 14-day study period was chosen because for the majority of the patients this length of follow-up would include a full hospitalisation. The mean length of stay in Belgian hospitals was 6 days on internal medicine wards and 18 days on geriatric wards (Flemish Agency for Care and Health cited in Trybou, 2011). This follow-up period was chosen to optimize the probability of capturing the moment patients developed a pressure ulcer, with regard to the limited availability of the study's standardised preventive measures.

6. CONCLUSION

Non-blanchable erythema, a urogenital disorder, and higher body temperature were found to be significantly associated with the development of pressure ulcers despite preventive measures. Predictive factors may differ between anatomical locations. Health care professionals as well as health care institutions continuously aim to provide pressure ulcer prevention tailored to the needs of the individual patient. Their goal is to improve resource use and reduce expenditures, while maintaining or improving the quality of care. Risk

assessment scales and scores are frequently used in daily care to tailor preventive measures to a specific patient, although there is no evidence that risk assessment scores can differentiate risk levels among patients (Beeckman et al., 2013a). The use of factors predicting pressure ulcers as found in this study may therefore be more appropriate to tailor preventive measures based on a stepped-care model. In this stepped-care model preventive measures will be adjusted in steps when patients' risk profile is changing or the current preventive measures fail. It also aims to encourage health care providers to continuously reassess the patients' needs and adapt the provided preventive measures on a regular basis. Further research should examine the effectiveness of stepped-care prevention.

Even if prevention is provided, continuous tailoring to the patients' needs remains necessary. The results of this study point out the importance of regular skin observation and timely detection of non-blanchable erythema in daily practice. The new finding of this study is the identification of IAD as a possible predictive factor for superficial sacral pressure ulcers. Therefore, further research is needed to assess the effect of including daily skin observation to detect non-blanchable erythema, as well as IAD as part of the patients' risk assessment. The possibility and nature of the relationship between superficial sacral pressure ulcers and IAD and the impact of prevention and treatment of IAD in the effectiveness of pressure ulcer prevention needs further exploration.

CONFLICT OF INTEREST

There are no conflicts of interest.

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CHAPTER 5

A SYSTEMATIC REVIEW OF THE COST OF PREVENTION AND TREATMENT OF PRESSURE ULCERS

Based on the article of Demarré L, Verhaeghe S, Van Hecke A, Grypdonck M, Lemey J, Annemans L & Beeckman D. A systematic review of the cost of prevention and treatment of pressure ulcers. *Under Review*.

ABSTRACT

Introduction: Pressure ulcers impose a substantial financial burden. The need for high-quality health care while expenditures are constrained entails the interest to calculate the cost of preventing and treating pressure ulcers and their impact on patients, healthcare, and society.

Aim: The aim of this paper is to provide insight into the economic impact of pressure ulcer prevention and treatment in an adult population.

Methods: A systematic literature review was performed conform the Cochrane Collaboration guidelines for systematic reviews. The search strategy contained index terms and key words related to pressure ulcers and cost. The search was performed in Medline, CINAHL, Web of Science, The Cochrane Library, Embase, and EconLit covering articles up to September 2013. Reference lists and conference abstracts were screened. Articles were eligible if they reported on direct medical cost of pressure ulcer prevention or treatment, and provided national cost estimates, cost per patient, or cost per patient per day. The Consensus on Health Economic Criteria checklist was used to assess methodological quality of the included studies.

Results: In total, 3396 articles were retrieved. After assessing eligibility, 33 articles were included. Ten articles reported on the cost of prevention as well as treatment, seven articles reported on cost of prevention, and 16 articles reported on the cost of pressure ulcer treatment. All articles were published between 1991 and 2013.

Cost of pressure ulcer prevention per patient at risk varied between €2.65 and €87.57 per day. Cost of pressure ulcer treatment ranged from €1.73 to €812.92 per patient per day. The methodological heterogeneity among studies was considerable, and encompassed differences regarding type of health economic design, cost components, and health outcomes.

Conclusion: Cost of pressure ulcer prevention and treatment differed considerable between studies. The cost to provide pressure ulcer prevention to patients at risk was higher in hospitalised patients compared to patients in home care or nursing homes. Cost of treatment tended to increase with pressure ulcer severity. Methodological heterogeneity among studies identified the need to use

the available, study design specific methodological guidelines to conduct health economic studies, and the need for additional pressure ulcer specific recommendations.

1. INTRODUCTION

Pressure ulcers impose a considerable burden. Besides their impact on the patients' overall well-being (physical, psychological, functional and social), pressure ulcers also entail a substantial financial concern for all involved parties (Gorecki et al., 2009; Hopkins et al., 2006; Langemo et al., 2000). A growing awareness of the economic impact of pressure ulcers is related to constrained public and healthcare finances. The scarce financial resources cannot meet all current health care needs (Posnett and Franks, 2008). Therefore it is important to provide insight in the cost related to the treatment of mainly avoidable events, such as pressure ulcers. Several studies have provided insight into the economic burden of pressure ulcers for society and health care payers, such as patients, health services, and insurers (Larg and Moss, 2011; Rice, 1967). These insights can help policymakers and health service management to identify the cost drivers for pressure ulcer prevention and treatment. Furthermore, it may guide the decision making of health care institutions about allocating healthcare resources such as materials and nursing staff.

Health economic studies can comprise direct and indirect costs, as well as medical and non-medical costs (Annemans, 2008; Rice, 1967). Direct medical costs are defined as disease related costs, such as prevention, detection, treatment, and rehabilitation, which are paid by the patient, healthcare institution, insurances, and/or government (Annemans, 2008; Rice, 1967). Direct non-medical costs are disease related costs, which are not part of the health services, such as travel costs to the health care provider, or costs related to the time that significant others spent to provide care for the patient. Indirect medical costs are future costs of general healthcare, such as the healthcare costs arising from living longer (Annemans, 2008). Indirect non-medical costs include costs related to reduced work productivity due to morbidity or premature death because of illness (Annemans, 2008). In general, indirect costs are often more difficult to measure objectively, and less easy to attribute to a specific disease (Dagenais et al., 2008).

A number of published studies have described the costs associated with pressure ulcer prevention and treatment. Summarising the costs of pressure

ulcer prevention is important for the government and health care payers to assess the impact of prevention on their budget (Schuurman et al., 2009; Severens et al., 2002) and when considering the expenditures of new preventive strategies (Xakellis et al., 1996b; Makai et al., 2010). Insights in the cost of pressure ulcer prevention and treatment may stimulate the attention for systematic risk assessment, and encourage investing in risk assessment research which improves the ability of correctly identifying patients at risk for pressure ulcer development. Moreover, insight in the cost of pressure ulcer treatment can motivate to focus more on prevention (Moore et al., 2013) and facilitate decision making regarding investment in new treatment options (Allman et al., 1987; Baxter, 2000).

Studies summarising the available data on cost of pressure ulcer prevention and treatment focussed on cost data in the United Kingdom (National Institute for Clinical Excellence, 2005) or did not aimed to perform a systematic search (Spetz et al., 2013). A systematic review summarising the available evidence on the cost of pressure ulcer prevention and treatment is however lacking.

2. AIM

The aim of this paper is to provide insight into the economic impact of pressure ulcer prevention and treatment in an adult population.

3. METHODOLOGY

3.1 DESIGN

A systematic review was performed. The Cochrane Collaboration guidelines for systematic reviews of interventions incorporating economic evidence were applied (The Cochrane Collaboration, 2008).

3.2 SEARCH STRATEGY

The search strategy contained index terms and key words related to pressure ulcers and cost (Table 1). The search string for pressure ulcer prevention and treatment was based on the search string of the Belgian Health Care Knowledge

Centre (KCE) Pressure Ulcer Report (Beeckman et al., 2013a). The search string for cost was based on the search string used in systematic reviews performed by the Cochrane Collaboration and KCE (Maher et al., 2012; McKinlay et al., 2006; Vrijens et al., 2009). The search was performed in six electronic databases: Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science, The Cochrane Library, Embase, and Econlit. Data retrieval was completed in September 2013. The following conference proceedings were screened: proceedings of the Annual European Pressure Ulcer Advisory Panel Meetings (2005-2013), and of the European Wound Management Association meetings (2001-2013). If appropriate, the authors of relevant conference proceedings were contacted to request additional information. The reference lists of the included articles were screened.

3.2 STUDY ELIGIBILITY

Title and abstract of all retrieved records were independently screened for eligibility by two researchers (IG & LD). Following criteria were used: (1) written in English, French or Dutch; (2) providing monetary data of at least the direct medical cost of pressure ulcer prevention or treatment; (3) retrieved from original research (except case studies), or health economic modelling using data from international literature; and (4) targeting an adult hospital, long term care/nursing home or home care population.

All types of health economic studies were eligible for inclusion if at least data were provided on direct medical cost of pressure ulcer prevention or treatment.

Records were excluded if: (1) there was a focus on a specific subpopulation, such as spinal cord injury patients or a specific pressure ulcer severity; (2) there was a focus on one specific preventive measure or one aspect of pressure ulcer prevention (such as mattresses or repositioning) and not on pressure ulcer prevention as a whole; (3) there was a focus on one specific treatment or one aspect of pressure ulcer treatment (such as dressings) and not on pressure ulcer treatment as a whole; or if (4) the preventive measures or treatments under

study were not in line with the recommendations of the NPUAP/ EPUAP guidelines (NPUAP & EPUAP, 2009).

Table 1 Search strategy

Concept	Search terms [1]
Cost	1. Cost and Cost Analysis [Mesh]
	2. Cost.tw
	3. Cost-benefit.tw
	4. Cost-effectiveness.tw
	5. Economic*.tw
Pressure ulcer	6. Pressure ulcer (MeSH)
	7. Pressure ulcers.tw
	8. Ulcer pressure.tw
	9. Ulcers pressure.tw
	10. Bedsore.tw
	11. Bedsores.tw
	12. Pressure sore.tw
	13. Pressure sores.tw
	14. Bed sore.tw
	15. Bed sores.tw
	16. Sore bed.tw
	17. Decubitus.tw
Cost AND Pressure ulcer	18. OR/1 –5
	19. OR/6 – 17
	20. AND/18 – 19

[1] Search terms were used in the MEDLINE search strategy and adapted for each database

Differences in assessment about the inclusion of the records were discussed until consensus was obtained. In case of doubt, the full text article was retrieved and screened in detail. Potentially interesting records were screened in full by one reviewer (LD). The reasons for exclusion of title, abstracts and full texts were documented (Moher et al., 2010) (Figure 1).

3.3 DATA EXTRACTION

A data extraction form was developed prior to the search and refined after pilot testing. Data extraction included the name of the authors, the year of publication,

the type of health economic study (cost-of-illness study, cost-effectiveness study, cost-utility analysis, or cost-benefit analysis, cost analyses, cost-description and cost-outcome description studies), the economic perspective specifying the chosen focus of the group baring the costs (societal, health care payer, institutional, patient's or mixed, the latter consisting of patient, institution, insurance perspective), the method of cost calculation (bottom-up/person-based approach, top-down/population-based approach), population (hospital, nursing home/long term care, and home care), intervention (prevention, treatment, inclusion of secondary prevention), costs (cost, currency, year of data collection, cost components incorporated), time horizon (timeframe used for health-related and cost outcomes), discounting (adjusting for future costs and effects that need to be included in the current calculations), analyses of uncertainty, data sources of health outcomes and cost components, and limitations. Data extraction was performed by one reviewer (LD). A second reviewer (JL) independently extracted data based on the data extraction form of a random sample of 15% of the articles. Only minor differences in data extraction occurred. These differences were discussed between both reviewers until consensus was reached.

3.4 QUALITY ASSESSMENT

The methodological quality of the included articles was assessed using an adapted version of Evers' Consensus on Health Economic Criteria (CHEC-) checklist (Evers et al., 2005). This checklist was recommended by the Cochrane Collaboration to perform a critical appraisal of full (cost-effectiveness, cost-utility, and cost-benefit) and partial (cost analyses, cost-description, and cost-outcome description) economic studies (The Cochrane Collaboration, 2008). The methodological quality was assessed by one reviewer (LD) and a random sample of 15% of the articles was double checked by a second reviewer (JL). The Cohen's Kappa correlation was calculated to determine the level of agreement between both assessors (Rousson et al., 2002) (κ=0.625). Disagreements in quality assessment were discussed until consensus was

reached. Because of the explorative nature of this review, the methodological quality of the studies was not set as a criterion for exclusion.

3.5 DATA SYNTHESIS

Data on national cost estimates, cost per patient, and the cost per patient per day were extracted from the included studies. Original data were changed to one single currency (Euro) and adjusted according to the inflation rates until 2013 based on the health index (FOD Economie and PF Economie, 2014). If the authors did not report the reference year of the data or the year of data collection, the year before the article was published was used as reference. Due to the methodological heterogeneity, results were synthesised narratively and no meta-analysis was performed.

4. RESULTS

4.1 GENERAL STUDY CHARACTERISTICS AND QUALITY ASSESSMENT

The literature search yielded 3396 articles (Medline: 845, CINAHL: 971, Web of Science: 980, The Cochrane Library: 154, Embase: 414, Econlit: 32), of which 1244 were duplicates. Title and abstract were screened, resulting in 110 potentially relevant articles. Based on full-text screening, 33 articles were withheld. Ten articles provided outcomes on both cost of prevention and treatment, seven only on cost of prevention and 16 articles exclusively on cost of treatment. No additional articles were included from reference list screening or reviewing conference proceedings (Figure 1).

An overview of the quality assessment is provided in Table 3. Articles on cost of pressure ulcer prevention included cost data from North America (US and Canada) and Europe (UK, Spain and The Netherlands). Several types of health economic studies were included. In six studies, a cost-effectiveness analysis was performed (Lyder et al., 2002; Makai et al., 2010; Padula et al., 2011; Xakellis et al., 1996b; Xakellis, Jr. et al., 1998; Foglia et al., 2012), other studies used a cost-of-illness design (Severens et al., 2002; Chan et al., 2013), a cost minimization design (Schuurman et al., 2009), or an economic impact model (Bayoumi et al., 2008). Two studies did not report on the health economic design

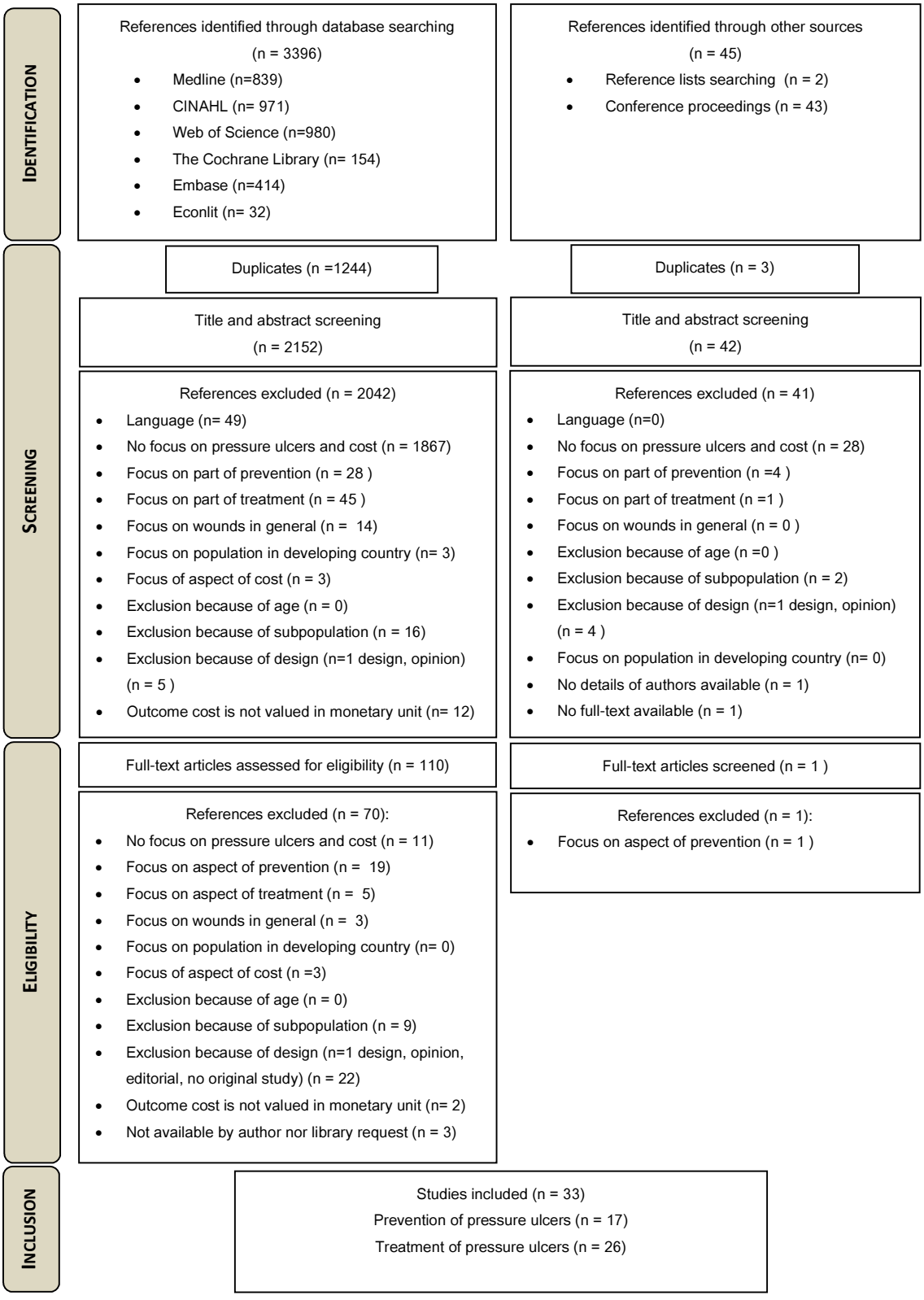

Figure 1 Flowchart of the systematic review process

being used (Beckrich et al., 1999; Berthier et al., 2005). The remaining articles used varying terminology referring to a cost evaluation (Agreda et al., 2007; Allman et al., 1999; Alterescu, 1989; Assadian et al., 2011; Baker, 1996; Bennett et al., 2004; Dzwierzynski et al., 1998; Frantz et al., 1991; Frantz et al., 1995a; Frantz et al., 2001; Haalboom, 1991; Hale, 1990; Hu et al., 1993b; Kumar et al., 2004; Oot-Giromini et al., 1989; Rees and Bashshur, 2007; Richardson et al., 1998; Van Den Bos et al., 2011; Xakellis et al., 1995; Xakellis et al., 1996a; Xakellis et al., 2001). The majority of the studies used a bottom-up approach to examine medical resource use (Agreda et al., 2007; Alterescu, 1989; Assadian et al., 2011; Bayoumi et al., 2008; Beckrich et al., 1999; Bennett et al., 2004; Dealey et al., 2012; Foglia et al., 2012; Frantz et al., 1991; Frantz et al., 1995a; Frantz et al., 2001; Gebhardt and Gebhardt, 2003; Haalboom, 1991; Hale, 1990; Hu et al., 1993; Lyder et al., 2002; Makai et al., 2010; Oot-Giromini et al., 1989; Padula et al., 2011; Rees and Bashshur, 2007; Richardson et al., 1998; Schuurman et al., 2009; Severens et al., 2002; Xakellis et al., 1995; Xakellis et al., 1996a; Xakellis et al., 1996b; Xakellis et al., 2001; Xakellis, Jr. et al., 1998), in six studies a top-down approach was used (Allman et al., 1999; Baker, 1996; Berthier et al., 2005; Dzwierzynski et al., 1998; Kumar et al., 2004; Van Den Bos et al., 2011). The articles were published between 1991 and 2013. The time horizon ranged from one day up to 5 years.

4.2 COST OF PRESSURE ULCER PREVENTION

The main study characteristics of the articles and their reported cost of pressure ulcer prevention are outlined in Table 3.

The cost calculations were related to a variety of preventive measures and methods. In two studies the cost calculation of preventive measures was based on a model created from best practice guidelines (Bennett et al., 2004; Dealey et al., 2012), and in six studies on a model based on findings from the literature (Bayoumi et al., 2008; Haalboom, 1991; Hu et al., 1993; Makai et al., 2010; Padula et al., 2011; Severens et al., 2002). In four studies cost calculation of preventive measures was based on real practice, collecting data alongside the

health economic study (Richardson et al., 1998; Schuurman et al., 2009; Xakellis et al., 2001; Xakellis, Jr. et al., 1998).

National annual cost of pressure ulcer prevention

The impact of cost of pressure ulcer prevention on the national annual budget was described in two studies from the Netherlands (Haalboom, 1991; Schuurman et al., 2009). In these studies, the annual cost of pressure ulcer prevention was estimated between €33.20 million and €160.4 million (Haalboom, 1991; Schuurman et al., 2009), or between €197,030 and €951,900 per 100,000 inhabitants. In the study by Haalboom (1991), a decision analytical model was used. In this model, the medical resource use was based on expert opinion and consensus (Haalboom, 1991). Schuurman et al. (2009) used a bottom-up cost minimization analysis assessing resource use from patients' study files and records (Schuurman et al., 2009).

Cost of pressure ulcer prevention per patient at risk

The cost of pressure ulcer prevention varied between €167.83 and €7,988.47 per hospitalised patient (Haalboom, 1991; Padula et al., 2011; Schuurman et al., 2009; Bennett et al., 2004; Dealey et al., 2012).

The time horizon in long-term care differed between studies (Bayoumi et al., 2008; Makai et al., 2010; Richardson et al., 1998; Xakellis et al., 1995; Xakellis et al., 1996a; Xakellis et al., 1996b; Xakellis et al., 2001; Xakellis, Jr. et al., 1998). Bayoumi et al. calculated the cost of prevention using a time horizon of 5 years and found an attributable cost between €53.66 and €111.04 to provide pressure ulcer prevention in residents at risk (Bayoumi et al., 2008). Xakelis et al. found a cost ranging between €273.33 and €613.33 using a time horizon of 3 months (Xakellis et al., 1995; Xakellis et al., 1996b), and ranging between €94.79 and €156.39 using a time horizon of 6 months (Xakellis et al., 2001; Xakellis, Jr. et al., 1998).

In two studies no differentiation was made between hospitalised patients and residents in long-term care (Bennett et al., 2004; Dealey et al., 2012), resulting

Table 2 Quality appraisals based on CHEC checklist (Evers et al.2005)

Reference	study population clearly described	competing alternatives clearly described	well-defined research question	economic study design appropriate for stated	chosen time horizon appropriate to include	actual perspective chosen appropriate	all important and relevant costs for each alternative	all costs measured appropriately in physical	costs valued appropriately	important and relevant outcomes for each	all health outcomes measured appropriately	all outcomes valued appropriately	is an incremental analysis of costs and outcomes of	all future costs and outcomes discounted	all important variables, whose values are uncertain,	conclusions follow from the data reported	does the study discuss generalizability of the	article indicates there is no potential conflict of interest	ethical and distributional issues discussed
Agreda et al (2007)	+	na	+	+	+	+	+	[+]	+	na	[+]	+	na	na	-	+	+	-	+
Allman et al (1999)	[+]	na	+	+	+	+	[+]	[+]	[+]	+	+	+	na	+	-	+	-	-	[+]
Allterescu et al (1989)	+	na	+	+	+	+	+	+	[+]	+	[+]	[+]	na	na	-	+	+	-	+
Assadian et al (2011)	+	na	+	+	+	+	[+]	[+]	[+]	na	[+]	[+]	na	na	-	+	[+]	+	+
Baker J. (1996)	+	na	+	+	+	+	+	+	[+]	[+]	+	[+]	na	na	-	[+]	-	-	-
Bayouimi et al. (2008)	+	+	+	+	+	+	+	+	+	+	+	[+]	+	+	+	+	+	-	+
Beckrich et al (1999)	[+]	na	+	[+]	+	-	[+]	[+]	[+]	[+]	+	+	na	na	+	[+]	-	-	+
Bennet et al (2004)	[+]	na	+	+	+	+	+	[+]	+	+	+	+	na	na	+	+	+	+	+
Berthier et al (2005)	+	na	+	[+]	+	+	+	+	[+]	+	+	+	na	na	-	+	[+]	-	[+]
Chan et al (2013)	[+]	+	+	+	+	+	+	+	[+]	+	[+]	[+]	na	na	-	+	[+]	-	+
Dealey et al (2012	+	na	+	+	+	+	+	[+]	+	+	+	+	na	na	[+]	+	+	+	+
Foglia et al (2012)	[+]	-	+	+	[+]	+	[+]	[+]	+	-	[+]	[+]	+	+	+	+	+	-	+
Frantz et al (1991)	+	na	+	+	+	+	+	[+]	+	+	+	+	na	na	-	+	+	-	+
Frantz et al. (1995)	+	na	+	+	+	+	+	[+]	+	+	+	+	na	na	-	+	+	-	+
Frantz et al. (2001)	+	na	+	+	+	+	+	[+]	+	+	+	+	na	na	-	+	+	-	+
Haalboom (1991)	+	na	+	[+]	[+]	+	[+]	[+]	+	[+]	+	+	na	na	-	+	[+]	-	+
Hale (1990)	-	na	+	-	+	-	-	-	-	-	-	+	na	na	-	+	-	-	-
Hu et al. (1993)	[+]	na	+	[+]	+	+	[+]	[+]	[+]	+	-	+	na	na	-	+	+	-	+

Table 2 Quality appraisals based on CHEC checklist (Evers et al.2005)

Reference	study population clearly described	competing alternatives clearly described	well-defined research question	economic study design appropriate for stated	chosen time horizon appropriate to include	actual perspective chosen appropriate	all important and relevant costs for each alternative	all costs measured appropriately in physical	costs valued appropriately	important and relevant outcomes for each	all health outcomes measured appropriately	all outcomes valued appropriately	is an incremental analysis of costs and outcomes of	all future costs and outcomes discounted	all important variables, whose values are uncertain,	conclusions follow from the data reported	does the study discuss generalizability of the	article indicates there is no potential conflict of interest	ethical and distributional issues discussed
Kumar et al. (2004)	+	na	+	+	+	+	[+]	[+]	+	+	[+]	[+]	na	na	-	+	+	-	+
Lyder et al. (2002)	-	+	+	[+]	+	+	[+]	[+]	[+]	+	-	[+]	-	na	-	+	-	[+]	-
Makai et al. (2010)	+	+	+	+	+	+	[+]	[+]	[+]	+	[+]	[+]	+	-	+	+	+	+	+
Oot-Giromini (1989)	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Padula et al. (2011)	+	+	+	+	+	+	+	[+]	+	+	+	+	+	+	+	+	+	-	+
Rees et al. (2007)	-	[+]	+	[+]	+	[+]	[+]	[+]	[+]	+	[+]	[+]	-	na	-	+	+	-	+
Richardson et al (1998)	+	na	+	+	+	+	+	[+]	[+]	+	+	[+]	na	na	-	[+]	-	-	+
Schuurman et al (2009)	+	+	+	+	+	+	+	[+]	[+]	+	+	[+]	na	na	+	+	+	-	+
Severens et al. (2002)	[+]	na	+	+	+	+	+	[+]	-	+	+	+	na	na	[+]	+	[+]	-	[+]
Van den Bos et al. (2011)	-	na	+	+	+	+	+	+	+	[+]	+	[+]	na	na	-	+	-	-	+
Xakellis et al. (1995)	+	na	+	+	[+]	+	+	[+]	+	+	+	+	na	na	-	+	-	-	+
Xakellis & Frantz (1996a)	-	na	+	+	+	+	+	[+]	+	+	+	+	na	na	-	+	+	-	+
Xakellis et al (1996b)	+	+	+	+	+	+	[+]	[+]	-	+	[+]	[+]	-	na	-	+	[+]	-	[+]
Xakellis et al (1998)	+	+	+	+	+	+	+	[+]	[+]	[+]	[+]	[+]	na	na	+	+	+	-	[+]
Xakellis et al (2001)	+	+	+	+	+	+	+	[+]	[+]	[+]	[+]	[+]	-	na	+	+	+	-	[+]

+: present, [+] partly present, na: not applicable, - absent

in a cost between €1,524 and €1,676 per patient at risk using a time horizon of 28 days.

Cost of pressure ulcer prevention per patient at risk per day

Cost of pressure ulcer prevention per patient per day was calculated for acute hospital care (Bennett et al., 2004; Dealey et al., 2012; Haalboom, 1991; Hu et al., 1993; Oot-Giromini et al., 1989; Padula et al., 2011; Schuurman et al., 2009; Severens et al., 2002), long-term care (Bayoumi et al., 2008; Bennett et al., 2004; Dealey et al., 2012; Hu et al., 1993; Lyder et al., 2002; Richardson et al., 1998; Severens et al., 2002; Xakellis et al., 1995), and home care setting (Severens et al., 2002).

Cost of pressure ulcer prevention per patient at risk per day varied between €5.39 and €87.57 in hospitals (Haalboom, 1991; Hu et al., 1993; Oot-Giromini et al., 1989; Padula et al., 2011; Schuurman et al., 2009; Severens et al., 2002). Cost per day for pressure ulcer prevention in long-term care residents varied between €2.65 and €19.69 (Hu et al., 1993b; Lyder et al., 2002; Richardson et al., 1998; Severens et al., 2002; Xakellis et al., 1995). The average cost of prevention for patients in long-term care and hospitals ranged between €53.69 and €59.84 (Bennett et al., 2004; Dealey et al., 2012). The cost of prevention per patient per day in home care ranged between €7.75 and €13.78 (Severens et al., 2002).

Table 3 Articles on Cost of Pressure Ulcer prevention

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/ Number**	**Study design**	**Type of prevention**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost) ***National***	***Per Capita***	***Per capita/day***
Bayoumi et al. (2008)	Canada CAD 2008	Long term care homes Number: National	Economic and health impact model based on decision analytic modelling	Intervention 1: alternate foam mattress Intervention 2: Alternate foam + 4-hourly repositioning Control: standard care	Incremental lifetime cost	Intervention 1: €12.58 million (C$17.34 million) Intervention 2: €14.32 million (C$19.75 million) Control group: €16.27million (C$77.60 million)	Intervention 1: €53.66 (C$80) Intervention 2: €58.01 (C$74) Control group: €111.04 (C$153,14)	-
Bennet *et al.* (2004)	UK GBP UK NHS unit costs at 2000 prices	Hospital or long term care and community care Number: National	Bottom-up cost evaluation	Protocols reflecting good clinical practice At risk= PU cat 1	-Treatment cost per episode of care and per patient	-	Cat.1: €1,675.53 (£1,064)	Cat. €1:59.84 (£38)
Dealey *et al.* (2012)	UK GBP UK NHS unit costs at 2011 prices	Hospital or long term care and not admitted for pressure ulcer. Number: National	Bottom-up cost evaluation	Protocols reflecting good clinical practice At risk= PU cat 1	Treatment cost per episode of care per patient Per severity Per level of complications	-	Cat 1: €1,524.95 (£1213.58)	Cat 1: €53.69 (£42.73)
Haalboom (1991)	The Netherlands NLG	Hospital	Economic evaluation based	Prevention = - extra nursing	Cost of prevention for	€160.4 million (ƒ223 million)	€808.29 (ƒ1,123.74)	€67.36 (ƒ93.65)

Table 3 Articles on Cost of Pressure Ulcer prevention

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/ Number**	**Study design**	**Type of prevention**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost)		
						National	***Per Capita***	***Per capita/day***
	Year not reported	Number: National	on modelling	care (in total 83 min/day) - physiotherapy - nutritional support - support surface	patient at risk (per day or per admission)			
Hu *et al.* (1993)	US USD 1991	Hospital and nursing home Number: Hospital (n= 20): hip fracture (n=9); paraplegia (n=3); intensive care (n=7) (n=8) Nursing home (n= 8)	cost evaluation based on case studies	Prevention and guideline implementation	- Cost of prevention and early treatment of stage I pressure ulcers - Cost of guideline implementation.	-	-	Hip fracture patient: €19.09 - €20.08 ($17.11- $18.0) Paraplegia patient: €39.35 - €40.88 ($35.27- :$36.64) Intensive care patients: €47.97 - €50.28 ($43.00- $45.07) Nursing home resident: €13.61 - €16.88 ($12.20- $15.13)
Lyder *et al.*	US	Nursing home	cost evaluation	Prevention after	Costs of	-	-	€17.73 ($19.17)

Table 3 Articles on Cost of Pressure Ulcer prevention

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/ Number**	**Study design**	**Type of prevention**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost)		
						National	***Per Capita***	***Per capita/day***
(2002)	USD 1999	residents Number: n=20	based on modelling	guideline implementation	prevention of PU:			
Makai *et al.* (2010)	The Netherlands EUR November 2007	Nursing homes; Number: n=88	Full economic analysis (CEA) based on a non-controlled pre post design and modelling (Markov model)	Control group: before implementation of quality improving program Intervention: quality improving program	Cost effectiveness of quality improving program.	-	Control group: €15.27 (€13.15) QIC: €44.73 (€38.52); excl. cost of implementation	
Oot-Giromini *et al.* (1989)	US USD Year not reported	Hospital Number: not reported (random sample)	Economic evaluation based on a prospective bottom up design DS: supplies based on patients bills	Prevention (hospital standards of care)	direct costs (labour + material cost)	-	-	€5.39 ($4.83)
Padula *et al.* (2011)	US USD	Hospital Number: not	full-economic analyses based	Intervention 1: prevention (full	Cost of prevention per	-	Intervention 1: €5,781.50 ($7276.35)	Intervention 1: €43.43 ($54.66)

Table 3 Articles on Cost of Pressure Ulcer prevention

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/ Number**	**Study design**	**Type of prevention**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost)		
						National	***Per Capita***	***Per capita/day***
	2009 (corrected for inflation to 2009 US$)	applicable (model)	on Semi-Markov model simulating	prevention defined by Reddy assumed) Standard care	patient per day, per patient		Standard care: €7,988.47 ($10,053.95)	Standard care: not reported
Richardson *et al.* (1998)	US USD 1996	Long term care. Number: n=30 (excl. of one patient with low-air-los rental)	Economic evaluation as part of a comparative prospective descriptive study	Cost of prevention was calculated for 4 Prevention: Risk assessment labour Mattress support surfaces, Chair support surfaces, Repositioning labour	Total cost for each subject: summing across categories, and cost per day.	-	€498.94 ($497.52)	€5.57 ($5.55)
Schuurman *et al* (2009)	The Netherlands EUR 2001- 2004	Hospital Number: n= 149 (TA: n=94; HA: n= 55)	Bottom- up economic evaluation	Intervention 1: technological approach Intervention 2: human approach	Cost of prevention -Technical approach (TA) -Human	TA: €33.20 million (€27.5 million) HA: €76.79 million (€63.6 million)	TA: €167.83 (€139) HA: €387.59 (€321)	TA: €15.70 (€13) HA: €28.98 (€24)

Table 3 Articles on Cost of Pressure Ulcer prevention

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/ Number**	**Study design**	**Type of prevention**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost)		
						National	***Per Capita***	***Per capita/day***
					approach (HA)			
Severens *et al.* (2002)	The Netherlands USD Year not reported	Home care, nursing homes, university and general hospitals. Number: National	Cost of illness	High risk (for some respondent identical to patients with Pu stage I)		-	-	Home Care: €7.75 - €13.78 ($8.38 - $14.90) Nursing Home: €2.65 - €19.69 ($2.87-$21.29) General hospital: €8.32 - €11.03 ($8.99-$11.92) University hospital: €54.85 - €87.57 ($59.29-$94.67)
Xakellis *et al.* (1995)	US USD 1991	Long term care Number: n=539	Cost evaluation of attributable cost of PU prevention	Prevention (turning, mattresses, cushions and protective devices)	Equipment for PU prevention, nursing care,	-	€273.33 ($245) over 3 months	€3.32 ($2.98)
Xakellis *et al.* (1996a)	US USD 1992-1993	Long term care Number:	Secondary data analyses of study	Prevention in patients with pressure ulcers	Support surfaces and repositioning	-	€613.33 ($550) over 3 months	-

Table 3 Articles on Cost of Pressure Ulcer prevention

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/ Number**	**Study design**	**Type of prevention**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost)		
						National	***Per Capita***	***Per capita/day***
		N=30 (developed 45 PU)	of Frantz 1995: retrospective descriptive analysis of additional cost of pressure ulcer treatment	category II-IV				
Xakellis *et al.* (1996b)	UK and US USD Intervention 1:1960 Intervention 2: 1991	Hospital Number: Intervention 1: n=250 Intervention 2: N=420	Cost effectiveness analysis	Intervention1: no prevention Intervention 2: prevention by repositioning; mattresses, cushions, heel protectors	Cost= cost of prevention & treatment	-	Intervention 1: $0 Intervention 2: €262.18 ($235) over 3 months	-
Xakellis *et al.* (1998)	US USD 1994- 1995	Long term care Number: Pre-protocol: n=69 Post-protocol: n=63	Quasi experimental pre-post-test design.	Pre protocol: no systematic preventive method Post protocol: Protocol based on AHCPR guidelines	Cost of assessing, Cost of prevention Cost of treatment	-	Pre protocol: $0 Post protocol: €94.79 ($91.56) over 6 months	-

Table 3 Articles on Cost of Pressure Ulcer prevention

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/ Number**	**Study design**	**Type of prevention**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost)		
						National	***Per Capita***	***Per capita/day***
Xakellis *et al.* (2001)	US USD 1994- 1995 & 1997	Long term care Number: Pre-protocol: n=69 Post-protocol: n=63 Post-protocol 2: n=71	Quasi experimental pre-post-test design.	Pre protocol: no systematic prevention Post protocol: based on AHCPR guidelines Post protocol 2 : 2 years after data collection	Xakellis et al. 1998	-	Pre protocol: $0 Post protocol 1: €132.53 ($130) Post protocol 2 : €156.39 ($158) over 6 months	-

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/** **Number**	**Study design/** **Data sources**	**PU severity**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost) ***National***	 ***Per Capita***	 ***Per capita/day***
Agreda *et al.* (2007)	Spain EUR 2006	National (hospital, residential and primary care) Number: Primary care: n=704 572 (1.86% of 37,880,215 beds) Hospital: n= 8466 (6.61% of 128,082 beds) Residential care: n=10761 (4.05% of 265,712 beds)	Bottom-up cost of illness study	PU 1-4 (per PU severity category)	-weekly treatment costs per patient (recalculated to cost per day) -cost per episode of care and -national cost of pressure ulcer treatment by PU grade and treatment setting	€535.37million (€461 million) Primary care: €121.44 million (€104.57 million) Hospital: €140.57 million (€121.04 million) Residential Care: €273.83 million (€235.79 million)	Primary care Cat. 1: €125.42 (€108) Cat.2: €225.49 (€220) Cat.3: €760.67 (€655) Cat.4: €3,330.69 (€2,868) Hospital: Cat.1: €19.74 (€17) Cat.2: €84.78 (€73) Cat.3: €625.96 (€539) Cat.4: €922.09 (€794) Residential care: Cat.1: €15.10 (€13) Cat.2: €358.58 (€309) Cat.3: €409.95 (€353)	Primary care Cat.1: €4.48 (€3.857) Cat.2: €8.46 (€7.286) Cat.3: €12.61 (€10.857) Cat.4= €33.35 (€28.714) Hospital: Cat.1: €2.82 (€2.429) Cat.2: €12.11 (€10.429) Cat.3: €89.42 (€77) Cat.4: €131.73 (€113.429) Residential care: Cat.1: €2.16 (€1.857) Cat.2: €51.26 (€44.143) Cat.3: €58.56 (€50.429) Cat.4: €63.71

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
						National	*Per Capita*	*Per capita/day*
							Cat.4: €445.95 (€384)	(€54.857)
Allman *et al.* (1999)	US USD Converted to prices: dec 1988 – june 1991	Hospital Number: N=286 (>55 years of age, confined to bed/ chair or with hip fracture)	Bottom-up economic evaluation, based on prospective cohort study	PU 2-4	Hospital costs using category-specific cost to charge ratios.	-	€16,990.04 ($15,229)	€812.66 ($728.66)
Alterescu *et al* (1989)	US USD November 1, 1986-31 January 1987	Hospital (one community teaching hospital) Number: n=23 (all patients with PU referred to enterostomal Therapy Nurse between 1 Nov 1986 and 31 Jan 1987)	Economic evaluation study, based on retrospective study	PU 1-4	Total costs (mean per patient/day)	-		€99.91 ($80.42)
Assadian *et al.* (2011)	Germany EUR January 2001	Hospitals (3 community hospitals)	Bottom-up prospective economic	PU 2-4	Total cost per day/patient	-	€1,255.89 (€991)	€65.90 (€52)

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
						National	*Per Capita*	*Per capita/day*
			evaluation					
		Number: n=35 (=all patients admitted with PU diagnosis PU besides primary diagnosis)						
Baker *et al.* (1996)	US USD 1988-1990	Hospital Number= 814 (residents with hospital admission)	Top-down budget impact analyses based on retrospective analysis of data from Medicaid patient claims	Not reported	Additional cost of claim for reimbursement based on cost of hospital stay associated and not associated with PU	-	€2,998.84 ($2,688)	-
Beckrich & Aronovitch (1999)	US USD Year not reported (based on Alterescu et al. 1989 & Allman et al 1995)	Hospital Number: n=373,560	Economic evaluation based on literature data	Hospital acquired PU 1-4	Annual Cost of hospital-acquired PU Cost of hospital-acquired PU per ulcer Cost of OR acquired PU	€2,468.865 million ($2,212.958 million)	€1,535.12 ($1,376) Cat. 1-2: €139.45 - €228.71 ($125-$205); Cat. 3-4: €15,641.28 - €25,575.05 ($14,020- $22,925)	
Bennet *et al.* (2004)	UK GBP	Hospital or long term care and	Bottom-up cost evaluation	PU 1-4 (per PU severity	-Treatment cost per episode of care and	€2.79bn (£1.77bn)	Cat. 1: €1,675.53 (£1,064)	Cat. 1: €59.84 (£38)

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number Data sources	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost) *National*	 *Per Capita*	 *Per capita/day*
	NHS unit costs at 2000 prices	community nursing/care of GP Number: National		category & level of complication)	per patient -Total cost of health and social care system in UK		Cat. 2: €6,217.11-€32,143.76 (£3,948-£20,412) Cat. 3: €9,999.65-€35,926.30 (£6,350-£22,814) Cat. 4: €12,204.30-€38,130.95 (£7,750-£24,214)	Cat. 2: €66.14-€308.65 (£42 - £196) Cat. 3: €78.74-€308.65 (£50-£196) Cat. 4: €78.74-€308.65 (£50-£196)
Berthier *et al.* (2005)	France EUR 2003	Hospital Number: n = 73	Budget impact analyses examining the effect of the "Associated Complication and Morbidity" pressure ulcer coding defect.	PU 1-4 (average)	Cost of stay in hospital for patients identified with PU based on existing MDG (Major Diagnostic Group code	-	€429.53 (€350) (Adjusted for extreme cases)	_
Chan *et al* (2013)	Canada CAD 2002-2006	Hospital Number: n=3874 (>65 years)	Cost-of-illness based on top down matched controlled cases	PU 2-4 (per PU severity category)	Cost of hospital acquired and pre-admission PU including direct and overhead costs	-	Hospital acquired PU: Cat. 2: €33,786.17 (C$43,930) Cat. 3: €52,544.30	

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
						National	*Per Capita*	*Per capita/day*
							(C$68,320) Cat. 4: €69,472.00 (C$90,330) Unstageable: €36,585.66 (C$47,570) Pre-admission PU: Cat.2: (C$10,810) Cat.3: €11,613.28 (C$15,100) Cat.4: €14,243.57 (C$18,520) Unstageable: €6,387.30 (C$8,305)	
Dealey *et al.* (2012)	UK GBP UK NHS unit costs at 2011 prices	Institutional setting (hospital of long term care) but not admitted solely for PU care. Number: National	Bottom-up cost evaluation	PU 1-4 (per PU severity category)	Treatment cost per episode of care and per patient fir PU of different severity and different level of complications	-	Cat. 1: €1,524.95 (£1213.58) Cat.2: €5527,40- €45048,02 (£4,398.79 -£35,849.90)	Cat.1: €53.69 (£42.73) Cat. 2: €58.93- €470.49 (£46.90- 374.42)

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
						National	*Per Capita*	*Per capita/day*
							Cat. 3: €9088,71-€48,609.33 (£7,232.93-£38,684.04) Cat. 4: €11,036.29-€50,556.92 (£8,782.85-£40,233.96)	Cat. 3: €71.34-€470.49 (£56.77-£374.42) Cat.4: €71.34-€470.49 (£56.77 - £374.42)
Foglia *et al.* (2012)	Italy EUR 2010 (discounted from 2008)	Home care Number: Advanced dressings group: n=201 Simple dressings group: n=150	Health Technology assessment model	Not reported	Treatment cost per month (recalculated to cost per day)		-	Simple dressings: €12.53 (€11.70) Advanced dressings: €9.18 (€8.573)
Frantz *et al.* (1991)	US USD November 1, 1983-October 31,1988. (salary of 1988 by adjusting the 1984 salary data)	Long term care residents Number: n=155 (240 PU)	Retrospective descriptive analysis of additional cost of pressure ulcer treatment	PU 1-4 (per PU severity category)	Number of PU, location of PU and corresponding treatments,	-	-	€6.57 ($5.35) Cat. 1: €8.87 ($7.22) Cat. 2: €3.64 ($2.96) Cat. 3: €2.16 ($1.76) Cat. 4: €5.88 ($4.79)

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
					National	*Per Capita*	*Per capita/day*
Frantz *et al.* (1995)	US USD January 1, 1992 – December 31, 1992	Long term care residents. Number: n= 50 (81 PU) Retrospective descriptive analysis of additional cost of pressure ulcer treatment	PU 1-4 (per PU severity category)	Location and number of PU, PU treatment, treatment duration, skill level of nursing personnel, number of days of treatment, frequency of treatment	-	€671.15 ($601.58)	€4.17 ($3.74) Cat. 1: €1.73 ($1.55) Cat. 2: €4.07 ($3.65) Cat. 3: €4.98 ($4.46) Cat. 4: €6.73 ($6.03)
Frantz *et al.* (2001)	US USD September 1, 1996 – August 31, 1997	Long term care residents Number: n= 31 (46 PU) Economic evaluation based on retrospective descriptive analysis	PU 2-4 (facility acquired open PU)	Location and number of PU, PU treatment, treatment duration, skill level of nursing personnel, number of days of treatment, frequency of treatment, use of support surfaces and repositioning	-	€401.85 ($406)	€4.76 ($4.81) Cat. 2: €3.88 ($3.92) Cat. 3: €7.14 ($7.21) Cat. 4: €7.07 ($7.14) Unstageable: €14.57 ($14.72)
Haalboom (1991)	The Netherlands NLG Year not reported	Hospital Number: national Economic evaluation based on modelling	PU 1-2 and PU 3-4	Cost of treatment	€338.07 million (ƒ470 million)	-	Cat. 1 or 2: €95.92 (ƒ133.35) Cat. 3 or 4:

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
						National	*Per Capita*	*Per capita/day*
								€93.11-€125.79 (ƒ129.45-ƒ174.88)
Hale (1990)	UK GBP June 1989	Hospital and community centres Number: n=27 patients with a PU	Economic evaluation of cost of treatment.	Not reported	Estimates of cost of used materials and nurses' time during treatment.	-	-	€106.49 (£ 53.95)
Kumar *et al.*(2004)	US USD 2000 $-values	Hospital, rural health, outpatient hospital, federally qualified health clinic, home care health Number: NR 2683 skin ulcers patients (PU, chronic ulcer, leg ulcer, ulcer of the lower limb)	Top down economic evaluation based on retrospective analysis of claim database	Not reported	Median and mean annual cost of hospital, physician visits and prescriptions per patient. Total annual cost for each of the 5 study period years.	-		1994: €11.67 ($12.28) 1995: €23.15 ($24.36) 1996: €22.38 ($23.55) 1997: €17.96 ($18.90) 1998: €22.77 ($23.96)
Oot-Giromini *et al.* (1989)	US USD	Hospital Number: NR	Economic evaluation based	PU 1-4	Direct costs (labour & material cost)	-	-	€13.34 ($11.96)

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
						National	*Per Capita*	*Per capita/day*
	Year not reported	(random sample)	on a prospective bottom up design					
Rees *et al.* (2007)	US USD 2004-2005	Homebound patients Number: N= 38 (group1: homebound patients with chronic pressure ulcer (n=19) group 2: historical cohort (n= 19)	Economic evaluation based on prospective research and retrospective chart analyses	Not reported (Chronic PU)	Use of service (ED visits, outpatient clinic visits outpatient clinic contact, hospitalisations, LOS, level of outpatient visit acuity and financial costs)	-	Inpatient/2years: €4,185.44-€13,600.95 ($4,852-$15,767) Outpatient/2years: €1,751-€1,248.21 ($2,030-$1,447)	Inpatient: €5.73-€18.60 ($6.65-$213.38) Outpatient: €2.40-€1.71 ($2.78-$1.98)
Schuurman *et al* (2009)	The Netherlands EUR 2001-2004	Hospital Number: n= 84 (Technical approach: n=26 ; Human approach: n= 58)	Bottom- up economic evaluation	PU 1-4 (per PU severity category)	Cost of treatment using technical approach (TA) or human approach (HA) per day; per patient. annual expenditures for the Dutch national health system by extrapolating from previously published national admission	TA: €215.89 million (€178.8 million) HA: €210.70 million (€174.5 million)	Cat. 1: TA: €510.75 (€423) HA: €425.02 (€352) Cat.2: TA: €840.38 (€696) HA: €603.72 (€500) Cat.3: TA: €988.89	Cat. 1: TA: €56.75 (€47) HA: €38.64 (€32) Cat. 2: TA: €70.03 (€58) HA: €60.37 (€50) Cat.3: TA: €76.07 (€63)

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
					National	*Per Capita*	*Per capita/day*
				data and data on prevalence of PU		(€819) HA: €1,487.57 (€1,232) Cat. 4: TA: €1,553.98 (€1,287) HA: €2,079.21 (€1,722)	HA: €106.25 (€88) Cat. 4: TA: €119.54 (€99) HA: €148.52 (€123)
Severens *et al.* (2002)	The Netherlands USD Year not reported	Home care, nursing homes, university and general hospitals. Number: National	Cost of illness	PU 1-4 (per PU severity category)	Volume of care parameters: time investment of personnel, use of medical materials, diagnostic and therapeutic interventions, extended length of home care of institutional care	€334.86 million - €2.59 billion ($362 million -$2.8 billion)	-	Cat. 1 Home Care: €9.37-€15.55 ($10.14-$16.81) Nursing Home: €8.49-€29.74 ($9.18-$32.15) General hospital: €8.45-€10.57 ($9.13-$11.43) University hospital: €57.74-€91.21 ($62.42-$98.60) Cat. 2 Home Care: €75.08-€97.65 ($81.16-$105.56) Nursing Home:

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost)		
						National	*Per Capita*	*Per capita/day*
								€27.54-€63.47 ($29.77-$68.61) General hospital: €28.52-€30.25 ($30.83-$32.70) University hospital: €86.20-€132.57 ($93.19-$143.31) Cat. 3 Home Care: €106.68-€142.68 $115.33-$154.24 Nursing Home: €53.92-€108.98 ($58.29-$117.81) General: hospital: €49.16-€59.68 ($53.14-$64.52) University hospital: €110.01-€174.05 ($118.93-$188.15) Cat. 4 Home Care: €138.27-€190.47 ($149.48-$205.91) Nursing Home:

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	Country Currency Fiscal year of data	Study population/ Number	Study design/ Data sources	PU severity	Type of reported data	Direct costs Converted & inflated cost (original cost) *National*	 *Per Capita*	 *Per capita/day*
								€108.37-€170.43 ($117.15-$184.24) General: hospital: €103.43-€109.71 ($111.81-$118.60) University hospital: €137.68-€209.35 ($148.84-$226.32)
Van den Bos *et al.* (2011)	US USD 2008	In- and outpatients Number: National	Top-down cost study based on actuarial approach trough medical claim data	Not reported	Elements of actuarial analysis: marginal costs, by period of time following the event, adjusted for survival and discounting	€2,615.69 million ($3,273 million)	€6,976.78 ($8,730)	
Xakellis *et al.* *(*1996a)	US USD 1992-1993	Long term care patients followed across multiple health care settings Number: n=30 (45 PU)	Secondary data analyses of study of Frantz 1995: retrospective descriptive analysis of additional cost of pressure ulcer treatment	PU 2-4	Number of PU, location of PU and corresponding treatments,	-	€1,432.48 ($1,284) over 3 months Incl. hospital costs: €5,184.38 ($4,647) over 3 months	-

Table 4 Articles on Cost of Pressure Ulcer treatment

Reference	**Country** **Currency** **Fiscal year of data**	**Study population/** **Number**	**Study design/** **Data sources**	**PU severity**	**Type of reported data**	**Direct costs** Converted & inflated cost (original cost)		
						National	***Per Capita***	***Per capita/day***
Xakellis *et al.* (1996b)	UK and US USD Intervention 1:1960 Intervention 2: 1991	Hospital Number: Intervention 1: n=250 Intervention 2: n=420	CEA DS: identical to Xakellis et al 1995 Cost of treatment from Frantz et al. 1995	Superficial and severe PU	Cost= cost of secondary prevention + treatment Intervention 1: no secondary prevention Intervention 2: prevention by repositioning; mattresses, cushions, heel protectors	-	Intervention 1: €186.31 ($167) Intervention 2: €273.33 ($245) over 12 weeks	-
Xakellis *et al.* (1998)	US USD 1994-1995	Long term care Number: Pre-protocol: n=16 (26 PU) Post-protocol: n=3 (5 PU)	Quasi experimental pre-post-test design. reimbursable charge,	PU 1-4	PU frequency Types of PU treatment Time needed to heel PU cost of treatment	-	Pre-protocol: €502.20 ($487) Post-protocol: €188.43 ($182) over 6 months	-
Xakellis *et al.* (2001)	US USD 1994- 1995 & 1997	Long term care Number: Pre-protocol: n=16 (26 PU) Post-protocol: n=3 (5 PU) 2 Years post-protocol: n=10	Quasi experimental pre-post-test design.	PU 1-4	Cfr. Xakellis 1998	-	Pre protocol: €660.60 ($648) Post protocol: €234.47 ($230) 2 Years post-protocol: €138.57 ($140) over 6 months	-

PU = Pressure Ulcer; Cat. = Category/Grade/Stage

4.3 COST OF PRESSURE ULCER TREATMENT

The main study characteristics and their reported costs of pressure ulcer prevention are outlined in Table 4.

Cost components included in the treatment cost varied widely between studies. The total treatment cost included the cost of materials for dressing changes, nursing time, surgery and debridement, (incremental) length of stay, medication, laboratory tests, radiology, secondary prevention (measures to prevent further deterioration, occurrence or recurrence of pressure ulcers), complications, physician visits, emergency room visits, and clinic contacts. Eight studies included secondary prevention (Bennett et al., 2004; Dealey et al., 2012; Frantz et al., 2001; Haalboom, 1991; Hu et al., 1993; Lyder et al., 2002; Schuurman et al., 2009; Severens et al., 2002), and five studies did not (Agreda et al., 2007; Assadian et al., 2011; Foglia et al., 2012; Hale, 1990; Oot-Giromini et al., 1989). One study reported on the cost of the cost of secondary prevention separate from the treatment cost (Xakellis et al., 1996a), and nine studies partially included cost of secondary prevention (Allman et al., 1999; Alterescu, 1989; Baker, 1996; Berthier et al., 2005; Dzwierzynski et al., 1998; Frantz et al., 1991; Frantz et al., 1995a; Kumar et al., 2004; Van Den Bos et al., 2011). In two studies it was not clear if secondary prevention was included (Beckrich et al., 1999; Van Den Bos et al., 2011).

National annual cost of pressure ulcer treatment

The national annual cost of pressure ulcer treatment was examined in Europe (Agreda et al., 2007; Bennett et al., 2004; Haalboom, 1991; Schuurman et al., 2009; Severens et al., 2002), and in the United States (Beckrich et al., 1999; Van Den Bos et al., 2011). National annual cost to treat all pressure ulcers varied between €334 million and €2.79 billion (Agreda et al., 2007; Bennett et al., 2004; Severens et al., 2002).

Cost of pressure ulcer treatment per patient

The cost of pressure ulcer treatment in hospitals varied between €19.74 for treating a category I pressure ulcer (non-blanchable erythema (NPUAP &

EPUAP, 2009)) without providing secondary prevention up to an average cost of €6,9471.99 for treating a pressure ulcer category IV (Agreda et al., 2007; Allman; Alterescu, 1989; Assadian et al., 2011; Baker, 1996; Beckrich et al., 1999; Berthier et al., 2005; Dzwierzynski et al., 1998; Schuurman et al., 2009). In long term care, costs ranged between €15.10 to treat a category I pressure ulcer without providing secondary prevention and €1,432.48 to treat a pressure ulcer category II-IV (Agreda et al., 2007; Frantz et al., 1995a; Frantz et al., 2001; Xakellis et al., 1996a; Xakellis et al., 2001). The cost of pressure ulcers in home care varied between €125.42 to treat a category I pressure ulcer without providing secondary prevention up to €3,330.69 to treat a category IV ulcer (Agreda et al., 2007).

Cost of pressure ulcer treatment per patient per day

Overall, average cost of pressure ulcer (category I-IV/II-IV) treatment ranged from €2.16 (Alterescu, 1989) to €812.66 per patient per day, including cost of prolonged length of stay (Allman et al. , 1999).

The cost of a category I pressure ulcer varied between €1.73 in long term care without incorporating costs of secondary prevention and €59.84 in hospitalised patients taking into account secondary prevention (Agreda et al., 2007; Bennett et al., 2004; Dealey et al., 2012; Frantz et al., 1991; Frantz et al., 1995a; Frantz et al., 2001; Schuurman et al., 2009; Severens et al., 2002). The cost for treating a category II pressure ulcer ranged between €3.64 in long term care residents and €470.49 in patients and residents with osteomyelitis (Agreda et al., 2007; Bennett et al., 2004; Dealey et al., 2012; Frantz et al., 1991; Frantz et al., 1995a; Frantz et al., 2001; Schuurman et al., 2009; Severens et al., 2002). The cost to treat a category III pressure ulcer varied between €2.16 in long term care patients and €470.49 in patients and residents with osteomyelitis (Agreda et al., 2007; Bennett et al., 2004; Dealey et al., 2012; Frantz et al., 1991; Frantz et al., 1995a; Frantz et al., 2001; Schuurman et al., 2009; Severens et al., 2002). The cost to treat a category IV pressure ulcer ranged from €11.13 in long term care patients to €470.49 in patients and residents with osteomyelitis (Agreda et al.,

2007; Bennett et al., 2004; Dealey et al., 2012; Frantz et al., 1991; Frantz et al., 1995a; Frantz et al., 2001; Schuurman et al., 2009; Severens et al., 2002).

5. DISCUSSION

The aim of this review was to systematically assess and summarise the literature on the economic impact of pressure ulcer prevention and treatment in an adult population. Seven studies addressing cost of pressure ulcer prevention and 16 studies considering cost of pressure ulcer treatment were included. Ten studies included cost data on both, prevention and treatment of pressure ulcers. The most frequently reported cost outcome was the cost per patient per day.

The results were reported in a narrative way because of the methodological heterogeneity of the extracted data. Substantial heterogeneity was found in the health economic designs being used, the included costs, setting, samples, methods for cost calculation, time horizon, economic perspective, and cost outcomes. Besides this substantial methodological heterogeneity, lack of transparency in data reporting hindered the correct interpretation of the data.

5.1 METHODOLOGICAL DISCUSSION

The majority of the studies did not specify the type of health economic design they applied, but used varying terminology for cost evaluation. The type of health economic design can significantly influence the results and thus the conclusions of a study (Larg and Moss, 2011; van Gils et al., 2010). The lack of clear rationale for the health economic designs may have caused the wide variation in included costs and the methods to measure these costs. Studies without a clearly defined health economic design will not be in line with the available methodological guidelines. Further research that examines the economic impact of pressure ulcer prevention or treatment should use the available guide or guidelines corresponding to the chosen health economic design (Larg and Moss, 2011). The use of the available guide can significantly improve the methodological quality, the validity of the results, as well as the transparency of reporting. Besides a generic guide, additional tailored recommendations for

pressure ulcer specific research are needed. These tailored recommendations can enhance (inter)national benchmarking of outcomes by advising on cost components that need to be included and the cost outcomes that need to be reported in pressure ulcer related cost-of-illness studies.

Generally, direct as well as indirect cost need be taken into account in health economic studies (Larg and Moss, 2011; Rice, 1967), but all studies in this review reported only direct medical costs. The economic impact of indirect costs on the total societal expenditures may be marginal for pressure ulcers because the cost of productivity loss due to pressure ulcer development in a mainly elderly population will probably be limited.

In this review, the most reliable variable to compare costs between different countries and settings was the cost per patient per day. This was due to less influencing factors affecting the cost outcomes, compared to the national annual cost or cost per patient. These influencing factors included the number of inhabitants, number or patients at risk, number patients with a pressure ulcer for the national annual cost of pressure ulcers, and included the length of stay, the time horizon, and loss to follow-up for the cost per patient. Furthermore, when providing the cost per patient per day as outcome measure, an average length of stay and/or healing times should be provided.

5.2 COST OF PRESSURE ULCER PREVENTION AND TREATMENT

One day of prevention for a patient or resident at risk costs between €3.26 and €107.45 per day (Haalboom, 1991; Padula et al., 2011; Schuurman et al., 2009; Bennett et al., 2004; Dealey et al., 2012; Bayoumi et al., 2008; Makai et al., 2010; Richardson et al., 1998; Xakellis et al., 1995; Xakellis et al., 1996a; Xakellis et al., 1996b; Xakellis et al., 2001; Xakellis, Jr. et al., 1998). Prevention provided to hospitalised patients (€8.01-€107.45) was more costly than for long term care residents (€3.26-€24.16) and in home care (€9.51-€16.91). One day of pressure ulcer treatment costs between €2.86 to €1,277.82 per patient or resident. These major differences were related to pressure ulcer severity. The

cost to treat a pressure ulcer complicated by cellulitis or osteomyelitis with need for surgical procedures and prolonged hospitalisation will significantly increase the estimated costs (Bennett et al., 2004; Dealey et al., 2012). Besides treatment cost per day, it was important to examine the cost of pressure ulcer treatment until the wound was completely healed, which was provided by the treatment cost per patient (€15.10-€26,706.52). Insight in these costs may help to draw the attention of government and health care institutions to pressure ulcer prevention. Treatment costs were usually provided for one specific healthcare setting (Allman et al., 1999; Alterescu, 1989; Baker, 1996; Beckrich et al., 1999; Berthier et al., 2005; Dzwierzynski et al., 1998; Frantz et al., 1991; Frantz et al., 1995a; Frantz et al., 2001; Oot-Giromini et al., 1989; Schuurman et al., 2009; Xakellis et al., 1996a; Xakellis et al., 2001), but patients or residents may move between healthcare settings during a treatment episode. Moreover, not all patients were followed until complete healing occurred. Therefore the provided cost is probably an underestimation of the real cost of treatment per patient.

5.3 STUDY LIMITATIONS

The majority (n=20) of the studies were published more than ten years ago and therefore may have become less relevant for the current healthcare situation. Treatment, and to a lesser extent prevention of pressure ulcers has evolved and changed over the last ten years (Baranoski and Ayello, 2012; Effraim, 2010). Wound dressings, wound closure methods, and insights on wound healing have changed and possibly even influenced time of healing, number of dressing changes, or nursing time. Furthermore, only direct medical costs were included in the studies. None of the studies included explored the impact of indirect medical costs or direct and indirect non-medical costs.

6. CONCLUSION

Cost of pressure ulcer prevention and treatment differed considerable between studies. The cost to provide pressure ulcer prevention to patients at risk seems to be higher in hospitalised patients compared to patients in home care or nursing homes. Cost of treatment tended to increase with pressure ulcer

severity. Methodological heterogeneity among studies identified the need to use the available, study design specific methodological guidelines to conduct health economic studies, and the need for additional pressure ulcer specific recommendations.

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CHAPTER 6

THE COST OF PREVENTION AND TREATMENT OF PRESSURE ULCERS IN FLANDERS: A COST-OF-ILLNESS STUDY

Based on the article of Demarré L, Verhaeghe S, Van Hecke A, Grypdonck M, Annemans L & Beeckman D. *The cost of prevention and treatment of pressure ulcers in hospitals and nursing homes in Flanders*. Under Review.

ABSTRACT

Introduction: The economic impact of pressure ulcer prevention and treatment is high. The results of cost-of-illness studies can assist the planning, allocation and priority setting of healthcare expenditures to improve the allocation of preventive measures. Data on the cost of current practice of pressure ulcer prevention or treatment in Flanders (Belgium) is lacking.

Aim: To examine the cost of pressure ulcer prevention and treatment in an adult population in hospitals and nursing homes from a mixed perspective.

Design: A cost-of-illness study was performed using a bottom-up approach.

Methods: Data were collected in a series of multicentre cross-sectional studies between 2008 and 2013. Data collection included data on risk assessment, pressure ulcer prevalence, preventive measures, unit cost of materials for prevention and treatment, nursing time measurements for activities related to pressure ulcer prevention and treatment, and nursing wages. The cost of pressure ulcer prevention and treatment in hospitals and nursing homes was calculated as annual cost for Flanders, per patient, and per patient per day.

Results: The cost for pressure ulcer prevention was €7.88 per hospitalised patient at risk per day and €2.15 per nursing home resident at risk per day. The cost of pressure ulcer prevention for patients and residents identified not at risk for pressure ulcer development was €1.44 per day in hospitals and €0.50 per day in nursing homes. The main cost driver was the cost of labour, responsible for 79% to 85% of the cost of prevention. The average cost of local treatment per patient per day varied between €2.34 and €77.36 in hospitals, and between €2.42 and €16.18 in nursing homes.

Conclusions: Related to methodological differences between studies, the cost of pressure ulcer prevention and treatment in hospitals and nursing homes in Flanders was found to be low compared to other international studies. Pressure ulcer specific recommendations as part of methodological guidelines to conduct cost-off-illness studies, are needed. A reliable risk assessment policy and a continuous monitoring of preventive measures to the patients' needs may decrease healthcare expenditures by lowering the costs of pressure ulcer incidence.

1. INTRODUCTION

Pressure ulcers are defined as localised injuries of the skin and/or underlying tissue over a bony prominence due to pressure and shear (NPUAP & EPUAP, 2009). Pressure ulcers are internationally considered as important quality indicators, and most pressure ulcers are avoidable (National Pressure Ulcer Advisory Panel, 2011; Van Den Bos et al., 2011). Besides an impact on the patients' overall well-being, pressure ulcers have a financial implication for society, patients, health care organisations, and insurances (Gorecki et al., 2009; Hopkins et al., 2006; Langemo et al., 2000; National Institute for Clinical Excellence, 2005; Spetz et al., 2013).

A recent systematic review pointed out that the cost of pressure ulcer prevention per patient at risk varied between €2.65 and €87.57 per day. The average cost of pressure ulcer treatment ranged between €1.73 and €812.92 per patient per day (Chapter 5). The majority of the studies were conducted more than a decade ago and the review included cost data collected in North America (US and Canada) and Europe (UK, Spain and The Netherlands) (Chapter 5).

Cost of pressure ulcer prevention and treatment is driven by labour cost, prolonged hospitalisation, pressure ulcer complications, and cost for materials (Dealey et al., 2012; Haalboom, 1991; Schuurman et al., 2009). Several studies indicated the significant weight of the cost of nursing labour compared to the cost of materials (Dealey et al., 2012; Frantz et al., 2001; Xakellis et al., 2001). Nursing times can vary as a result of the methodology used to estimate the duration of these times. This variation in study methodology can significantly influence the estimated total cost. Several studies used subjective time measurements, such as expert opinion or Delphi method, to estimate the duration of nursing activities related to pressure ulcer prevention and treatment (Agreda et al., 2007; Alterescu, 1989; Assadian et al., 2011; Bayoumi et al., 2008; Frantz et al., 1995b; Hale, 1990; Severens et al., 2002). Nursing times measured through direct observation by a researcher were found to result in smaller estimates than when measured using a Delphi method (Boudt, 2013; Burke et al., 2000). When measuring average time spend on an activity related

to pressure ulcer prevention and treatment the method of direct observation is most accurate (Burke et al., 2000). The main limitation of this method is the high cost of direct observation for extended periods, therefore transparently and detailed reported results of such time measurements will enhance the quality of cost-of-illness studies and can be used in future cost-of-illness studies.

The results of cost-of-illness studies can assist policy makers and health care service managers in planning, allocating and prioritising expenditures in order to improve the allocation of preventive measures (Larg and Moss, 2011). Furthermore, insights into the cost-of-illness can emphasize the need for pressure ulcer prevention, thereby improving the quality of care (Moore et al., 2013), diminishing costs for treatment and prolonged hospitalisation.

The implementation of international guidelines in care as usual is not always successful. Inadequate, incomplete or lacking preventive measures were observed in the majority of patients at risk in several studies (Baumgarten et al., 2010; Beeckman et al., 2013; Gunningberg, 2005; van Gaal et al., 2011; Vanderwee et al., 2011). On the other hand, an important part of the patients assessed as not at risk received (some) preventive measures. In Belgian hospitals more than 70% of the patients not at risk received preventive measures (Vanderwee et al., 2011). Most studies have calculated the cost of preventive measures based on models or algorithms of prevention which were created from best practice guidelines or based on findings from the literature (preventive measures under highly standardised conditions) (Chapter 5). In these model-based cost calculations, the cost of prevention in patients not at risk is not included in the total cost and the cost of patients at risk will probably be higher compared to cost calculations based on care as usual (this is the care provided to patients without interference of research/researchers). Model-based cost calculations can be useful to provide insight in the cost of evidence based prevention and/or treatment, but only cost calculations based on usual care can reflect the actual expenditures and economic impact of pressure ulcer prevention and treatment in current practice.

For Flanders (Belgium), no data on the cost of pressure ulcer prevention or treatment are available.

2. AIM

The aim of this study is to calculate the cost of pressure ulcer prevention and treatment in an adult hospitals and nursing homes population using a mixed perspective. This mixed perspective, which specifies the chosen focus of the group bearing the cost, consists of the perspective of the patient, institution, and insurances.

3. METHODOLOGY

3.1 DESIGN

A cost-of-illness study was performed using a bottom-up approach (person-based approach calculating the resources used in individuals receiving pressure ulcer prevention or treatment). A cost-of-illness study was chosen to identify the disease-attributable costs that occur concurrently with pressure ulcer prevention and treatment to assess the total current economic burden of prevention and treatment of this health problem. A bottom-up approach calculating costs by directly tracing resources was used to quantify resource use solely attributable to pressure ulcer prevention and treatment. The cost of medical resource use was based on data from hospitals and nursing homes collected by direct observation.

Data were collected in a series of multicentre cross-sectional studies (Table 1). Data collection was performed between 2008 and 2013.

3.2 DATA SOURCES

An overview of the data collected in hospitals and nursing homes is provided in Table 1.

Hospitals:

Data on risk assessment (Braden scale or presence of a pressure ulcer), pressure ulcer prevalence, and prevention being applied were retrieved from the 2008 Belgian prevalence study (Vanderwee et al., 2011).

The unit cost (per day) of materials for prevention and treatment were collected in a random sample of ten hospitals. To calculate the treatment cost, 78 treatments were observed.

Nursing time measurements were performed for activities related to risk assessment, patient repositioning, the application of materials, local wound treatments (cleansing, use of topical agents, dressing changes), and documentation. A sample size of 15 observations for each activity was pursued (Van Goubergen, 2005). In total, 1717 measurements were performed in 753 patients admitted to a convenience sample of 15 hospitals in Flanders.

The nursing labour cost per second was calculated by multiplying the nursing time of each activity with the nursing wages. The nursing wages were based on the manual for cost-based pricing of hospital interventions of the Belgian Health Care Knowledge Centre (Swartenbroekx, 2012).

Nursing homes

Data on risk assessment (Braden scale or presence of pressure ulcer), pressure ulcer prevalence, and prevention being applied were collected using the European Pressure Ulcer Advisory Panel (EPUAP) minimum dataset and EPUAP methodology to collect the data (Vanderwee et al., 2007a; Vanderwee et al., 2011).

The unit cost (per day) of materials for prevention and treatment were collected in a sample of 20 nursing homes, drawn from the 84 nursing homes of the prevalence study. To calculate the treatment cost, 59 treatments were observed.

Nursing time measurements were performed for similar activities as in hospitals. In total, 1052 measurements were performed in 198 residents admitted to a convenience sample of 20 nursing homes.

3.2 COSTS CALCULATIONS

The total cost of pressure ulcer prevention and pressure ulcer treatment was calculated as annual cost for Flanders, per patient, and per patient per day in hospitals and nursing homes. The formulas used to calculate the cost of pressure ulcer prevention and treatment were provided in Table 2.

All costs were provided in Euro and adjusted to the inflation rate in 2013 based on the health index (FOD Economie and PF Economie, 2014).

3.2 SENSITIVITY ANALYSES

The results of the study are subject to uncertainty, which was handled by a sensitivity analysis. Sensitivity analyses were performed to examine the influence of variance due to device related uncertainties (lifespan of materials; viscoelastic foam as a standard mattress in an organisation).

3.3 ETHICAL CONSIDERATIONS

The study was approved by the Ethics Review Committee of Ghent University Hospital, and the Ethics Review Committees of all participating hospitals and nursing homes (B/67020083249, B/670201213428, B/670201214217, B/670201215256).

Table 1 Overview of the data collected in hospitals and nursing homes in Flanders: type of data, data sources, setting and sample

Type of data	Data source/Reference Hospitals	Data source/Reference Nursing homes	Setting and sample Hospitals		Setting and sample Nursing Homes	
Prevalence data: • Demographic data • Risk assessment (Braden Scale or presence of a pressure ulcer) • Pressure ulcer prevalence category I-IV • Preventive measures in bed and chair[1]	Vanderwee et al. (2011) Data of frequency of risk assessment and skin assessment was adopted from Gunningberg et al. (2011)	Data collected by teams of two observers (including one nurse from the ward being surveyed, and one nurse from a different ward) using the EPUAP minimum dataset Data of frequency of skin assessment adopted from Gunningberg et al. (2011). No further risk assessment was assumed	Hospitals Wards Patients	n=48 n=454 n=11 792	Nursing homes Wards Residents	n=84 n=294 n=8008)

Table 1 Overview of the data collected in hospitals and nursing homes in Flanders: type of data, data sources, setting and sample

Cost of materials
• Pressure ulcer prevention
  ○ mattresses
  ○ cushions
• Local treatment
  ○ dressings
  ○ wound cleaning solutions,
  ○ disinfectants
  ○ sets
  ○ consult of general practitioner
  ○ consult of surgeon
  ○ surgery
  ○ medication
  ○ nutritional supplements
  ○ contact precaution materials
	Hire/purchase prices of preventive devices from resources manager
	Lifespan of the devices: based on information of medical technology companies
	Type and amount of materials used for pressure ulcer treatment: direct observation by researcher
	Prices of materials: pharmacy and the logistics department (adjusted for discounts), if missing official prices from databases of The National Institute for Health and Disability Insurance (NIHDI) were used (downloaded from http://www.riziv.be/drug/nl/)
		Hire/purchase prices of preventive devices from resources manager
		Lifespan of the devices: based on information of medical technology companies
		Type and amount of materials used for pressure ulcer treatment: direct observation by researcher
		Prices of materials: pharmacy and the logistics department (adjusted for discounts), if missing official prices from databases of NIHDI were used (downloaded from http://www.riziv.be/drug/nl/)
			Hospitals
			Wound treatments
				n=10
				n=78
					Nursing homes
					Wound treatments
						n=20
						n=59

Nursing times for activities related to prevention and treatment	Data collected through direct observation by the researcher (LD), using a chronometer	Data collected through direct observation by the researchers (LD, DB, HD), using a chronometer	Hospitals Patients Time measurements	n=15 n=753 n=1717	Nursing homes Residents Time measurements	n=20 n=198 n=1052

Table 1 Overview of the data collected in hospitals and nursing homes in Flanders: type of data, data sources, setting and sample

Labour cost	Cost of nursing wages based manual for cost-based pricing of hospital interventions of the Belgian Health Care Knowledge Centre (Swartenbroekx, 2012)	Cost of the wages provided by the organisations and based on NIHDI	Data retrieved from manual for cost-based pricing of hospital interventions of the Belgian Health Care Knowledge Centre (Swartenbroekx, 2012)	Nursing homes	n=20

[1] Preventive measures in bed and chair: including primary prevention and secondary prevention (measures to prevent further deterioration, occurrence or recurrence of pressure ulcers)

Table 2 Formulas to calculate the cost of pressure ulcer prevention and treatment

Prevention	Hospitals	Nursing homes
Cost of prevention per patient or resident per day	Unit cost devices/day/patient + labour cost prevention/ patient/day[1]	Unit cost devices/resident/day + labour cost prevention/ resident/day[1]
Cost of prevention per patient	Cost/patient/day x 7.57 (the average length of stay in hospitals) [2]	Not applicable (no data on average length of stay in nursing homes available)
Annual cost of prevention	Patient at risk= (% of patients at risk x cost/patient at risk/day x 8.52 million (number of care days per year[3]))	Resident at risk= (% of resident at risk x cost/resident at risk/day x 69 902 (number of residencies[4]) x 365)
	Patient not at risk= (% of patients not at risk x cost/patient not at risk/day x 8.52 million (number of care days per year[3]))	Resident not at risk= (% of resident not at risk x cost/resident not at risk/day x 69 902 (number of residencies[4]) x 365)
Local treatment [5]	Hospitals	Nursing homes
Cost of treatment per patient or resident per day [10]	Unit cost materials/patient/ day + labour cost/patient/ day	Unit cost materials/resident/ day + labour cost/resident/ day
Cost of treatment per patient or resident [10]	PU[6] category I= Cost /patient /day x 7.57 (average length of stay) PU category II-IV= Cost /patient/day x (7.57 (average length of stay[2]) + (4.31 (extra length of stay due to pressure ulcer[5])x €366.85	PU category I= Cost / resident/day x 28 days (healing time PU category I) [9]; PU category II= Cost / resident/day x 94 days (healing time PU category II) [9]; PU category III= Cost / resident/day x 127 days (healing time PU category III) [9]; PU category IV= Cost / resident/day x 155 days (healing time PU

Table 2 Formulas to calculate the cost of pressure ulcer prevention and treatment

Local treatment [5]	Hospitals	Nursing homes
Annual cost of treatment	((% of patients with a PU category I x cost/patient PU category I x 8.52 million (number of care days per year[3])) + (% of patients with a pressure category II x cost/patient PU category II x 8.52 million) + (% of patients with a pressure category III x cost/patient PU category III x 8.52 million) + (% of patients with a pressure category IV x cost/patient PU category IV x 8.52 million (number of care days per year[3]))	((% of residents with a PU category I x cost/resident/day PU category I x 69 902 (number of residencies[4]) x 365) + (% of residents with a PU category II x cost/resident/day PU category II x 69 902 (number of residencies[4]) x 365) + (%of residents with a PU category III x cost/resident/day PU category III x 69 902 (number of residencies[4]) x 365) + (% of residents with a PU category IV x cost/resident/day PU category IV x 69 902 (number of residencies[4]) x 365)

[1]Type, amount and frequency of preventive measures per patient or resident were used from the prevalence data; [2]Average length of stay in hospitals of 7.57 days adopted from Trybou (2011); [3] Number of care days adopted from Flemish Institution for Health Care downloaded from http://www.zorg-en-gezondheid.be/Cijfers/Zorgaanbod-en-verlening/Ziekenhuizen/Bezettingsgraad-en-verblijfsduur-Vlaamse-ziekenhuizen/; [4] Number of residencies adopted from Flemish Institution for Health Care downloaded from http://www.zorg-en-gezondheid.be/programmatiewoonzorgcentra/; [5]Cost of secondary prevention (measures to prevent further deterioration, occurrence or recurrence of pressure ulcers) was provided separately from cost of local treatment to avoid double counting of preventive measures; [6]PU: pressure ulcer; [7] Extra length of stay controlled for comorbidities of 4.31 days adopted from Graves et al. (2011) controlling for comorbidities; [8] Hospitalisation cost per day in a hospital in Flanders was retrieved from the from databases of the National Institute for Health and Disability Insurance (NIHDI) (http://www.riziv.be/); [9]Average healing time per pressure ulcer severity category adopted from Dealey et al. (2012); [10] Calculated per PU severity category I-IV

4. RESULTS

4.1 DEMOGRAPHIC DATA AND PRESSURE ULCER PREVALENCE

In hospitals, 38% (n=4482) of the patients were younger than 70 years, 55% (n=6517) were female, and 29% (n=3453) were at risk. Non-blanchable erythema was present in 6.3% (n=738) of the patients. Pressure ulcer prevalence category II, category III and category IV was respectively 3.6% (n=426), 2.5% (n=294), and 1.6% (n=192).

In nursing homes, 52% (n=4169) of the residents were aged between 80 and 89 years, and 29% (n=2284) was older. Seventy five percent (n=6052) were female, and 37% (n=2993) of the residents were at risk. Non-blanchable erythema was present in 10.5% (n=840) of the nursing home residents. Pressure ulcer prevalence category II, category III and category IV was respectively 2.9% (n=230), 1.9% (n=152), and 1.1% (n=87).

4.2 COST OF PRESSURE ULCER PREVENTION

Hospitals

The average cost of pressure prevention for patients at risk was €7.88 (SD=8.21), consisting of 79% cost for labour and of 21% cost for devices (Table 5). An overview of the nursing times related to activities for prevention and treatment is provided in Table 3. The average cost per activity for repositioning of a bedridden patient was €1.98 and €3.82 for a not-bedridden patient. An overview of the cost of devices for prevention is provided in Table 4. The average cost per day was €4.89 for an alternating device, €0.09 for a viscoelastic foam mattress and €0.05 for a viscoelastic foam cushion.

Some of the patients not at risk received prevention, resulting in an average cost of €1.44 (SD=4.26) per patient per day (Table 5).

The average cost for a patient at risk was €59.65 per hospitalisation, and €10.90 for a patient not at risk.

The annual cost of pressure ulcer prevention in hospitals was €28.34 million, consisting of €19.67 million for patients at risk and €8.67 million for patients not at risk.

Nursing homes

The average cost of pressure prevention for a residents at risk was €2.15 (SD=3.10), consisting of 85% cost for labour and 15% cost for devices (Table 5). The average cost per activity for repositioning of a bedridden resident was €0.86 and €3.44 for a not-bedridden resident (Table 3). The average cost per day was €0.71 for an alternating device, €0.10 for a viscoelastic foam mattress, and €0.04 for a viscoelastic foam cushion (Table 4).

Some of the residents not at risk received preventive measures, resulting in an average cost of €0.50 (SD=1.61) per nursing home resident per day (Table 5).

The annual cost of pressure ulcer prevention in nursing homes was €17.53 million, consisting of €9.54 million for residents at risk and €7.99 million for residents not at risk.

4.3 COST OF PRESSURE ULCER TREATMENT

Table 6 provides an overview of the cost for the local treatment of pressure ulcers and the cost for secondary prevention in hospitals and nursing homes. The results are given for each pressure ulcer category.

Hospitals

The average cost of treatment per patient per day varied between €2.34 (SD=1.14) to treat a category I pressure ulcer up to €77.36 (SD=35.95) to treat a category IV pressure ulcer. The average cost per day for secondary prevention varied between €6.83 (SD=8.16) per patient with a pressure ulcer category I and €10.74 (SD=8.46) per patient with a pressure ulcer category IV.

Table 3 Nursing time and costs related to nursing activities for prevention

Activity	Hospitals			Nursing homes		
	Mean time (s)/activity	Mean cost (€)	% (n) patients receiving the activity	Mean time (s) /activity	Mean cost (€)	% (n) patients receiving the activity
Risk assessment	63.71	0.61	N.A. [1]	106.48	1.03	N.A.[1]
Repositioning in bed (bedridden)	200.28	1.98	4.2 (504)	88.67	0.86	1.2 (101))
Repositioning in bed (not-bedridden)	236.10	2.55	13.7 (1628)	192.93	2.11	9.1 (735)
Repositioning in chair	99.56	0.98	8.8 (1039)	55.88	0.54	9.6 (779)
Registration of repositioning	9.90	0.09	N.A.[2]	1.98	0.02	N.A.[2]
Heel offloading	29.23	0.58	22.9 (2695)	5.23	0.05	13.1 (1053)

[1] Frequency of risk assessment was not included in the data collection. Data of frequency of assessing risk was used from Gunningberg et al. (2011);

[2] Frequency of registration of repositioning was not included in the data collection, a frequency of once per shift was assumed

Table 4 Cost of mattresses and cushions per day based on a variable lifespan

Device	Hospital						Nursing home					
	Mean cost/day (€) for minimum/mean/maximum lifespan						*Mean cost/day (€) for minimum/mean/maximum lifespan*					
	Min. Lifespan (years)	Min. Cost/day Mean (Min, Max)	Mean Lifespan (years)	Mean Cost/day Mean (Min, Max)	Max. Lifespan (years)	Max. Cost/day Mean (Min, Max)	Min. Lifespan (years)	Min. Cost/day Mean (Min, Max)	Mean Lifespan (years)	Mean Cost/day Mean (Min, Max)	Max. Lifespan (years)	Max. Cost/day Mean (Min, Max)
Viscoelastic foam mattress	5	0.13, 0.09-0.17	7	0.09 0.06-0.12	9	0.07 0.05-0.09	5	0.14 0.08-0.24	7	0.10 0.06-0.17	9	0.08 0.05-0.13
Alternating mattress[1]	5	5.11 0.85-16.94	7	4.89 0.16-16.94	9	4.76 0.47-16.94	5	0.87 0.34-3.86	7	0.71 0.24-3.86	9	0.62 0.19-3.86
Static air mattress	1	0.51 0.40-0.67	2	0.25 0.20-0.33	3	0.17 0.13-0.22	1	0.45 0.41-0.50	2	0.22 0.20-0.25	3	0.15 0.13-0.17
Viscoelastic foam cushion	3	0.08 0.03-0.17	5	0.05 0.02-0.10	7	0.04 0.01-0.07	3	0.07 0.04-0.15	5	0.04 0.03-0.09	7	0.03 0.02-0.06
Static air	1	0.50 0.17-1.28	2	0.25 0.09-0.64	3	0.16 .06-0.43	1	0.19 0.14-0.24	2	0.09 0.07-0.12	3	0.06 0.05-0.08
Gel cushion	1	0.45 0.12-0.78	3	0.15 0.04-0.26	5	0.09 0.02-0.16	1	0.45[2] 0.12-0.78	3	0.15[2] 0.04-0.26	5	0.09[2] 0.02-0.16

Table 4 Cost of mattresses and cushions per day based on a variable lifespan

Device	Hospital *Mean cost/day (€) for minimum/mean/maximum lifespan*						Nursing home *Mean cost/day (€) for minimum/mean/maximum lifespan*					
	Min. Lifespan (years)	Min. Cost/day Mean (Min, Max)	Mean Lifespan (years)	Mean Cost/day Mean (Min, Max)	Max. Lifespan (years)	Max. Cost/day Mean (Min, Max)	Min. Lifespan (years)	Min. Cost/day Mean (Min, Max)	Mean Lifespan (years)	Mean Cost/day Mean (Min, Max)	Max. Lifespan (years)	Max. Cost/day Mean (Min, Max)
Heel cushion	3	0.10 0.03-0.27	5	0.06 0.02-0.16	7	0.04 0.02-0.12	3	0.09 0.05-0.13	5	0.05 0.03-0.08	7	0.04 0.02-0.05
Ring cushion	1	0.24 0.08-0.40	2	0.15 0.04-0.26	3	0.05 0.02-0.16	1	0.02	2	0.03	3	0.02

[1] In hospitals 50% of the alternating devices was rented and 50% was purchased, in nursing homes 11% of the alternating devices was rented and 89% was purchased; [2] Missing in nursing homes; data used from the cost of devices in hospitals

Table 5 The cost of pressure ulcer prevention per patient per day in hospitals and nursing homes in Flanders

Cost per patient /day	**Total**	Material	Labour
	€/day (SD)	€/day (SD)	€/day (SD)
Hospitals			
Patient at risk	7.88 (8.21)	1.68 (2.25)	6.21 (7.51)
Patient not at risk	1.44 (4.26)	0.25 (0.85)	1.19 (4.04)
Nursing homes			
Residents at risk	2.15 (3.10)	0.32 (0.30)	1.83 (3.01)
Resident not at risk	0.50 (1.61)	0.10 (0.13)	4.4 (1.58)

The average cost for the local treatment of a pressure ulcer category I summed up to €17.71 per hospitalisation. The average cost to treat a pressure ulcer category II, category III, and category IV summed up to respectively, €1709.54, €1,784.86, and €2,500.16 per hospitalisation (not including the cost of secondary prevention). The annual cost for pressure ulcer treatment was €165.75 million (Table 6).

Nursing homes

The average cost of treatment per resident per day varied between €2.42 (SD=1.15) to treat a category I pressure ulcer up to €16.18 (SD=4.93) to treat a category IV pressure ulcer in nursing homes. The average cost for secondary prevention varied between €2.14 (SD=3.19) up to €3.49 (SD=3.97) per resident per day (Table 6).

The average cost to heal a pressure ulcer category I, category II, category III, and category IV summed up to €67.76, €368.48, €1,276.35, and €2,507.90 (not including the cost of secondary prevention), assuming a healing time of respectively 28, 94, 127, and 155 days (Dealey et al., 2012).

The annual cost for pressure ulcers in nursing homes was €18.80 million, based on 69,902 residencies per year (Table 6).

Overall, this accounts for a cost of pressure ulcer prevention and treatment of €36.13 per inhabitant of Flanders.

4.4 SENSITIVITY ANALYSES

Analysis of uncertainty concerning the lifespan of preventive devices (minimum versus maximum lifespan)

In hospitals, minimum lifespan of preventive devices resulted in 3% higher cost of pressure ulcer prevention per day for a patient at risk compared to the maximum lifespan (€7.80; SD=8.18 - €8.02; SD=8.27), and 6% per day for a patient not at risk (€1.41; SD=4.25) - €1.50; SD=4.29).

In nursing homes, minimum lifespan of preventive devices resulted in 32% higher cost of pressure ulcer prevention per day for a resident at risk compared to maximum lifespan (2.10€; SD=3.08 - 2.78; SD=3.21), and 21% per day for a resident not at risk (0.48€; SD=1.60 - 0.58€; SD=1.66).

Analysis of uncertainty concerning the use of viscoelastic foam mattresses as standard mattress

If a viscoelastic foam mattress was not included in the cost of prevention, the average cost of pressure ulcer prevention reduced with 18% per hospitalised patient at risk per day (€6.49; SD=7.59), and 15% per hospitalised patient not at risk (€1.23; SD=4.07).

In nursing homes, the cost of pressure ulcer prevention reduced with 2% per resident at risk per day (€2.10; SD=3.10), and with 14% per resident not at risk (€0.43; SD=1.61).

5. DISCUSSION

The aim of this study was to examine the cost of pressure ulcer prevention and treatment in an adult hospitals and nursing home population using a mixed perspective. The cost for pressure ulcer prevention is €7.88 per hospitalised patient at risk per day and €2.15 per nursing home resident at risk per day. The cost of pressure ulcer prevention for patients and residents identified not at risk for pressure ulcer development was €1.44 per day in hospitals and €0.50 per day in nursing homes. The main cost driver was the cost of labour, responsible for 79% to 85% of the cost of prevention. The average cost of local treatment per patient per day varied between €2.34 (category I) and €77.36 (category IV) in hospitals, and between €2.42 (category I) and €16.18 (category IV pressure ulcer) in nursing homes.

Table 6 The cost of pressure ulcer treatment per day, per episode, and per year in hospitals and nursing homes in Flanders

Hospitals		**Treatment**			**Secondary prevention**	
Cost per patient/resident	Mean cost (€)/day (SD)	Mean material (€)/day (SD)	Mean labour cost (€)/day (SD)	Mean cost (€)/day (SD)	Mean material cost (€)/day (SD)	Mean labour cost (€)/day (SD)
Category I	2.34 (1.14)	0.47 (0.23)	0.88 (1.49)	6.83 (8.16)	1.46 (2.15)	5.39 (7.54)
Category II	10.81 (4.25)	2.90 (1.14)	7.91 (3.11)	8.86 (8.90)	2.14 (2.36)	6.46 (8.12)
Category III	17.15 (7.33)	7.91 (3.38)	9.24 (3.95)	9.84 (8.78)	2.68 (2.41)	7.16 (7.92)
Category IV	77.36 (35.95)	68.42 (31.79)	8.94 (4.16)	10.74 (8.46)	2.88 (2.39)	7.86 (7.92)
Nursing homes						
Category I	2.42 (1.15)	0.16 (0.07)	2.26 (1.07)	2.14 (3.19)	0.32 (0.30)	1.82 (3.09)
Category II	3.92 (1.33)	1.93 (0.65)	2.00 (0.67)	2.56 (3.14)	0.42 (0.33)	2.14 (3.05)
Category III	10.05 (2.81)	3.73 (1.04)	6.32 (1.77)	3.35 (3.42)	0.55 (0.30)	2.79 (3.32)
Category IV	16.18 (4.93)	9.09 (2.77)	7.08 (2.16)	3.49 (3.97)	0.52 (0.31)	2.97 (3.91)
Hospital	Length of stay	Cost extra length of stay	Mean total cost/episode of care	Pressure ulcer prevalence	Episodes of care/year	Annual cost of treatment [4]
Category I	7.57 days[1]	N.A.	€17.71	6.3%	1,125,370[1]	€1,255,609
Category II	11.88 days[2]	€1,581.12 [3]	€1,709.54	3.6%	1,125,370[1]	€69,259,141
Category III	11.88 days[2]	€1,581.12 [3]	€1,784.86	2.5%	1,125,370[1]	€50,215,697
Category IV	11.88 days[2]	€1,581.12 [3]	€2,500.16	1.6%	1,125,370[1]	€45,017,680
Total cost treatment						€**165,748,128**

Table 6 The cost of pressure ulcer treatment per day, per episode, and per year in hospitals and nursing homes in Flanders

Nursing homes	Healing times	Total cost/episode of care Mean	Pressure ulcer prevalence	Number of residencies	Annual cost of treatment [4]
Category I	28 days [5]	€67.76	10.5%	69,902[1]	€6,483,166
Category II	94 days [5]	€368.48	2.9%	69,902[1]	€2,900,458
Category III	127 days[5]	€1,276.35	1.9%	69,902[1]	€4,871,942
Category IV	155 days [5]	€2,507.90	1.1%	69,902[1]	€4,541,023
Total cost of treatment					€**18,796,589**

[1] Flemish Institution for Health Care; [2]Graves et al. 2005; [3] Dealey et al. 2012; [4]Secundary prevention not included; [5] Cost per extra length of stay: 366.85€/day in a hospital in Flanders (FOD Economie and PF Economie, 2014)

5.1 COST OF PRESSURE ULCER PREVENTION

The cost of pressure ulcer prevention in hospitals and nursing homes was low compared to other studies. A systematic review reported a cost for pressure ulcer prevention per patient at risk per day varying between €5.39 and €87.57 in hospitals, and between €2.65 and €19.69 in nursing homes (Chapter 5). Several reasons may account for this finding. The present study used the cost of preventive measures based on care as usual, whereas calculations the study of Dealey et al (2012), Bayoumi et al (2008), and Bennet et al (2004), and others were based on prevention provided compliant to guidelines (Chapter 5). As a result, the average cost of prevention per patient per day measured in the present study was lower than when prevention compliant to the guidelines was provided. Another reason for the low cost may be related to the collection of time measurements by direct observation. This more accurate method may have lowered the costs of prevention given the high share of labour cost in the total cost.

This study points out that the cost of prevention for patients who are considered not at risk is high. This is partly linked with our decision to include the cost of a viscoelastic foam mattress as an attributable cost related to pressure ulcer prevention. However, we observed that in some hospitals and nursing homes in Belgium, a viscoelastic foam mattress is used as a standard mattress for each patient for comfort purposes. Considering the results of the sensitivity analyses, this was not the main reason for the cost of prevention in patients not at risk.
In the present study, the majority of the patients did not receive the correct preventive measures compliant to the guideline. This was less than needed for patients at risk and more than needed for patient not at risk. A structured risk assessment policy, consisting of accurate and consistent screening as well as continuously monitoring and adaptation of the preventive measures can lead to reducing the health care expenditures related to pressure ulcer prevention. Decreasing pressure ulcer incidence related costs as well as decreasing costs of inadequate and incomplete prevention can generate cost savings. Further

research should focus on the extent of the possible costs savings per averted case.

The study pointed out that the cost of prevention provided to patients perceived not at risk was high (€8.67 million in hospitals and €7.99 million in nursing homes). Device related costs, for example created by late or forgotten removal/relocation of mattresses or cushions in patients that were once at risk but already recovered, can give cause to cost savings. The vast majority of the cost for patients not at risk was labour related. Legitimate reasons for this labour cost in patients perceived as not at risk can be related to the cost of risk assessment in all patients, and to differences in risk assessment method that may have led to the identification of other patients at risk. If activities related to prevention were provided to patients that are not in need of these preventive measures, this labour cost can be seen as an opportunity cost because this nursing time is not available to do other patient activities. Although this may not directly lead to health care savings for institutions and government, due to the nursing shortage a correct allocation of nursing time is needed. Because healthcare resources for pressure ulcer prevention (labour and materials) are limited, attention must be given to use the available resources as efficient as possible.

5.2 COST OF PRESSURE ULCER TREATMENT

Compared to other studies, the cost of pressure ulcer treatment was low. A systematic review reported on a cost of pressure ulcer treatment per patient per day varying between €1.73 and €812.92 (Chapter 5). As for pressure ulcer prevention, data on the type and amount of materials used to treat a pressure ulcer were collected by direct observation, and not based on expert opinion. Also labour time was measured by direct observation, which was found to be an accurate method for measuring the duration of nursing activities (Burke et. al, 2000), but may provide conservative aggregated nursing times because the time related to activities, such as ordering wound dressings, education and training, shift hand-over and patient transport was not included in the total nursing time.

Finally, the observed treatments of pressure ulcers were mainly conservative treatments. Surgical treatments or complications were included, but rarely observed. Medical resource use was based on prevalence data and observed one or two days per hospital. Pressure ulcers category IV or pressure ulcers with severe complications are less common than superficial or non-complicated pressure ulcers, in this study respectively 1.1% - 1.6% for pressure ulcer category IV and 1.9% - 10.5% for pressure ulcers category III or less. Therefore, there may have been an under-observation of these events. Due to the high cost of complications in severe pressure ulcers (Dealey et al., 2012) the cost of local pressure ulcer treatment presented in this study are conservative. Further research needs to include data about medical resource use to treat a category IV pressure ulcer during the full hospitalisation period or until complete healing to provide more accurate cost estimates.

The cost of pressure ulcer treatment per day was remarkably lower in nursing homes compared to hospitals, even when the cost of extra length of stay was not included. The type and materials used to treat a pressure ulcer in nursing homes differed from those used in hospitals. Financial implications for the nursing home resident were known to the nurse providing wound treatment, and often explicitly weighted when treating pressure ulcers in nursing homes. Whereas in hospitals, the costs of materials are less known to the nurse providing the wound treatment. Furthermore the availability of materials was more restricted in nursing homes compared to hospitals. More insight in the cost of materials, such as dressings, sets and cleaning solutions need to be provided to all nurses involved in pressure ulcer treatment to enable them in a conscientious examination of costs and benefits of treatment options.

Another important reason for higher cost of pressure ulcer treatment is that specialised pressure ulcer treatment, such as surgery or re-evaluation of non-healing wounds, is provided in hospitals. Although seldom observed in this study, such a specialised treatment led to higher costs in hospitals, whereas follow-up treatment and monitoring were associated with lower costs. The latter treatment was usually provided in nursing homes.

5.3 LIMITATIONS

Besides the above mentioned underestimation of the cost of severe pressure ulcers and their complications, this study has encompassed several other limitations. No empirical data were available on the percentage of overlay mattresses versus matrass replacements. Therefore the mathematical mean of all alternating devices was used.

Furthermore, no data were available on extra length of stay related to pressure ulcer risk or treatment. It is not clear whether pressure ulcer risk leads to extra length of stay. The current calculations of the cost of pressure ulcer treatment assume no attributable length of stay for patients with a Braden score of 16 or less and patients with a pressure ulcer category I, which may be an underestimation of the true cost. Furthermore, no data were available on the extra length of stay for each separate pressure ulcer category. Therefore, an overall extra length of stay for pressure ulcers category II-IV was used. This may have led to an overestimation of the cost of superficial pressure ulcers (category II-III) and an underestimation of the cost of severe pressure ulcers (category IV).

The percentage of patients in which risk assessment is done, is not known for the Belgian hospital or nursing home population. Gunningberg et al. (2011) reported that 6.0% to 10.7% of the patients in general hospitals, and 60.1% to 60.5% of the patients in a teaching hospital received respectively, a risk assessment and skin assessment (Gunningberg et al., 2011). These percentages were used to calculate the cost for pressure ulcer prevention in hospitals. For nursing homes, the assumption that skin assessment was performed in 6% of the residents was adopted. It is not clear to what extent these figures accurately reflect the risk and skin assessment in care as usual in Flanders.

6. CONCLUSION

The cost for pressure ulcer prevention was €7.88 per hospitalised patient at risk per day and €2.15 per nursing home resident at risk per day. The cost of treatment per hospitalised patient per day varied between €2.34 and €77.36, and between €2.42 and €16.18 in nursing homes residents. The cost of pressure

ulcer prevention and treatment in hospitals and nursing homes in Flanders was found to be low compared to other international studies, mainly due to methodological differences between studies. There is need for pressure ulcer specific recommendations as part of methodological guidelines to conduct cost-off-illness studies. A decrease of health care expenditures may be achieved by implementing a reliable screening policy and a continuous monitoring of preventive measures to the patient's needs by lowering the costs of pressure ulcer incidence.

CONFLICT OF INTEREST

There are no conflicts of interest.

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CHAPTER 7

GENERAL DISCUSSION

The aim of this chapter is to discuss and to reflect on the main findings of this thesis. Following topics will be addressed: key findings, contributions to risk assessment, the relation between pressure ulcer aetiology and preventive measures, and the impact of pressure ulcers on quality of care and budgets. In a separate section, some methodological issues will be addressed. In a final section, recommendations for practice, and further research will be discussed.

1. KEY FINDINGS

1.1 EFFECTIVENESS OF ALTERNATING DEVICES

To compare the effectiveness of several types of alternating devices, two studies were conducted. First an RCT was conducted to compare the effectiveness of multi-stage and one-stage ALPAMs. No significant difference in cumulative pressure ulcer incidence between multi-stage and one-stage ALPAMs was found. Secondly, secondary data analyses on a pooled database were conducted to compare the effectiveness of APAM overlays with multi-stage and one-stage ALPAMs. Fewer pressure ulcers developed on multi-stage ALPAMs compared to APAM overlays, but no difference was found between one-stage ALPAMs and APAM overlays. Time to develop ulcers did not differ by mattress type.

Similar to the study of Nixon et al. (2006a), the results from our study found no differences in effectiveness between APAM overlays and one-stage ALPAMs. A significantly lower pressure ulcer incidence was found in the multi-stage ALPAM group compared to the APAM overlay group (Demarré et al., 2013). This finding was based on non-randomised comparative analyses of patient data from two separate studies. Therefore, prudency is advised in the interpretation of these findings. It is difficult to determine the relative contribution of each of the numerous differences in mattress design that could explain these findings. The hypothesis is that a combination of features of the mattresses was associated with lower pressure ulcer incidences on multi-stage ALPAMs compared to APAM overlays. This combination of features includes lower inner air cell pressures, the use of a sensor which continuously measures weight distribution

and adjusts the pressure in the cells, and the gradual inflation and deflation of the air cells. One feature on itself, working on one specific etiological factor of pressure ulcer development, could not empirically be demonstrated to have a surplus value (Demarré et al., 2012a; Nixon et al., 2006a). An RCT is needed to confirm if multi-stage ALPAMs, including a combination of features and acting on different etiological mechanisms at once, are more effective than APAM overlays.

Although pressure ulcer incidences in our study were in line with the international literature (McInnes et al., 2012), they are still high for adverse events that are considered avoidable. One of the possibilities for further decreasing pressure ulcers is the improvement of prevention of heel pressure ulcers. No pressure or shear is applied to the heel when they are really offloaded. Pressure ulcer prevention provided at the heels differed between study groups. Patients on a one-stage and multi-stage ALPAM had no additional heel offloading. The one-stage ALPAM contained low alternating pressure air cells at the heels, whereas the multi-stage ALPAM included an ultra-low continuous pressure zone at the heels. For the APAM overlay group, a pillow under the legs was used to support the heels. However, in all groups heel pressure ulcers still occurred. Vanderwee et al. (2006) suggested from their findings, comparing heel offloading with a pillow on viscoelastic foam as well as on an APAM overlay, that the support surface underneath influenced the pressure ulcer development at the heels (Vanderwee et al., 2005). When patients pushed away or relocated the pillow under their legs, or if bottoming out of the pillow occurred, the heels touched the support surface underneath. A meta-analysis of Nicosia et al. (2007) found that pressure redistributing mattresses were associated with a lower incidence of heel pressure ulcers compared to a standard mattress, both without heel offloading. Nevertheless, offloading the heels remains the most appropriate and effective way to prevent heel pressure ulcers (Huber et al., 2008), because only then 0mm/Hg can be achieved at the heels. The meta-analyses of 2007 found insufficient evidence that one heel offloading device outperformed another (Nicosia et al., 2007), but a

2009 pooled database study by Heyneman et al. (2009) found that a wedge-shaped cushion was more effective in offloading the heel than a regular pillow (Heyneman et al., 2009). Due to the methodological limitations related to pooled database studies, an RCT is needed to confirm these findings. When using a pillow, continuous attention and efforts must be made to educate both patients and nurses to provide correct heel offloading. Further research should also focus on the development of devices that are simultaneously effective and well tolerated by patients.

1.2 Pressure ulcer risk factors in patients who receive preventive measures

Factors predicting the development of pressure ulcers in hospitalised patients who receive preventive measures were identified using secondary data analyses of the ALPAM study. Non-blanchable erythema, presence of a urogenital disorder, and higher body temperature were associated with the development of pressure ulcers category II-IV. Models identifying predicting factors associated with superficial and severe pressure ulcers need to be prudently interpreted. Due to the low event rate in the sub-analyses, these multivariate models may lack accuracy and power.

There is an evident need to consistently and correctly identify the patients who are at risk to develop pressure ulcers while receiving standardised preventive measures. Methods to identify these patients are essential to provide tailored preventive measures, only to those patients who will benefit from it, and to use the limited health care resources for pressure ulcer prevention (labour and materials) most effectively. Many studies addressed risk assessment methods to predict pressure ulcer development (Beeckman et al., 2013a; Coleman et al., 2013; Balzer et al., 2007; Balzer et al., 2014), but only a few addressed this issue in patients who already receive preventive measures (Manzano et al., 2013; Nixon et al., 2006a). Risk assessment scales, such as the Braden scale, aim to correctly identify patients at risk for pressure ulcer development, but were found to predict the development of pressure ulcers only to some extent

(Schoonhoven et al., 2002). Furthermore, the findings in our study indicated that the lower range of the Braden scale (between 6 and 16) was unable to identify those patients who were at risk of pressure ulcer development while receiving preventive measures. On-going research will hopefully lead to the development of new accurate tools that can be adopted in a clinical setting, to identify patients at risk while receiving preventive measures (Gefen et al., 2013; Aliano et al., 2014). Much is expected from research on the use of ultrasound findings and the measurement of biochemical markers which can be diagnosed from blood or urine samples when tissue is damaged (Gefen et al., 2013; Aliano et al., 2014). Until then, the predictive factors identified in our study can help health care professionals to recognize these patients at risk of developing pressure ulcers even when preventive measures are applied.

1.3 COST OF PRESSURE ULCER PREVENTION AND TREATMENT

In Chapter 5 a systematic review on cost of pressure ulcer prevention and treatment in an adult population was performed, providing a robust overview of the economic impact of pressure ulcer prevention and treatment. The cost of pressure ulcer prevention per patient at risk varied between €2.65 and €87.57 per day. The cost of pressure ulcer treatment ranged from €1.73 to €812.92 per patient per day. The studies encompassed a considerable methodological heterogeneity in terms of the type of health economic design, health economic perspective, the cost components, and the health outcomes. This overview of the available evidence can facilitate benchmarking with future economic evaluations of measures for prevention or treatment of pressure ulcers.

For the first time a study was conducted giving insight in the cost of pressure ulcer prevention and treatment as provided in usual care in Flemish hospitals and nursing homes. The cost of pressure ulcer prevention and treatment in Flanders was examined using a cost-off-illness design with a mixed perspective. In hospitals, a cost for pressure ulcer prevention of €7.88 per patient at risk per day was found. In nursing homes, a cost of €2.15 per resident at risk per day was calculated. The cost of pressure ulcer prevention for patients and residents

perceived not at risk for pressure ulcer development was €1.44 per day in hospitals and €0.50 per day in nursing homes. The main cost driver was found to be the cost of labour, rather than the cost of devices. The average cost of local treatment per patient per day varied from €2.34 (category I) to €77.36 (category IV) in hospitals, and from €2.42 (category I) to €16.18 (category IV pressure ulcer) in nursing homes.

Direct cost of pressure ulcer prevention and treatment depends on the unit cost of resources, type and frequency of complications and cost of labour. Several studies indicated that nursing time cost accounted for a major share in the total cost of pressure ulcer prevention and treatment compared to the resource cost (Richardson et al., 1998; Schuurman et al., 2009; Frantz et al., 1995a; Haalboom, 1991; Schuurman et al., 2009). However, the methodological rigour to report on time measurements is often low. The method used for measuring or estimating nursing time related to pressure ulcer prevention or treatment included a Delphi procedure (Alterescu, 1989; Foglia et al., 2012), questionnaires (Agreda et al., 2007; Hu et al., 1993), interviewing researchers or experts (Makai et al., 2010; Severens et al., 2002), workload measurements (Frantz et al., 1995a; Lyder et al., 2002; Richardson et al., 1998; Xakellis et al., 1995), self-recording by nurses (Schuurman et al., 2009), but was also frequently not reported (Agreda et al., 2007; Assadian et al., 2011; Bayoumi et al., 2008; Bennett et al., 2004; Oot-Giromini et al., 1989). These differences in measurement methods, may have led to varying time estimation results in the cost calculations of pressure ulcer prevention and treatment. In our study, direct observation was used to measure the average time of activities, thereby enhancing the quality of the cost estimates. Direct observation was found to be an accurate method for measuring the duration of nursing activities (Burke et. al, 2000), but may provide conservative aggregated nursing times because the time related to activities, such as ordering wound dressings, education and training, shift hand-over, and patient transport was not included in the total nursing time.

2. CONTRIBUTIONS TO INSIGHTS INTO PRESSURE ULCER RISK ASSESSMENT

Risk assessment aims to accurately and consistently identify patients at risk for pressure ulcer development, and distinguish them from those who are not (Balzer et al., 2013; Defloor and Grypdonck, 2004). None of the existing methods for risk assessment, such as the sole use of risk assessment scales, clinical judgement based on key risk factors, and skin observation, appropriately identify patients at risk. There is no sound evidence supporting the superiority of one risk assessment method over the others (Beeckman et al., 2013a). International guidelines recommend a structured risk assessment procedure combining all of the previously described methods (Beeckman et al., 2013a; NPUAP & EPUAP, 2009). Risk assessment should be performed at the first contact with the patient, and reassessment needs to be undertaken at regular time intervals, tailored to the patients' needs (Beeckman et al., 2013a).

The identification of patients who are still at risk for pressure ulcer development despite receiving prevention did not get much research attention. These 'high risk' patients, however, need preventive measures adjusted to their increased vulnerability. Braden (2012) addressed levels of risk for pressure ulcer development based on the Braden scale risk scores: scores between 15 and 18 would indicate *some* risk, 13 or 14 *moderate* risk, between 10 and 12 *high* risk, and ≤ 9 *very high* risk (Braden, 2012). Evidence to link the results of risk assessment scores to successive preventive measures is, however, lacking (Balzer et al., 2013; NPUAP & EPUAP, 2009). Our study confirmed that the lower range of the Braden scale (between 6 and 16) did not identify the patients who were still at risk to develop a pressure ulcer despite receiving prevention. Therefore, alternative approaches for risk assessment to identify high risk patients are clearly needed. The specific factors identified in this thesis, the presence of non-blanchable erythema, a urogenital disorder, and higher body temperature, can contribute to identify 'high risk' patients, and thus support health care professionals in adapting preventive measures.

As tissue damage can develop in the underlying tissue before visible changes of the skin (Berlowitz and Brienza, 2007; Gefen, 2009), a comprehensive risk

assessment to identify 'high risk' patients, must include the assessment of all (direct and indirect) risk factors and not only those detectable at the level of the skin.

On-going research may lead to the development of new accurate tools identifying patients at risk while receiving preventive measures (Gefen et al., 2013; Aliano et al., 2014). Promising research about ultrasound and biochemical markers may support risk assessment using blood or urine samples to diagnose (invisible) tissue damage (Gefen et al., 2013; Aliano et al., 2014).

Risk assessment can importantly impact health care expenditures. The identification of those patients who will benefit from prevention can lead to a more targeted and effective use of the limited health care resources. The available evidence about predictive factors for pressure ulcer development, complemented with factors emerging from further research, can assist health care professionals to identify 'high risk' patients.

3. PRESSURE ULCER AETIOLOGY AND PREVENTIVE MEASURES

Pressure ulcer aetiology is complex. Several interacting mechanisms result in skin and/or tissue damage. Loerakker et al. (2011) proposed, in a study that focused on the effects of tissue deformation, ischemia, and reperfusion in the development of deep tissue injuries, hypotheses linking aetiological mechanisms with different types of preventive measures (Loerakker et al., 2011). Preventive measures that increase the contact area may prevent damage related to deformation by keeping the internal tissue deformations below the deformation threshold. Patient repositioning and the use of alternating devices may prevent damage related to ischemia and ischemia-reperfusion injury by limiting the period of ischemia (Loerakker et al., 2011). Furthermore, gradual reperfusion of ischemic tissue is reported as a possible method to prevent an ischemic reperfusion injury (Okamoto et al., 1986; Unal et al., 2001).

In this thesis two studies were included that compare the effectiveness of several types of alternating devices. In the first study the effect of an ALPAM with a gradual, multi-stage inflation and deflation cycle was compared to an ALPAM with a one-stage steep inflation and deflation cycle of the air cells. No significant difference in cumulative pressure ulcer incidence was found between patients allocated to a multi-stage ALPAM and patients allocated to a one-stage ALPAM (Demarré et al., 2012a). In a subsequent study, the patient data from the two previously conducted RCTs were pooled (Demarré et al., 2012a; Vanderwee et al., 2005). A significantly lower pressure ulcer incidence on multi-stage ALPAMs compared to APAM overlays, and no difference between APAM overlays and one-stage ALPAMs was found (Demarré et al., 2013). The findings from our study were based on non-randomized comparative analyses on a pooled database. Therefore, prudency is needed in the interpretation of these findings. Our preliminary evidence, suggesting that less pressure ulcers develop on multi-stage ALPAMs compared to APAM-overlays, could not be explained by one specific feature in mattress design. It is difficult to determine the relative contribution of each of the differences between both mattresses and to associate them with possible aetiologic mechanisms. A hypothesis can be proposed that the combination of features may be responsible for our findings. These features consisted of lower inner air cell pressures and the use of a sensor which continuously measures weight distribution and adjusts the pressure in the cells, thus preserving internal tissue deformation below the threshold, and the gradual inflation and deflation of the air cells, thus decreasing damage related to ischemia-reperfusion. One feature by itself, influencing one specific aetiological factor of pressure ulcer development, could not empirically be demonstrated to be clinical effective (Demarré et al., 2012a), but a combination of all these features, acting on different aetiological mechanisms at the same time may explain why multi-stage ALPAMs were associated with a lower pressure ulcer incidence (Demarré et al., 2013).

4. PRESSURE ULCERS: IMPACT ON QUALITY OF CARE AND BUDGETS

The results of this thesis point out the need for more emphasis on pressure ulcer prevention in daily practice. As described above, the implementation of pressure ulcer prevention compliant to guidelines should include a systematic, recurrent risk-assessment on regular time intervals, the allocation of preventive measures compliant to guidelines in patients at risk, as well as intensified prevention in patients at high risk (Vanderwee et al., 2011; Demarré et al., 2012a; Demarré et al., 2012b). Implementation of prevention guidelines and quality improvement can be guided by regular feedback of monitored results. This feedback can encourage health care professionals and can provide follow-up on the improvements in usual care towards best practices. These improvements can significantly influence patient safety and the quality of care (Gunningberg et al., 2012). Pressure ulcer prevalence and incidence figures have been recognised as indicators of quality and safety of healthcare services. Other meaningful indicators of quality of care include the proportion of patients receiving risk assessment and concordance of the preventive measures with the guidelines (Pinkney et al., 2014; Gunningberg et al., 2012). The results of previous research in Flanders (Demarré et al., 2012b; Vanderwee et al., 2011) are in line with the international findings demonstrating that, in a majority of the patients at risk, pressure ulcer prevention is incomplete, inadequate or absent (Gunningberg et al., 2012; Vanderwee et al., 2011).

Improvement can be achieved by further focussing on the implementation of guidelines and by increasing the overall quality of care in health care settings. A multi-facetted and multi-disciplinary approach, consisting of the implementation of ‘care bundles of best practices’, awareness campaigns, staff education, and clinical monitoring and feedback can improve the implementation of guidelines and care protocols (Beeckman et al., 2013a; Beeckman et al., 2013b). Healthcare services can provide in-service and on-the-job training, including direct feedback on risk assessment methods and the level of customised preventive measures to improve guideline and protocol implementation (Beeckman et al., 2013a; Niederhauser et al., 2012; van Gaal et al., 2011).

Quality of care regarding pressure ulcer prevention can be further improved when health care professionals listen and accurately respond to patients' and carers' observations, and when they respond promptly to clear signs that risk factors are present (Beeckman et al., 2011; Pinkney et al., 2014). This prompt response to the patient's needs to provide pressure ulcer prevention compliant to guidelines, may also be influenced by nurses' attitudes and knowledge (Grol & Wensing, 2004). Previous studies in Belgian hospitals and nursing homes found insufficient knowledge concerning pressure ulcer prevention, which may lead to misconceptions about preventive strategies and can result in inadequate prevention (Beeckman et al., 2011; Demarré et al., 2012b). Furthermore, nurses' attitudes towards pressure ulcer prevention were found to significantly predict their compliance with prevention guidelines. Therefore guideline implementation strategies should also focus on improving nurses' knowledge and attitude to effectively increase the application of prevention compliant to guidelines (Beeckman et al., 2011; Demarré et al., 2012b).

The improvement of quality of care regarding pressure ulcer prevention can be guided by the regular measurement of quality indicators. In Belgium, the Federal Council of Nursing Care Quality developed a set of pressure ulcer specific quality indicators for hospitals that need to be monitored at regular time intervals. These quality indicators include both outcome as well as process indicators. For nursing homes, the Flemish Agency for Care and Health developed a frame of reference for quality and safety of healthcare services, also including some pressure ulcer related indicators. These sets of indicators aim to improve quality and safety of care by standardising the development of a minimal well-considered quality policy.

Monitoring of pressure ulcer specific quality indicators is mandatory for Flemish hospitals and nursing homes, but the results are not public nor are they coupled to financial incentives. Rather than prevention (labour and materials), the current Belgian health care services' financing emphasizes reimbursement of treatment of severe pressure ulcers. In contrast to the Belgian situation and the situation in

many other European countries, the treatment of hospital-acquired pressure ulcers is financially penalised in the United States (Gunningberg et al. 2012; NPUAP, 2011). Changes in reimbursement policy and hospital staffing in the United States seem to have increased the awareness hospital-acquired pressure ulcers as a negative patient outcome and may have prompted more systematic risk assessment and a more timely start of preventive measures (Gunningberg et al. 2012). It is not clear to what extent the United States reimbursement policy has led to the allocation of preventive measures to patients not at risk for pressure ulcer development and associated futile costs. Our study on cost of pressure ulcer prevention in Flemish hospitals and nursing homes reported on the extent of the futile costs (of which the avoidance may result in cost savings) and opportunity costs (of which the avoidance may result in a better allocation of resources) related to the pressure ulcer prevention in patients not at risk. Therefore, adopting United States alike reimbursement policies seems not recommended at this time. Other possibilities to increase the awareness can be explored, such as the creation of an edifying award for hospitals, nursing homes and home care organisations with low nosocomial pressure ulcer incidences (for example “skin friendly hospital” by analogy with “baby friendly hospital”).

Further, organisational aspects have been found to significantly influence pressure ulcer incidence (Park et al, 2014). In multivariate-analyses, nurse staffing and nurses turnover rates were found to affect pressure ulcer incidence. Higher turnover negatively affected the quality of patient care and this independently from staffing level. Higher staffing levels were associated with lower pressure ulcer incidences (Park et al., 2014). Investments in sufficient staffing levels and minimization of turnover rates may also influence pressure ulcer incidences.

Cost savings may be achieved when pressure ulcers can be prevented through improved guideline implementation in clinical practice. In our study, the cost of local pressure ulcer treatment in Flanders varied between €2.34 and €77.36 per

patient per day. With an annual cost of 165 million Euro, when costs of prolonged hospitalisation are included, pressure ulcer treatment significantly impact overall health care expenditures in Flanders. Avoiding the development of pressure ulcers and subsequent treatment costs, can be achieved by focussing on pressure ulcer prevention (Beeckman et al., 2013a; van Gaal et al., 2011).

The focus on prevention must also include the re-evaluation at regular intervals of the current preventive measures provided to the patient. This re-evaluation must be based on reassessment of risk including both patients not receiving preventive measures and those who currently do. Some patients identified not at risk receive pressure ulcer preventive measures, creating futile costs. Our cost study found that futile cost for prevention in hospitals and nursing homes in Flanders counted up to 8.67 million Euro. The resources should be used more effectively, because healthcare resources for pressure ulcer prevention (labour and materials) are limited.

5. METHODOLOGICAL ISSUES

5.1 RCTS AND SAMPLE SIZE

Well designed and sufficiently powered RCT-designs are considered the golden standard to determine the most effective intervention, and this also holds true for pressure ulcer preventive measures (The Cochrane Collaboration, 2008). An RCT is characterised by experimentation, control, and randomisation (Polit and Beck, 2008). If randomisation is successful, the effect of experimental treatments, such as multi-stage and one-stage ALPAMs, can be determined without it being influenced by differences in baseline characteristics of the patients (Polit and Beck, 2008). Large-scale RCTs in pressure ulcer prevention are difficult to carry out and very time consuming. In the ALPAM-study 20 months were needed to collect data in five hospitals. Furthermore, the ability to carry out an RCT largely depends on the willingness of the institutions, health care professionals, and patients to participate in the study. The quality of the data collection partly depends on the nurses' dedication to the study when

involved in the inclusion and the follow-up of patients and this quality may diminish with longer periods of data collection. A major problem in conducting these types of RCTs is the low event rate and the subsequent need for large sample sizes. In our ALPAM study two types of pressure ulcer prevention at the heels were provided. Pressure ulcer incidence at the heel site was 1.9% (n=6) on one-stage ALPAMs compared to 1.3% (n=4) on multi-stage ALPAMs. Based on these figures, a sample size of almost eleven thousand patients (α=0.05; β =0.20) is needed to find a significant difference between groups, if a true difference would exists. There is a need for RCTs examining currently used and new devices for heel prevention that are both effective and well tolerated by patients, but the sample sizes needed to compare such preventive measures are enormous.

Another example of the same problem is the need for further research about the implementation of tailored prevention in patients who already receive preventive measures. More attention is needed to perform re-evaluation of care, when standardised prevention is provided. This re-evaluation can be based on predictive factors to identify 'high risk' patients. Signs of changing risk or inadequate prevention must lead to adaptation of the patients' preventive care plan. Studies examining the effectiveness of the implementation protocols will have a limited number of patients eligible for inclusion in the study (i.e. at risk while receiving preventive measures). Therefore, such a study will need to include patients during an extensive period of time to have a sufficiently powered study.

Creative solutions and collaborations will be needed to tackle these problems. International research groups, collaborating in identifying most important research goals, in developing a standardised core-outcome set, and a minimum-dataset can enhance uniformity. This uniformity can improve the methodological quality of original studies as well as contribute to the ability of performing systematic reviews, meta-analyses or pooled database analyses. These pooled database analyses can partly concede to the problem of the need of large

sample size. By pooling data, the sample size can be increased and provide new comparative analyses based on existing data. However, the lack of randomisation remains a major problem and therefore, large-scale RCTs may still be advised to confirm findings.

The current finding that the annual cost of pressure ulcer treatment in Flanders is four times the cost of pressure ulcer prevention, may emphasise the need for more resources to be committed to pressure ulcer prevention research. There is a discrepancy between the relevance of pressure ulcer prevention and the availability of methodologically sound clinical studies focusing on risk assessment and preventive measures (Beeckman et al., 2013a). Original research is preferably funded by grants from independent funding agencies, but rigorously regulated collaboration with medical device industries may also create new opportunities to test innovative technologies in pressure ulcer prevention.

5.2 COMPLEXITY OF RISK FACTOR STUDIES

Findings from studies examining risk factors for pressure ulcer development depend on several methodological factors, including the use of prevalence or incidence data (and time to follow-up), the inclusion of potential risk factors in the model and how they are measured, the outcome, the sample size, and the (variation in) preventive measures. All of these methodological factors influence the risk factors identified to predict pressure ulcer development (Coleman et al., 2013).

In a recent review, Coleman et al. (2013) pointed out the need to include a comprehensive range of key risk factors in multivariate analyses. In a subsequent study, a risk factor minimum dataset was proposed to overcome the range of frequently occurring methodological problems of risk factor studies (Coleman et al., 2014). When using this minimum dataset in further risk factor research, large scale multivariate analyses and meta-analyses will be facilitated (Coleman et al., 2014). When conducting our study on risk factors this minimum dataset was not yet available. Our risk factor study did not include data on the presence of shock or organ failure to examine their association with pressure

ulcer development, as proposed in the minimum dataset (Coleman et al., 2014), but a urogenital disorder was found predictive for pressure ulcer development. None of the baseline characteristics collected in our study could explain the increased risk for patients with a urogenital disorder to develop a pressure ulcer compared to those without. A possible reason for the finding may be that if the presence of urogenital disorders referred to a diagnosis of infection, the presence of urogenital disorders may also be related to shock and/or organ failure. Therefore further risk factor research should include these factors related to shock and organ failure. Furthermore, the minimum dataset defined by Coleman et al. (2014) could be complemented by factors emerging from other and new studies, such as the presence of IAD.

Finally, Coleman's' minimum dataset is developed for risk factor studies including a broad population of patients. Further research would be needed to adapt the current tool to the detection of 'high risk' patients or to develop a similar minimum dataset for patients at 'high risk'. However, conducting this research yielding reliable models of risk factors for the prediction of pressure ulcer development is challenging (Balzer et al., 2013). In our study on risk factors, the low event rate limited the multivariate analyses. The wide confidence intervals of the potentially predictive factors for developing a severe pressure ulcer, and to a lesser extend for superficial pressure ulcers, resulted in a lower reliability of these multivariate models. Therefore, again sufficient sample sizes are needed to ensure the statistical power (Balzer et al., 2013) and the accuracy of the odds ratios (Peduzzi et al., 1995). Further, the preventive measures provided to the 'high risk' patients need to be comparable and standardised in all patients included in a study (Balzer et al., 2013). Therefore, tailored pressure ulcer prevention based on the patient's risk factors would need to be standardised in new prevention protocols to allow comparable and reproducible research.

5.3 PRESSURE ULCER COST STUDIES GUIDELINES

A cost-of-illness design is appropriate to quantify the medical costs caused by an illness or a condition (Hodgson and Meiners, 1982; Larg and Moss, 2011). The majority of studies on cost of pressure ulcer prevention and treatment lack a clear conceptualisation of the study design, or did not include a detailed description of the prevention or treatment (Chapter 5). Furthermore, the costs items included in the total cost of prevention and treatment, and methodology or sources may largely affect the outcome of health economic evaluations (Larg and Moss, 2011; WHO, 2009).

Several guidelines corresponding to several health economic designs are available (Larg and Moss, 2011), although the methodological rigour used to develop these guidelines varied. The use of the currently available guidelines may improve the methodological quality and the validity of the results, as well as the transparency of reporting. Besides generic guidelines, pressure ulcer specific recommendations for health economic designs are needed. These pressure ulcer specific recommendations must include recommendations to enhance quality of data collection as well as quality of data reporting, thereby enhancing (inter)national benchmarking of outcomes.

Pressure ulcer specific recommendations for cost-of-illness studies can advise on costs items that need to be included and how they must be measured, as well as on the cost outcomes and how they must be measured.

The costs included in the study will affect the cost outcome. Cost-of-illness studies, generally take into account both direct and indirect cost (Larg and Moss, 2011; Rice, 1967). The economic impact of indirect costs on the total societal expenditures may be marginal for pressure ulcers because the cost of productivity loss due to pressure ulcer development in a mainly elderly population will probably be limited, but this low impact of indirect costs is not yet examined.

Cost of pressure ulcer prevention and treatment is mainly driven by labour cost, which depends on the methodology used to estimate the duration of these times. Direct time measurements were found to provide more accurate time estimates than other, more subjective measurement methods (Boudt, 2013; Burke et al., 2000). Therefore it is recommended to use data on time measurements retrieved by direct observation with a minimum of 15 observations per activity (Van Goubergen, 2005).

Pressure ulcer specific recommendations for cost-of-illness studies could provide a checklist of mandatory and recommended items and outcomes to report.

Mandatory items could include items such as the population under study, the research aim, the health economic perspective used (with a clear definition), the included cost items to measure the cost of prevention and treatment and how they were measured, and the cost outcomes and how they were compiled. For example, in cost-of-illness studies it is recommended to report the mean costs instead of the median costs. Despite the skewness of the cost distribution, the arithmetic mean is found to be the most informative because it provides information about the cost of prevention and treatment in all patients. This positive skewness is a common issue in health economic research when presenting the cost per patient. Few individuals with high needs tend to use most of the health care resources (Graves et al., 2005; Thompson and Barber, 2000). Health economic studies need to report on the arithmetic mean of costs to enhance benchmarking between study results (Thompson and Barber, 2000).

Recommended items could include separately reporting cost for labour and materials. This would be of surplus value for benchmarking with other countries and between health care services. For example, the remarkably lower cost of pressure ulcer treatment per day in nursing homes compared to hospitals can stimulate critical review of current treatment practices.

6. RECOMMENDATIONS FOR PRACTICE

Emphasis on a structured risk assessment followed by re-evaluation of the provided prevention is needed. Health care professionals need to be informed about their compliance with current prevention guidelines. Furthermore, they need to be aware of the impact of pressure ulcers on the patients' well-being, and be informed on the monetary burden of pressure ulcer treatment for all parties involved. Preventive measures are sometimes provided to those not at risk for pressure ulcer development, creating an unnecessary cost.

Once prevention is provided, signs of changing risk profile or inadequate prevention must lead to an adaptation of the patients' preventive care plan, improving the allocation of the available resources (Demarré et al., 2013; Vanderwee et al., 2011).

Training to enhance nurses' awareness on pressure ulcer prevention must be included in the basic education of nurses. Enhanced awareness on prevention is also needed in daily practice. A multi-facetted and multi-disciplinary approach, in which healthcare services provide in-service and on-the-job training with a clear focus on re-assessment and tailoring of preventive measures, may decrease pressure ulcer development.

One of the most important and recurrent questions of health care practitioners is to which patients which preventive measures should be applied. Several studies reported in this thesis aimed to contribute to answering this question. Our findings suggest that there is preliminary evidence that a multi-stage ALPAM may be more effective in the prevention of pressure ulcers when compared to an APAM overlay. Multi-stage ALPAMs are associated with considerable costs for purchase and maintenance, compared to less costly APAMs. Therefore, prudency is advised in the allocation of these multi-stage ALPAMs.

Besides the focus on cost of preventive measures, enhanced awareness in daily practice of the financial implications involved in pressure ulcer treatment is needed in daily practice. The cost of the materials used for pressure ulcer

treatment needs to be clear and transparently communicated to the nurses providing the wound treatment. Costs of materials, frequency of wound treatment and the patient's comfort need to be more explicitly weighted when treating pressure ulcers to enhance the awareness of the total cost of pressure ulcer treatment for all parties involved.

7. RECOMMENDATIONS FOR FURTHER RESEARCH

Several indications for further research were presented in this thesis, but special attention can be drawn to the following recommendations.

Preliminary evidence suggests that less pressure ulcers develop on multi-stage ALPAMs compared to APAM overlays, but multi-stage ALPAMs bring along considerable costs for purchase and maintenance when compared to less costly APAMs. Cost-effectiveness analyses can provide insight whether the costs related to the purchase and maintenance of these sophisticated devices are warranted by their possible benefits, if conducted along an RCT. Furthermore, RCTs are generally conducted on several wards and hospitals. Therefore, multilevel analyses need to be used to correct possible grouping structures on ward or hospital level.

Currently no risk assessment methods exist or are in use to identify patients at risk for pressure ulcer development while receiving preventive measures. Approaches for risk assessment to identify high risk patients are clearly needed. Further research to develop new, simple, and accurate tools to identify these high risk patients is needed (Gefen et al., 2013; Aliano et al., 2014). Promising research about ultrasound and biochemical markers may support risk assessment, using blood or urine samples to diagnose (invisible) tissue damage (Gefen et al., 2013; Aliano et al., 2014).

In this thesis the cost of pressure ulcer prevention of care as usual in nursing homes and hospitals was reported. The majority of the observed treatments of severe pressure ulcers were conservative treatments and surgical treatments or complications were rarely observed. Medical resource use was based on

prevalence data and observed one or two days per hospital, which may have led to an under-observation of severely complicated pressure ulcers and costly treatments. Further research needs to include data about medical resource use to treat a category IV pressure ulcer during the full hospitalisation period or until complete healing to provide more accurate cost estimates.

The hypothesis that cost savings may be achieved when pressure ulcers can be prevented through improved guideline implementation need to be examined in clinical practice. Further research should provide insight in the cost of pressure ulcer prevention compliant to guidelines and the cost per averted pressure ulcer.

REFERENCE LIST

Ackaert,S., Annemans,L., De Smedt,D., Grietens,H., Simoens,S., 2010. Modelontwikkeling voor de economische evaluatie van welzijns- en gezondheidsprojecten. In: Acco Leuven, Leuven, pp. 5-128.

Agreda,J.J.S., Bou,J.E.T.I., Posnett,J., Soriano,J.V., Miguel,L.S., Santos,M.M., 2007. The burden of pressure ulcers in Spain. Wounds-A Compendium of Clinical Research and Practice 19 (7), 201-206.

Aliano,K., Low,C., Stavrides,S., Luchs,J., Davenport,T., 2014. The correlation between ultrasound findings and clinical assessment of pressure-related ulcers: is the extent of injury greater than what is predicted? Surgical Technology International 24 , 112-116.

Allman,R.M., 1998. The impact of pressure ulcers on health care costs and mortality. Advances in Wound Care 11 (3 Suppl), 2-Jun.

Allman,R.M., Goode,P.S., Burst,N., Bartolucci,A.A., Thomas,D.R.,1999. Pressure ulcers, hospital complications, and disease severity: impact on hospital costs and length of stay. Advances in Wound Care 12 (1), 22-30.

Allman,R.M., Goode,P.S., Patrick,M.M., Burst,N., Bartolucci,A.A., 1995. Pressure ulcer risk factors among hospitalized patients with activity limitation. Journal of the American Medical Association 273 (11), 865-870.

Allman,R.M., Keruly,J.C., Smith,C.R., 1987. Cost effectiveness of air-fluidized beds versus conventional therapy for pressure sores. Clinical Research 35 , A728.

Alterescu,V., 1989. The financial costs of inpatient pressure ulcers to an acute care facility. Decubitus 2 (3), 14-23.

Ankrom,M.A., Bennett,R.G., Sprigle,S., Langemo,D., Black,J.M., Berlowitz,D.R., Lyder,C.H., 2005. Pressure-related deep tissue injury under intact skin and the current pressure ulcer staging systems. Advances in Skin & Wound Care 18 (1), 35-42.

Annemans,L., 2008. Health economics for non-economists. An introduction to the concepts, methods and pitfalls of health economic evaluations. In: Academia Press, Gent, pp. 1-106.

Antokal,S., Brienza,S., Bryan,N., Herbe,L., Logan,S., Maguire,J., Strang,K., Vanbruaene,M., Van Ranst,J., Siddiqui,A., 2012. Friction Induced Skin

Injuries - Are They Pressure ulcers? A National Pressure Advisory Panel White Paper. In: National Pressure Ulcer Advisory Panel, pp. 1-2.

Arokoski,J.P., Surakka,J., Ojala,T., Kolari,P., Jurvelin,J.S., 2005. Feasibility of the use of a novel soft tissue stiffness meter. Physiol Meas. 26 (3), 215-228.

Assadian,O., Oswald,J.S., Leisten,R., Hinz,P., Daeschlein,G., Kramer,A., 2011. Management of leg and pressure ulcer in hospitalized patients: direct costs are lower than expected. GMS Krankenhaushygiene interdisziplinar 6 (1), Doc07.

Baker,J., 1996. Medicaid claims history of Florida long-term care facility residents hospitalized for pressure ulcers. Journal of Wound, Ostomy, & Continence Nursing 23 (1), 23-25.

Balzer,K., Kopke,S., Luhmann,D., Haastert,B., Kottner,J., Meyer,G., 2013. Designing trials for pressure ulcer risk assessment research: methodological challenges. International Journal of Nursing Studies 50 (8), 1136-1150.

Balzer,K., Kremer,L., Junghans,A., Halfens,R.J., Dassen,T., Kottner,J., 2014. What patient characteristics guide nurses' clinical judgement on pressure ulcer risk? A mixed methods study. International Journal of Nursing Studies 51 (5), 703-716.

Balzer,K., Pohl,C., Dassen,T., Halfens,R., 2007. The Norton, Waterlow, Braden, and Care Dependency Scales: comparing their validity when identifying patients' pressure sore risk. Journal of Wound Ostomy and Continence Nursing 34 (4), 389-398.

Baranoski,S., Ayello,E.A., 2012. Wound dressings: an evolving art and science. Advances in Skin & Wound Care 25 (2), 87-92.

Bates-Jensen,B.M., McCreath,H.E., Kono,A., Apeles,N.C., Alessi,C., 2007. Subepidermal moisture predicts erythema and stage 1 pressure ulcers in nursing home residents: a pilot study. J Am. Geriatr. Soc. 55 (8), 1199-1205.

Baumgarten,M., Margolis,D., Orwig,D., Hawkes,W., Rich,S., Langenberg,P., Shardell,M., Palmer,M.H., McArdle,P., Sterling,R., Jones,P.S., Magaziner,J., 2010. Use of Pressure-Redistributing Support Surfaces Among Elderly Hip Fracture Patients Across the Continuum of Care: Adherence to Pressure Ulcer Prevention Guidelines. The Gerontologist 50 (2), 253-262.

Baxter,H., Baxter,H., 2000. A comparison of two hydrocolloid sheet dressings. Br. J. Community Nurs. 5 (11), 572-577.

Bayoumi,A., John,B.A., Chen,M.H., Chen,W., Farahati,F., Krahn,M., Machado,M., Pham,B., Sander,B., Stern,A., Thein,H.H., Wodchis,W., Woo,G., Carcone,S., Sikich,N., Gomes,T., Sibbald,G., Norton,L., Kozell,K., Englesakis,M., 2008. The cost-effectiveness of prevention strategies for pressure ulcers in long-term care homes in Ontario: projections of the Ontario pressure ulcer model. NHS. Economic Evaluation Database.

Beckrich,K., Aronovitch,S.A., Beckrich,K., Aronovitch,S.A., 1999. Hospital-acquired pressure ulcers: a comparison of costs in medical vs. surgical patients. Nursing Economics 17 (5), 263-271.

Beeckman,D., Matheï,C., Van Lancker,A., Van Houdt,S., Vanwalleghem,G., Gryson,L., Heyman,H., Thyse,C., Stordeur,S., Van den Heede,K., 2013a. Een nationale richtlijn voor Decubituspreventie. Good Clinical Practice (GCP). In: Brussel: Federaal Kenniscentrum voor de Gezondheidszorg (KCE).

Beeckman,D., Clays,E., Van,H.A., Vanderwee,K., Schoonhoven,L., Verhaeghe,S., 2013b. A multi-faceted tailored strategy to implement an electronic clinical decision support system for pressure ulcer prevention in nursing homes: a two-armed randomized controlled trial. Int. J Nurs Stud. 50 (4), 475-486.

Beeckman,D., Defloor,T., Schoonhoven,L., Vanderwee,K., 2011. Knowledge and attitudes of nurses on pressure ulcer prevention: a cross-sectional multicenter study in Belgian hospitals. Worldviews Evid. Based Nurs 8 (3), 166-176.

Beeckman,D., Schoonhoven,L., Boucque,H., Van,M.G., Defloor,T., 2008. Pressure ulcers: e-learning to improve classification by nurses and nursing students. Journal of Clinical Nursing 17 (13), 1697-1707.

Beeckman,D., Schoonhoven,L., Fletcher,J., Furtado,K., Gunningberg,L., Heyman,H., Lindholm,C., Paquay,L., Verdu,J., Defloor,T., 2007. EPUAP classification system for pressure ulcers: European reliability study. Journal of Advanced Nursing 60 (6), 682-691.

Beeckman,D., Schoonhoven,L., Fletcher,J., Furtado,K., Heyman,H., Paquay,L., Defloor,T., 2010. Pressure ulcers and incontinence-associated dermatitis: effectiveness of the Pressure Ulcer Classification education tool on classification by nurses. Quality & Safety in Health Care 19 (5), e3.

Beeckman, D., Schoonhoven, L., Verhaeghe, S., Heyneman, A., & Defloor, T., 2009. Prevention and treatment of incontinence-associated dermatitis: literature review. Journal of Advanced Nursing, *65,* 1141-1154. doi:10.1111/j.1365-2648.2009.04986.x

Bennett,G., Dealey,C., Posnett,J., 2004. The cost of pressure ulcers in the UK. Age and Ageing 33 (3), 230-235.

Bergstrom,N., Braden,B., Kemp,M., Champagne,M., Ruby,E., 1998. Predicting pressure ulcer risk: a multisite study of the predictive validity of the Braden Scale. Nursing Research 47 (5), 261-269.

Bergstrom,N., Braden,B.J., Laguzza,A., Holman,V., 1987. The Braden Scale for Predicting Pressure Sore Risk. Nurs. Res. 36 (4), 205-210.

Berlowitz,D.R., Wilking,S.V., 1990. The short-term outcome of pressure sores. J Am. Geriatr. Soc. 38 (7), 748-752.

Berlowitz, D. R., & Brienza, D. M. (2007). Are all pressure ulcers the result of deep tissue injury? A review of the literature. *Ostomy and Wound Management, 53,* 34-38.

Berthier,F., Daideri,G., Gendreike,Y., Brocker,P., Quaranta,J.-F., Staccini,P., 2005. Influence of the quality of CMA coding on the valorisation of a hospital's activity - An example about pressure ulcers. Journal d'Economie Medicale 23 (2), 73-81.

Black, J. M. (2005). Moving toward consensus on deep tissue injury and pressure ulcer staging. *Advances in Skin & Wound Care, 18,* 415-1. doi:10.1097/00129334-200510000-00008

Bosboom,E.M., Bouten,C.V., Oomens,C.W., van Straaten,H.W., Baaijens,F.P., Kuipers,H., 2001. Quantification and localisation of damage in rat muscles after controlled loading; a new approach to study the aetiology of pressure sores. Medical Engineering & Physics 23 (3), 195-200.

Boudt,D., 2013. Preventie van decubitus: de kost van de huidige preventieve maatregelen in Vlaamse ziekenhuizen. In: Universiteit Gent, Gent.

Bouten,C., Oomens,C., Colin,D., Bader,D., 2005. The Aetiology of Pressure Ulcers: A Hierarchical Approach. In: Bader,D., Bouten,C., Colin,D., Oomens,C.W. (Eds.), Pressure Ulcer Research. Current and Future Perspectives. Springer, Heidelberg, pp. 1-9.

Bouten,C.V., Oomens,C.W., Baaijens,F.P., Bader,D.L., 2003. The etiology of pressure ulcers: skin deep or muscle bound? Archives of Physical Medicine and Rehabilitation 84 (4), 616-619.

Braden,B.J., 2012. The Braden Scale for Predicting Pressure Sore Risk: reflections after 25 years. Adv Skin Wound Care 25 (2), 61.

Braden,B., Bergstrom,N., 1987. A conceptual schema for the study of the etiology of pressure sores. Rehabilitation Nursing 12 (1), 8-12.

Braden,B.J., Bergstrom,N., 1989. Clinical utility of the Braden scale for Predicting Pressure Sore Risk. Decubitus 2 (3), 44-1.

Braden,B.J., Bergstrom,N., 1994. Predictive validity of the Braden Scale for pressure sore risk in a nursing home population. Research in Nursing and Health 17 (6), 459-470.

Brandeis,G.H., Ooi,W.L., Hossain,M., Morris,J.N., Lipsitz,L.A., 1994. A longitudinal study of risk factors associated with the formation of pressure ulcers in nursing homes. J Am. Geriatr. Soc. 42 (4), 388-393.

Brown,G., 2003. Long-term outcomes of full-thickness pressure ulcers: healing and mortality. Ostomy Wound Manage. 49 (10), 42-50.

Burke,T.A., McKee,J.R., Wilson,H.C., Donahue,R.M., Batenhorst,A.S., Pathak,D.S., 2000. A comparison of time-and-motion and self-reporting methods of work measurement. J Nurs Adm 30 (3), 118-125.

Byford, S., Raftery, J., 1998. Economics notes. Perspectives in economic evaluation. British Medical Journal 316, 1529

Cavicchioli,A., Carella,G., 2007. Clinical effectiveness of a low-tech versus high-tech pressure-redistributing mattress. Journal of Wound Care 16 (7), 285-289.

Ceelen,K.K., Stekelenburg,A., Loerakker,S., Strijkers,G.J., Bader,D.L., Nicolay,K., Baaijens,F.P.T., Oomens,C.W.J., 2008. Compression-induced damage and internal tissue strains are related. Journal of Biomechanics 41 (16), 3399-3404.

Chan,B., Ieraci,L., Mitsakakis,N., Pham,B., Krahn,M., 2013. Net costs of hospital-acquired and pre-admission PUs among older people hospitalised in Ontario. J Wound Care 22 (7), 341-346.

Cleemput,I., Van Wilder,P., Vrijens,F., Huybrechts,M., Ramaekers,D., 2008. Guidelines for Pharmacoeconomic Evaluations in Belgium. Health Technology Assessment (HTA). Brussels: Health Care Knowledge Centre (KCE). KCE Reports 78C (D/2008/10.273/27) https://kce.fgov.be/sites/default/files/page_documents/d20081027327.pdf, Brussel.

Coleman,S., Gorecki,C., Nelson,E.A., Closs,S.J., Defloor,T., Halfens,R., Farrin,A., Brown,J., Schoonhoven,L., Nixon,J., 2013. Patient risk factors for pressure ulcer development: Systematic review. International Journal of Nursing Studies 50(7):974-1003. doi: 10.1016/j.ijnurstu.2012.11.019

Coleman,S., Nixon,J., Keen,J., Wilson,L., McGinnis,E., Dealey,C., Stubbs,N., Farrin,A., Dowding,D., Schols,J.M., Cuddigan,J., Berlowitz,D., Jude,E., Vowden,P., Schoonhoven,L., Bader,D.L., Gefen,A., Oomens,C.W., Nelson,E.A., 2014. A new pressure ulcer conceptual framework. Journal of Advanced Nursing. doi: 10.1111/jan.12405

Compton,F., Hoffmann,F., Hortig,T., Strauss,M., Frey,J., Zidek,W., Schafer,J.H., 2008. Pressure ulcer predictors in ICU patients: nursing skin assessment versus objective parameters. Journal of Wound Care 17 (10), 417-4.

Dagenais,S., Caro,J., Haldeman,S., 2008. A systematic review of low back pain cost of illness studies in the United States and internationally. Spine Journal 8 (1), 8-20.

Daniel,R.K., Priest,D.L., Wheatley,D.C., 1981. Etiologic factors in pressure sores: an experimental model. Archives of Physical Medicine and Rehabilitation 62 (10), 492-498.

Dealey,C., Lindholm,C., 2006. Pressure Ulcer Classification. In: Romanelli,M., Clark,M., Cherry,G., Colin, Defloor,T. (Eds.), Science and Practice of Pressure Ulcer Management. Springer, London, pp. 37-41.

Dealey,C., Posnett,J., Walker,A., 2012. The cost of pressure ulcers in the United Kingdom. Journal of Wound Care 21 (6), 261- 261-2, 264, 266.

Defloor,T., 1999. The risk of pressure sores: a conceptual scheme. Journal of Clinical Nursing 8 (2), 206-216.

Defloor,T., 2000. The effect of position and mattress on interface pressure. Applied Nursing Research 13 (1), 2-11.

Defloor,T., De Bacquer,D., Grypdonck,M.H., 2005a. The effect of various combinations of turning and pressure reducing devices on the incidence of pressure ulcers. International Journal of Nursing Studies 42 (1), 37-46.

Defloor,T., Grypdonck,M.F., 2004. Validation of pressure ulcer risk assessment scales: a critique. Journal of Advanced Nursing 48 (6), 613-621.

Defloor,T., Grypdonck,M.H., 1999. Sitting posture and prevention of pressure ulcers. Applied Nursing Research 12 (3), 136-142.

Defloor,T., Schoonhoven,L., Fletcher,J., Furtado,K., Heyman,H., Lubbers,M., Witherow,A., Bale,S., Bellingeri,A., Cherry,G., Clark,M., Colin,D., Dassen,T., Dealey,C., Gulacsi,L., Haalboom,J., Halfens,R., Hietanen,H., Lindholm,C., Moore,Z., Romanelli,M., Soriano,J.V., 2005b. Statement of the European Pressure Ulcer Advisory Panel--pressure ulcer classification: differentiation between pressure ulcers and moisture

lesions. Journal of Wound Ostomy and Continence Nursing 32 (5), 302-306.

Defloor,T., Schoonhoven,L., Katrien,V., Weststrate,J., Myny,D., 2006. Reliability of the European Pressure Ulcer Advisory Panel classification system. J Adv Nurs 54 (2), 189-198.

Defloor,T., Van den Bossche,K., Derre,B., Feyaerts,S., Grypdonck,M., 2004. Belgische richtlijnen voor decubituspreventie. In: Federaal ministerie van Sociale Zaken, Volksgezondheid en Leefmilieu, Brussels.

Demarré,L., Beeckman,D., Vanderwee,K., Defloor,T., Grypdonck,M., Verhaeghe,S., 2012a. Multi-stage versus single-stage inflation and deflation cycle for alternating low pressure air mattresses to prevent pressure ulcers in hospitalised patients: A randomised-controlled clinical trial. International Journal of Nursing Studies 49 (4), 416-426.

Demarré,L., Vanderwee,K., Defloor,T., Verhaeghe,S., Schoonhoven,L., Beeckman,D., 2012b. Pressure ulcers: knowledge and attitude of nurses and nursing assistants in Belgian nursing homes. Journal of Clinical Nursing 21 (9-10), 1425-1434.

Demarré,L., Verhaeghe,S., Van Hecke,A., Grypdonck,M., Clays,E., Vanderwee,K., Beeckman,D., 2013. The effectiveness of three types of alternating pressure air mattresses in the prevention of pressure ulcers in Belgian hospitals. Res. Nurs Health 36 (5), 439-452.

Dzwierzynski,W.W., Spitz,K., Hartz,A., Guse,G., Larson,D.L., 1998. Improvement in resource utilization after development of a clinical pathway for patients with pressure ulcers. Plastic and reconstructive surgery 102 (6), 2006-2011.

Effraim,J., 2010. Assessment and Management of Pressure Ulcers in the Elderly. Drugs & Aging 27 (4), 311-325.

European Pressure Ulcer Advisory Panel, 1999. Guidelines on treatment of pressure ulcers. EPUAP Review 1 , 31-33.

Evers,S., Goossens,M., de,V.H., van,T.M., Ament,A., 2005. Criteria list for assessment of methodological quality of economic evaluations:

Consensus on Health Economic Criteria. Int. J Technol. Assess. Health Care 21 (2), 240-245.

FOD Economie, PF Economie, 2014. De Gezonheidsindex. Historiek van 1994 tot heden. l'Idice santé. Historique de 1994 a nos jours. In: Brussels (last downloaded from http://statbel.fgov.be/nl/modules/publications/statistiques/economie/prijzen__consumptieprijsindex_vanaf_1920_en_gezondheidsindex_vanaf_1994.jsp on December 2013).

Foglia,E., Restelli,U., Napoletano,A.M., Coclite,D., Porazzi,E., Bonfanti,M., Croce,D., 2012. Pressure ulcers management: an economic evaluation. Journal of Preventive Medicine & Hygiene 53 (1), 30-36.

Frantz,R.A., Bergquist,S., Specht,J., F., 1995a. The cost of treating pressure ulcers following implementation of a research-based skin care protocol in a long-term care facility. Advances in Wound Care 8 (1), 36-45.

Frantz,R.A., Gardner,S., Harvey,P., Specht,J., F., 1991. The cost of treating pressure ulcers in a long-term care facility. Decubitus 4 (3), 37-38.

Frantz,R.A., Gardner,S., Harvey,P., Specht,J., 1995b. The cost of treating pressure ulcers in a long-term care facility. Decubitus 4 (3), 37-38.

Frantz,R.A., Gardner,S., Specht,J.K., McIntire,G., 2001. Integration of pressure ulcer treatment protocol into practice: clinical outcomes and care environment attributes. Outcomes Management for Nursing Practice 5 (3), 112-120.

Gawlitta,D., Li,W., Oomens,C.W., Baaijens,F.P., Bader,D.L., Bouten,C.V., 2007a. The relative contributions of compression and hypoxia to development of muscle tissue damage: an in vitro study. Annals of Biomedical Engeneering 35 (2), 273-284.

Gawlitta,D., Oomens,C.W., Bader,D.L., Baaijens,F.P., Bouten,C.V., 2007b. Temporal differences in the influence of ischemic factors and deformation on the metabolism of engineered skeletal muscle. Journal of Applied Physiology 103 (2), 464-473.

Gebhardt,K.S., Gebhardt,K.S., 2003. Cost-effective management of pressure-relieving equipment in a large teaching trust. Journal of Tissue Viability 13 (2), 74-77.

Gefen,A., 2007. The biomechanics of sitting-acquired pressure ulcers in patients with spinal cord injury or lesions. International Wound Journal 4 (3), 222-231.

Gefen, A., 2009. Reswick and Rogers pressure-time curve for pressure ulcer risk. Part 1. Nursing Standard*, 23,* 64-74.

Gefen,A., 2010. The biomechanics of heel ulcers. Journal of Tissue Viability 19 (4), 124-131.

Gefen,A., Farid,K.J., Shaywitz,I., 2013. A review of deep tissue injury development, detection, and prevention: shear savvy. Ostomy Wound Management 59 (2), 26-35.

Gefen,A., Gefen,N., Linder-Ganz,E., Margulies,S.S., 2005. In vivo muscle stiffening under bone compression promotes deep pressure sores. Journal of Biomechanical Engeneering 127 (3), 512-524.

Gefen,A., van,N.B., Bader,D.L., Oomens,C.W., 2008. Strain-time cell-death threshold for skeletal muscle in a tissue-engineered model system for deep tissue injury. Journal of Biomechanics 41 (9), 2003-2012.

Gorecki,C., Brown,J.M., Nelson,E.A., Briggs,M., Schoonhoven,L., Dealey,C., Defloor,T., Nixon,J., 2009. Impact of pressure ulcers on quality of life in older patients: a systematic review. Journal of the American Geriatrics Society 57 (7), 1175-1183.

Gorecki,C., Closs,S.J., Nixon,J., Briggs,M., 2011. Patient-reported pressure ulcer pain: a mixed-methods systematic review. Journal of Pain and Symptom Management 42 (3), 443-459.

Graves,N., Birrell,F., Whitby,M., 2005. Effect of pressure ulcers on length of hospital stay. Infection Control and Hospital Epidemiology 26 (3), 293-297.

Gray,M., Beeckman,D., Bliss,D.Z., Fader,M., Logan,S., Junkin,J., Selekof,J., Doughty,D., Kurz,P., 2012. Incontinence-associated dermatitis: a

comprehensive review and update. Journal of Wound Ostomy and Continence Nursing 39 (1), 61-74.

Gray,M., Bliss,D.Z., Doughty,D.B., Ermer-Seltun,J., Kennedy-Evans,K.L., Palmer,M.H., 2007. Incontinence-associated dermatitis: a consensus. Journal of Wound Ostomy and Continence Nursing 34 (1), 45-54.

Gunningberg,L., 2004. Risk, prevalence and prevention of pressure ulcers in three Swedish healthcare settings. Journal of Wound Care 13 (7), 286-290.

Gunningberg,L., 2005. Are patients with or at risk of pressure ulcers allocated appropriate prevention measures? International Journal of Nursing Practice 11 (2), 58-67.

Gunningberg,L., Donaldson,N., Aydin,C., Idvall,E., 2012. Exploring variation in pressure ulcer prevalence in Sweden and the USA: benchmarking in action. Journal of Evaluation in Clinical Practice 18 (4), 904-910.

Gunningberg,L., Stotts,N.A., 2008. Tracking quality over time: what do pressure ulcer data show? International Journal for Quality in Health Care 20 (4), 246-253.

Haalboom,J.R., 1991. [The costs of decubitus]. [Dutch]. Nederlands Tijdschrift voor Geneeskunde 135 (14), 606-610.

Hagisawa,S., Shimada,T., 2005. Skin Morphology and Its Mechanical Properties Associated with Loading. In: Bader,D., Bouten,C., Colin,D., Oomens,C. (Eds.), Pressure Ulcer Research. Current and Future Perspectives. Springer-Verlag Berlin, pp. 161-185.

Hale,C., 1990. Pressure sores: assessing the cost. Nursing Times 86 (25), 66-71.

Halfens,R.J., Bours,G.J., Van Ast,W., 2001. Relevance of the diagnosis 'stage 1 pressure ulcer': an empirical study of the clinical course of stage 1 ulcers in acute care and long-term care hospital populations. Journal of Clinical Nursing 10 (6), 748-757.

Heyneman,A., Vanderwee,K., Grypdonck,M., Defloor,T., 2009. Effectiveness of two cushions in the prevention of heel pressure ulcers. Worldviews and Evidence Based Nursing 6 (2), 114-120.

Hodgson,T.A., Meiners,M.R., 1982. Cost-of-illness methodology: a guide to current practices and procedures. Milbank Mem. Fund. Q. Health Soc. 60 (3), 429-462.

Hopkins,A., Dealey,C., Bale,S., Defloor,T., Worboys,F., 2006. Patient stories of living with a pressure ulcer. Journal of Advanced Nursing 56 (4), 345-353.

Horn,S.D., Bender,S.A., Ferguson,M.L., Smout,R.J., Bergstrom,N., Taler,G., Cook,A.S., Sharkey,S.S., Voss,A.C., 2004. The National Pressure Ulcer Long-Term Care Study: pressure ulcer development in long-term care residents. J Am. Geriatr. Soc. 52 (3), 359-367.

Hu,T.W., Stotts,N.A., Fogarty,T.E., Bergstrom,N., 1993. Cost analysis for guideline implementation in prevention and early treatment of pressure ulcers. Decubitus 6 (2), 42-46.

Huber,J., Reddy,R., Pitham,T., Huber,D., 2008. Increasing heel skin perfusion by elevation. Adv Skin Wound Care 21 (1), 37-41.

Hudgens,M.G., Taha,T.E., Omer,S.B., Jamieson,D.J., Lee,H., Mofenson,L.M., Chasela,C., Kourtis,A.P., Kumwenda,N., Ruff,A., Bedri,A., Jackson,J.B., Musoke,P., Bollinger,R.C., Gupte,N., Thigpen,M.C., Taylor,A., , van der Horst, C. (2013). Pooled individual data analysis of 5 randomized trials of infant nevirapine prophylaxis to prevent breast-milk HIV-1 transmission. Clinincal Infectious Diseases, 56, 131-139. doi:10.1093/cid/cis808

Hurd,T., Posnett,J., 2009. Point prevalence of wounds in a sample of acute hospitals in Canada. International Wound Journal 6 (4), 287-293.

Iivarinen,J.T., Korhonen,R.K., Julkunen,P., Jurvelin,J.S., 2011. Experimental and computational analysis of soft tissue stiffness in forearm using a manual indentation device. Medical Engineering and Physics 33 (10), 1245-1253.

Khan, F., Carnochan, F. M., Abbot, N. C., & Wilson, S. B. (1991). The effect of oxygen supplementation on post-occlusive reactive hyperaemia in human

forearm skin. International Journal of Microcirculation Clinical and Experimental, 10, 43-53.

Kosiak,M., 1961. Etiology of decubitus ulcers. Archives of Physical Medicine and Rehabilitation 42 , 19-29.

Kottner,J., Balzer,K., 2010. Do pressure ulcer risk assessment scales improve clinical practice? Journal of Multidisciplinary Healthcare 3 , 103-111.

Kottner,J., Balzer,K., Dassen,T., Heinze,S., 2009a. Pressure ulcers: a critical review of definitions and classifications. Ostomy Wound Management 55 (9), 22-29.

Kottner,J., Gefen,A., 2012. Incidence of pressure ulcers as primary outcomes in clinical trials: a comment on McInnes et al. (2012). International Journal of Nursing Studies 49 (3), 372-374.

Kottner,J., Gefen,A., Lahmann,N., 2011. Weight and pressure ulcer occurrence: a secondary data analysis. Int. J. Nurs. Stud. 48 (11), 1339-1348.

Kottner,J., Halfens,R., Dassen,T., 2009b. An interrater reliability study of the assessment of pressure ulcer risk using the Braden scale and the classification of pressure ulcers in a home care setting. International Journal of Nursing Studies 46 (10), 1307-1312.

Kottner,J., Wilborn,D., Dassen,T., Lahmann,N., 2009c. The trend of pressure ulcer prevalence rates in German hospitals: Results of seven cross-sectional studies. Journal of Tissue Viability 18 (2), 36-46.

Kraemer,H.C., 2010. Epidemiological methods: about time. International Journal of Environmental Research and Public Health 7 (1), 29-45.

Krouskop,T.A., Reddy,N.P., Spencer,W.A., Secor,J.W., 1978. Mechanisms of decubitus ulcer formation--an hypothesis. Medical Hypotheses 4 (1), 37-39.

Kumar,R.N., Gupchup,G.V., Dodd,M.A., Shah,B., Iskedjian,M., Einarson,T.R., Raisch,D.W., Kumar,R.N., Gupchup,G.V., Dodd,M.A., Shah,B., Iskedjian,M., Einarson,T.R., Raisch,D.W., 2004. Direct health care costs of 4 common skin ulcers in New Mexico Medicaid fee-for-service patients. Advances in Skin & Wound Care 17 (3), 143-149.

Lachenbruch,C., Tzen,Y.T., Brienza,D.M., Karg,P.E., Lachenbruch,P.A., 2013. The relative contributions of interface pressure, shear stress, and temperature on tissue ischemia: a cross-sectional pilot study. Ostomy Wound Management. 59 (3), 25-34.

Lahmann,N.A., Kottner,J., 2011. Relation between pressure, friction and pressure ulcer categories: a secondary data analysis of hospital patients using CHAID methods. International Journal of Nursing Studies 48 (12), 1487-1494.

Landis,J.R., Koch,G.G., 1977. The measurement of observer agreement for categorical data. Biometrics 33 (1), 159-174.

Langemo,D.K., Melland,H., Hanson,D., Olson,B., Hunter,S., 2000. The lived experience of having a pressure ulcer: a qualitative analysis. Advances in Skin and Wound Care 13 (5), 225-235.

Larg,A. and Moss, J.R., 2011. Cost-of-Illness Studies: A Guide to Critical Evaluation. PharmacoEconomics 29 (8), 653-671.

Levy,A., Kopplin,K., Gefen,A., 2013. Simulations of skin and subcutaneous tissue loading in the buttocks while regaining weight-bearing after a push-up in wheelchair users. Journal of Mechanical Behavior of Biomedical Materials 28 , 436-447.

Linder-Ganz,E., Gefen,A., 2009. Stress analyses coupled with damage laws to determine biomechanical risk factors for deep tissue injury during sitting. Journal of Biomechincal Engineering 131 (1), 011003.

Linder-Ganz,E., Shabshin,N., Itzchak,Y., Gefen,A., 2007. Assessment of mechanical conditions in sub-dermal tissues during sitting: a combined experimental-MRI and finite element approach. Journal of Biomechanics 40 (7), 1443-1454.

Linder-Ganz,E., Engelberg,S., Scheinowitz,M., Gefen,A., 2006. Pressure-time cell death threshold for albino rat skeletal muscles as related to pressure sore biomechanics. Journal of Biomechanics 39 (14), 2725-2732.

Loerakker,S., Manders,E., Strijkers,G.J., Nicolay,K., Baaijens,F.P., Bader,D.L., Oomens,C.W., 2011. The effects of deformation, ischemia, and

reperfusion on the development of muscle damage during prolonged loading. Journal of Applied Physiology 111 (4), 1168-1177.

Loerakker,S., Solis,L.R., Bader,D.L., Baaijens,F.P., Mushahwar,V.K., Oomens,C.W., 2013. How does muscle stiffness affect the internal deformations within the soft tissue layers of the buttocks under constant loading? Computer Methods in Biomechanics and Biomedical Engineering 16 (5), 520-529.

Lyder,C.H., Shannon,R., Empleo,F.O., McGeHee,D., White,C., 2002. A comprehensive program to prevent pressure ulcers in long-term care: exploring costs and outcomes. Ostomy/Wound Management 48 , 52-62.

Maher,A., Miake-Lye,I., Beroes,J., Shekelle,P., 2012. Treatment of Metastatic Non-Small Cell Lung Cancer: A Systematic Review of Comparative Effectiveness and Cost-Effectiveness. Department of Veterans Affairs (US). Available from: http://www.ncbi.nlm.nih.gov/books/NBK153078/ downloaded March 18th 2014, Washington (DC).

Makai,P., Koopmanschap,M., Bal,R., Nieboer,A.P., Makai,P., Koopmanschap,M., Bal,R., Nieboer,A.P., 2010. Cost-effectiveness of a pressure ulcer quality collaborative. Cost Effectiveness & Resource Allocation 8 , 11.

Manzano,F., Pérez,A.M., Colmenero,M., Aguilar,M.M., Sánchez-Cantalejo,E., Reche,A.M., Talavera,J., López,F., Frías-Del Barco,S., Fernández-Mondejar,E., 2013. Comparison of alternating pressure mattresses and overlays for prevention of pressure ulcers in ventilated intensive care patients: a quasi-experimental study. Journal of Advanced Nursing.

Marchette,L., Arnell,I., Redick,E., 1991. Skin ulcers of elderly surgical patients in critical care units. Dimensions of Critical Care Nursing 10 (6), 321-329.

McGinnis,E., Stubbs,N., 2011. Pressure-relieving devices for treating heel pressure ulcers. Cochrane Database Syst. Rev.(9), CD005485.

McInnes,E., Bell-Syer,S.E., Dumville,J.C., Legood,R., Cullum,N.A., 2008. Support surfaces for pressure ulcer prevention. Cochrane Database of Systematic Reviews(4), CD001735.

McInnes,E., Jammali-Blasi,A., Bell-Syer,S., Dumville,J., Cullum,N., 2012. Preventing pressure ulcers-Are pressure-redistributing support surfaces effective? A Cochrane systematic review and meta-analysis. International Journal of Nursing Studies 49 (3), 345-359.

McKinlay,R.J., Wilczynski,N.L., Haynes,R.B., 2006. Optimal search strategies for detecting cost and economic studies in EMBASE. BMC Health Services Research 6, 67.

McNair, P. D., Jackson, T. J., Borovnicar, D. J., McNair, P. D., Jackson, T. J., & Borovnicar, D. J. (2010). The US Medicare policy of not reimbursing hospital-acquired conditions: what impact would such a policy have in Victorian hospitals? Medical Journal of Australia, 193, 22-25.

Miller,G.E., Seale,J., 1981. Lymphatic clearance during compressive loading. Lymphology 14 (4), 161-166.

Moher,D., Liberati,A., Tetzlaff,J., Altman,D.G., 2010. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. International Journal of Surgery 8 (5), 336-341.

Moore,Z., Cowman,S., Posnett,J., 2013. An economic analysis of repositioning for the prevention of pressure ulcers. Journal of Clinical Nursing 22 (15-16), 2354-2360.

Moore,Z.E., Cowman,S., 2014. Risk assessment tools for the prevention of pressure ulcers. Cochrane Database of Systematic Reviews 2 , CD006471.

Moore,Z., 2009. The effect of repositioning 3 hourly at night, using the 30 degree tilt, on the incidence of pressure ulcers, in older persons at risk of pressure ulcer development hospitalised in long-term care settings [PhD Thesis]. In: Royal College of Surgeons in Ireland, Dublin.

National Institute for Clinical Excellence, 2005. Clinical Practice Guidelines. The use of pressure-relieving devices (beds, mattresses and overlays) for the prevention of pressure ulcers in primary and secondary care. In: Royal College of Nursing, London

National Pressure Ulcer Advisory Panel (NPUAP) , 2007. National Pressure Ulcer Advisory Panel Support Surface Standards Initiative. Terms an Defenitions Related to Support Surfaces. In: National Pressure Ulcer Advisory Panel. Retrieved from http://www.npuap.org/NPUAP_S3I_TD.pdf..

National Pressure Ulcer Advisory Panel, 2011. Pressure Ulcers: Avoidable or Unavoidable? Results of the National Pressure Ulcer Advisory Panel Consensus Conference. Ostomy Wound Management 57 (2), 24-37.

National Pressure Ulcer Advisory Panel and European Pressure Ulcer Advisory Panel, 2010. International Review: Pressure Ulcer Prevention. Pressure, shear, friction and microclimate in context. A consensus document. In: Wounds International, London.

Nicosia,G., Gliatta,A.E., Woodbury,M.G., Houghton,P.E., 2007. The effect of pressure-relieving surfaces on the prevention of heel ulcers in a variety of settings: a meta-analysis. Int. Wound J 4 (3), 197-207.

Niederhauser,A., VanDeusen,L.C., Parker,V., Ayello,E.A., Zulkowski,K., Berlowitz,D., 2012. Comprehensive programs for preventing pressure ulcers: a review of the literature. Advances in Skin and Wound Care 25 (4), 167-188.

Nixon, J., Cranny, G., & Bond, S. (2005). Pathology, diagnosis, and classification of pressure ulcers: comparing clinical and imaging techniques. Wound Repair & Regeneration, 13, 365-372. doi:10.1111/j.1067-1927.2005.130403.x

Nixon, J. (2001). The pathopysiology and etiology of pressure ulcers. In Morison, M. J. (Ed.), The Prevention and Treatment of Pressure Ulcers (pp. 17-36). London: Mosby.

Nixon,J., Cranny,G., Bond,S., 2007. Skin alterations of intact skin and risk factors associated with pressure ulcer development in surgical patients: a cohort study. International Journal of Nursing Studies 44 (5), 655-663.

Nixon,J., Nelson,E.A., Cranny,G., Iglesias,C.P., Hawkins,K., Cullum,N.A., Phillips,A., Spilsbury,K., Torgerson,D.J., Masonon,S.b.o.t.P.T.G., 2006a.

Pressure relieving support surfaces: a randomised evaluation. Health Technology Assessment 10 (22).

Nixon,J., Cranny,G., Iglesias,C., Nelson,E.A., Hawkins,K., Phillips,A., Torgerson,D., Mason,S., Cullum,N., PRESSURE Trial Group, 2006b. Randomised, controlled trial of alternating pressure mattresses compared with alternating pressure overlays for the prevention of pressure ulcers: PRESSURE (pressure relieving support surfaces) trial. BMJ 332 (7555), 1413.

Nonnemacher,M., Stausberg,J., Bartoszek,G., Lottko,B., Neuhaeuser,M., Maier,I., 2009. Predicting pressure ulcer risk: a multifactorial approach to assess risk factors in a large university hospital population. J. Clin. Nurs. 18 (1), 99-107.

Norton,D., McLaren,R., Exton-Smith,A., 1975. An investigation of Geriatric Nursing Problems in Hospitals. Churchill Livingstone, New York.

NPUAP & EPUAP, 2009. Prevention and Treatment of Pressure Ulcers: Clinical Practice Guideline. National Pressure Ulcer Advisory Panel, Washington DC.

Okamoto,F., Allen,B.S., Buckberg,G.D., Bugyi,H., Leaf,J., 1986. Reperfusion conditions: importance of ensuring gentle versus sudden reperfusion during relief of coronary occlusion. The Journal of Thoracic and Cardiovascular Surgery 92 (3 Pt 2), 613-620.

Ooi,W.L., Morris,J.N., Brandeis,G.H., Hossain,M., Lipsitz,L.A., 1999. Nursing home characteristics and the development of pressure sores and disruptive behaviour. Age Ageing 28 (1), 45-52.

Oot-Giromini,B., Bidwell,F.C., Heller,N.B., Parks,M.L., Prebish,E.M., Wicks,P., Williams,P.M., 1989. Pressure ulcer prevention versus treatment, comparative product cost study. Decubitus 2 (3), 52-54.

Padula,W.V., Mishra,M.K., Makic,M.B., Sullivan,P.W., Padula,W.V., Mishra,M.K., Makic,M.B., Sullivan,P.W., 2011. Improving the quality of pressure ulcer care with prevention: a cost-effectiveness analysis. Medical Care 49 (4), 385-392.

Papanikolaou,P., Lyne,P., Anthony,D., 2007. Risk assessment scales for pressure ulcers: a methodological review. International Journal of Nursing Studies 44 (2), 285-296.

Park, S.H., Boyle, D.K., Bergquist-Beringer, S., Staggs, V.S., Dunton, N.E.,Concurrent and Lagged Effects of Registered Nurse Turnover and Staffing on Unit -Acquired Pressure Ulcers. Health Service Research, doi 10.1111/1475-6773.12158.

Parish,L.C., Lowthian,P., Witkowski,J.A., 2007. The decubitus ulcer: many questions but few definitive answers. Clinincal Dermatology 25 (1), 101-108.

Patel,S., Knapp,C.F., Donofrio,J.C., Salcido,R., 1999. Temperature effects on surface pressure-induced changes in rat skin perfusion: implications in pressure ulcer development. J Rehabilitation Research & Development 36 (3), 189-201.

Peduzzi, P., Concato, J., Feinstein, A.R., Holford, T.R., 1995. Importance of events per independent variable in proportional hazards regression analysis. II. Accuracy and precision of regression estimates. Journal of Clinical Epidemiology 48 (12), 1503–1510.

Peirce,S.M., Skalak,T.C., Rodeheaver,G.T., 2000. Ischemia-reperfusion injury in chronic pressure ulcer formation: A skin model in the rat. Wound Repair & Regeneration 8 (1), 68-76.

Petzold,T., Eberlein-Gonska,M., Schmitt,J., 2014. Which factors predict incident pressure ulcers in hospitalised patients? A prospective cohort study. British Journal of Dermatology, n/a.

Phillips,L., Goossens,R., Takahashi,M., Clark,M., 2012. Technology update: Defining 'active' pressure redistribution. Wounds International 3 (3), 52-56.

Pieper,B., Sugrue,M., Weiland,M., Sprague,K., Heimann,C., 1997. Presence of pressure ulcer prevention methods used among patients considered at risk versus those considered not at risk. Journal of Wound Ostomy and Continence Nursing 24 (4), 191-199.

Pinkney,L., Nixon,J., Wilson,L., Coleman,S., McGinnis,E., Stubbs,N., Dealey,C., Nelson,A., Patterson,M., Keen,J., 2014. Why do patients develop severe pressure ulcers? A retrospective case study. BMJ Open. 4 (1), e004303.

Polit,D., Beck,C.T., 2008. Nursing Research. Generating and Assessing Evidence for Nursing Practive. Lippincott Williams&Wilkins, Philadelphia.

Posnett,J., Franks,P.J., 2008. The burden of chronic wounds in the UK. Nursing Times 104 (3), 44-45.

Pretto,E.A.Jr., 1991. Reperfusion injury of the liver. Transplantation Proceedings 23 (3), 1912-1914.

Reddy, N. P. (1990). Effects of mechanical stresses on lymph and interstitial fluid flows. In Bader, D. L. (Ed.), Pressure sores. Clinical practice and scientific approach. (pp. 203-220). London: MacMillan.

Redelings,M.D., Lee,N.E., Sorvillo,F., 2005. Pressure ulcers: more lethal than we thought? Advances in Skin and Wound Care 18 (7), 367-372.

Reed,R.L., Hepburn,K., Adelson,R., Center,B., McKnight,P., 2003. Low serum albumin levels, confusion, and fecal incontinence: are these risk factors for pressure ulcers in mobility-impaired hospitalized adults? Gerontology 49 (4), 255-259.

Rees,R.S., Bashshur,N., 2007. The effects of TeleWound management on use of service and financial outcomes. Telemedicine Journal and E-Health 13 (6), 663-674.

Reid,R.R., Sull,A.C., Mogford,J.E., Roy,N., Mustoe,T.A., 2004. A novel murine model of cyclical cutaneous ischemia-reperfusion injury. Journal of Surgical Research 116 (1), 172-180.

Reuler,J.B., Cooney,T.G., 1981. The pressure sore: pathophysiology and principles of management. Ann. Intern. Med 94 (5), 661-666.

Rice,D.P., 1967. Estimating the cost of illness. American Journal of Public Health and the Nation's Health 57 (3), 424-440.

Richardson,G.M., Gardner,S., Frantz,R.A., Richardson,G.M., Gardner,S., Frantz,R.A., 1998. Nursing assessment: impact on type and cost of interventions to prevent pressure ulcers. Journal of Wound, Ostomy, & Continence Nursing 25 (6), 273-280.

Rousson,V., Gasser,T., Seifert,B., 2002. Assessing intrarater, interrater and test-retest reliability of continuous measurements. Statistics in Medicine 21 (22), 3431-3446.

Saleh,M., Anthony,D., Parboteeah,S., 2009. The impact of pressure ulcer risk assessment on patient outcomes among hospitalised patients. J Clin. Nurs 18 (13), 1923-1929.

Sanada,H., Sugama,J., Kitagawa,A., Thigpen,B., Kinosita,S., Murayama,S., 2007. Risk factors in the development of pressure ulcers in an intensive care unit in Pontianak, Indonesia. International Wound Journal 4 (3), 208-215.

Schoonhoven,L., Grobbee,D.E., Donders,A.R., Algra,A., Grypdonck,M.H., Bousema,M.T., Schrijvers,A.J., Buskens,E., 2006. Prediction of pressure ulcer development in hospitalized patients: a tool for risk assessment. Quality & Safety in Health Care 15 (1), 65-70.

Schoonhoven,L., Haalboom,J.R., Bousema,M.T., Algra,A., Grobbee,D.E., Grypdonck,M.H., Buskens,E., 2002. Prospective cohort study of routine use of risk assessment scales for prediction of pressure ulcers. British Medical Journal 325 (7368), 797.

Schuurman,J.P., Schoonhoven,L., Defloor,T., van Engelshoven,I., van Ramshorst,B., Buskens,E., 2009. Economic Evaluation of Pressure Ulcer Care: A Cost Minimization Analysis of Preventive Strategies. Nursing Economic$ 27 (6), 390-415.

Severens,J., Habraken,J., Duivenvoorden,S., Frederiks,C., 2002. The Cost of Illness of Pressure Ulcers in the Netherlands. [Article]. Advances in Skin & Wound Care 15 (2), 72-77.

Shea,J.D., 1975. Pressure sores: classification and management. Clin. Orthop. Relat Res.(112), 89-100.

Spetz,J., Brown,D.S., Aydin,C., Donaldson,N., 2013. The value of reducing hospital-acquired pressure ulcer prevalence: an illustrative analysis. Journal of Nursing Administration 43 (4), 235-241.

Stekelenburg,A., Gawlitta,D., Bader,D.L., Oomens,C.W., 2008. Deep tissue injury: how deep is our understanding? Archives of Physical Medicine and Rehabilitation 89 (7), 1410-1413.

Stekelenburg,A., Oomens,C.W., Strijkers,G.J., Nicolay,K., Bader,D.L., 2006. Compression-induced deep tissue injury examined with magnetic resonance imaging and histology. Journal of Applied Physiology 100 (6), 1946-1954.

Stekelenburg,A., Strijkers,G.J., Parusel,H., Bader,D.L., Nicolay,K., Oomens,C.W., 2007. Role of ischemia and deformation in the onset of compression-induced deep tissue injury: MRI-based studies in a rat model. Journal of Applied Physiology 102 (5), 2002-2011.

Swartenbroekx,N., 2012. Handleiding voor op-kosten-gebaseerde prijsbepaling van ziekenhuisinterventies. Manual for cost-based pricing of hospital interventions. Health Technology Assessment (HTA).

Tanner,C.A., 2006. Thinking like a nurse: a research-based model of clinical judgment in nursing. Journal of Nursing Education 45 (6), 204-211.

The Cochrane Collaboration, 2008. Cochrane Handbook for Systematic Reviews of Interventions. John Wiley & Sons, Chichester, England.

Theaker,C., Kuper,M., Soni,N., 2005. Pressure ulcer prevention in intensive care - a randomised control trial of two pressure-relieving devices. Anaesthesia 60 (4), 395-399.

Theisen,S., Drabik,A., Stock,S., 2012. Pressure ulcers in older hospitalised patients and its impact on length of stay: a retrospective observational study. Journal of Clinical Nursing 21 (3-4), 380-387.

Thompson,S.G., Barber,J.A., 2000. How should cost data in pragmatic randomised trials be analysed? BMJ 320 (7243), 1197-1200.

Tissue Viability Society, 2010. Laboratory measurement of the interface pressures applied by active therapy support surfaces: A consensus document. Journal of Tissue Viability 19 (1), 2-6.

Trybou,J., 2011. Itinera Institute Analyse. De ziekenhuisfinanciering: uitdagingen, sterktes en kansen tot verbetering. In: Itinera Institute. Downloaded from:

http://www.itinerainstitute.org/upl/1/default/doc/20110701_Ziekenhuisfinanciering.pdf on 28/11/2012.

Tsuji,S., Ichioka,S., Sekiya,N., Nakatsuka,T., 2005. Analysis of ischemia-reperfusion injury in a microcirculatory model of pressure ulcers. Wound Repair & Regeneration 13 (2), 209-215.

Unal,S., Ozmen,S., DemIr,Y., Yavuzer,R., LatIfoglu,O., Atabay,K., Oguz,M., 2001. The effect of gradually increased blood flow on ischemia-reperfusion injury. Annals of Plastic Surgery 47 (4), 412-416.

Van Den Bos,J., Rustagi,K., Gray,T., Halford,M., Ziemkiewicz,E., Shreve,J., 2011. The $17.1 billion problem: the annual cost of measurable medical errors. Health Affairs 30 (4), 596-603.

Van den Heede,K., Clarke,S.P., Sermeus,W., Vleugels,A., Aiken,L.H., 2007. International Experts' Perspectives on the State of the Nurse Staffing and Patient Outcomes Literature. Journal of Nursing Scholarship 39 (4), 290-297.

van Gaal,B.G.I., Schoonhoven,L., Mintjes,J.A.J., Borm,G.F., Koopmans,R.T.C.M., van Achterberg,T., 2011. The SAFE or SORRY? programme. Part II: Effect on preventive care. International Journal of Nursing Studies 48 (9), 1049-1057.

van Gils,P.F., Hamberg-van Reenen,H.H., van den Berg,M., Tariq,L., de Wit,G.A., 2010. The scope of costs in alcohol studies: Cost-of-illness studies differ from economic evaluations. Cost Effectiveness & Resource Allocation 8 , 15.

Van Goubergen,D., 2005. Tijdstudie. Normstelling. In: Ghent University, Ghent, pp. 16-17.

Vanderwee,K., Clark,M., Dealey,C., Gunningberg,L., Defloor,T., 2007a. Pressure ulcer prevalence in Europe: a pilot study. Journal of Evaluation in Clinical Practice 13 (2), 227-235.

Vanderwee,K., Defloor,T., Beeckman,D., Demarré,L., Verhaeghe,S., Van,D.T., Gobert,M., 2011. Assessing the adequacy of pressure ulcer prevention in hospitals: a nationwide prevalence survey. BMJ Quality & Safety 20 (3), 260-267.

Vanderwee,K., Grypdonck,M., De,B.D., Defloor,T., 2009. The identification of older nursing home residents vulnerable for deterioration of grade 1 pressure ulcers. J. Clin. Nurs. 18 (21), 3050-3058.

Vanderwee,K., Grypdonck,M., Defloor,T., 2007b. Non-blanchable erythema as an indicator for the need for pressure ulcer prevention: a randomized-controlled trial. Journal of Clinical Nursing 16 (2), 325-335.

Vanderwee,K., Grypdonck,M.H., Defloor,T., 2005. Effectiveness of an alternating pressure air mattress for the prevention of pressure ulcers. Age Ageing 34 (3), 261-267.

Vrijens,F., Hulstaert,F., Gordts,B., De Laet,C., Devriese,S., Van De Sande,S., Huybrechts,M., Peeters,G., 2009. Nosocomial Infections in Belgium, part 2: Impact on Mortality and Costs. Health Services Research (HSR). In: Federal Health Care Knowledge Centre (KCE), Brussels.

Whittington,K.T., Briones,R., 2004. National Prevalence and Incidence Study: 6-year sequential acute care data. Advances in Skin & Wound Care 17 (9), 490-494.

WHO, 2009. WHO guide to identifying the economic consequences of diseases and injury. In: WHO; downloaded on May 5th 2014 from http://www.who.int/choice/publications/d_economic_impact_guide.pdf, Geneva.

Wong,V.K., Stotts,N.A., 2003. Physiology and prevention of heel ulcers: The state of science. Journal of Wound Ostomy and Continence Nursing 30 (4), 191-198.

Woodward,M., 2005. Epidemiology. Study Design and Data Analysis. Chapman & Hall/CRC, Florida.

Xakellis,G.C., Frantz,R., 1996a. The cost of healing pressure ulcers across multiple health care settings. Advances in Skin & Wound Care 9 (6), 18-22.

Xakellis,G.C., Frantz,R., Lewis,A., Xakellis,G.C., Frantz,R., Lewis,A., 1995. Cost of pressure ulcer prevention in long-term care. Journal of the American Geriatrics Society 43 (5), 496-501.

Xakellis,G.C., Frantz,R.A., Lewis,A., Harvey,P., 2001. Translating pressure ulcer guidelines into practice: it's harder than it sounds. Advances in Skin & Wound Care 14 , 249-307.

Xakellis,G.C., Jr., Frantz,R.A., Lewis,A., Harvey,P., 1998. Cost-effectiveness of an intensive pressure ulcer prevention protocol in long-term care. Advances in Wound Care 11 (1), 22-29.

Xakellis,G.C., Frantz,R.A., Xakellis,G.C., Frantz,R.A., 1996b. The cost-effectiveness of interventions for preventing pressure ulcers. Journal of the American Board of Family Practice 9 (2), 79-85.

APPENDIX

Appendix: **List of tables and figures**

Figures

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Tables

Chapter 1

Chapter 2

Chapter 3

SUMMARY

The research outline pursued with this thesis can be divided in three parts. In the first part, studies to compare the effectiveness of several interventions for the prevention of pressure ulcers were conducted. Pressure ulcer prevention focusses on the reduction of the amount and duration of pressure and shear. An alternating device intermittently removes pressure and shear from vulnerable areas. It provides pressure relief via cyclic inflating and deflating air cells. Systematic reviews and (inter)national guidelines demonstrate inconclusive results as to the superiority of one specific alternating pressure device. An example of an active support surface is an alternating pressure air mattress (APAM), available as overlays or replacement mattress, and ALPAMs (Alternating Low Pressure Air Mattresses). Differences between several types of active support surfaces can be related to differences in surface characteristics, such as cycle time, air cell inflation sequence, and pressure amplitude. The inflation and deflation of the air cells of an APAM and ALPAMs are characterized by a steep, one-stage inflation or deflation.
ALPAMs were designed by the medical technology industry to generate lower pressures compared to APAMs. More recently these ALPAMs have been modified so that the transition from deflated air cell to inflated air cell is more gradual or multi-staged. As more complex technology does not necessarily lead to more effective devices, the aim of the first trial was to examine the influence of a multi-stage inflation and deflation cycle versus a one-stage inflation and deflation cycle. The multi-stage ALPAM did not result in a significantly lower pressure ulcer incidence compared to the one-stage ALPAM. Both mattresses were equally effective to prevent pressure ulcers. The time to develop a pressure ulcer was comparable in both groups.

Secondly, the effectiveness of an APAM overlay was compared with the effectiveness of a one-stage and a multi-stage ALPAM. A reduced incidence of pressure ulcers was found in the multi-stage ALPAM group compared to the APAM overlay group. No significant differences in pressure ulcer development were found between a one-stage ALPAM and an APAM overlay. The median time to develop a pressure ulcer was similar among groups.

Despite preventive measures provided in the effectiveness studies, a proportion of the patients developed a pressure ulcer. The identification of these 'high risk' patients is examined in the second part of this dissertation and is crucial to further improve the quality of care. The aim of a subsequent study was to identify factors that independently predicted the development of a pressure ulcer in an at risk population who received standardised preventive care. The presence of non-blanchable erythema, having a urogenital disorder, and higher body temperature were found to be predictive factors associated with the development of a pressure ulcer.

In the third part of this thesis the cost of pressure ulcer prevention and treatment was addressed. International literature found a cost of pressure ulcer prevention per patient at risk varying between €2.65 and €87.57 per day. The cost of pressure ulcer treatment ranged from €1.73 to €812.92 per patient per day. These studies encompassed a considerable methodological heterogeneity in terms of the type of health economic design, health economic perspective, the cost components, and the health outcomes. In a subsequent study insight was provided into the cost of pressure ulcer prevention and treatment in hospitals and nursing homes in Flanders using a mixed perspective. In hospitals, a cost for pressure ulcer prevention of €7.88 per patient at risk per day was found. In nursing homes, a cost of €2.15 per resident at risk per day was calculated. The cost of pressure ulcer prevention for patients and residents perceived not at risk for pressure ulcer development was €1.44 per day in hospitals and €0.50 per day in nursing homes. The main cost driver was found to be the cost of labour, rather than the cost of devices. The average cost of treatment per patient per day varied from €2.34 (category I) to €77.36 (category IV) in hospitals, and from €2.42 (category I) to €16.18€ (category IV pressure ulcer) in nursing homes.

SAMENVATTING

Het doel van dit proefschrift was drieledig. In het eerste deel werden onderzoeken uitgevoerd om de effectiviteit van verschillende druk verdelende systemen te vergelijken in de preventie van decubitus. Adequate decubituspreventie wordt verkregen door een reductie in de duur en de intensiteit van de druk- en schuifkrachten. Een methode om de duur van druk- en schuifkrachten te verminderen is het gebruik van alternerende systemen. Deze alternerende systemen zorgen voor drukopheffing door het cyclisch opblazen (inflatie) en leeglaten (deflatie) van luchtcellen. Systematische reviews en (inter)nationale richtlijnen geven aan dat er geen klinische bewijskracht is om één alternerend systeem boven een ander aan te bevelen. Voorbeelden van alternerende systemen zijn APAMs (alternerende druk matrassen), beschikbaar als oplegmatras of matras vervangend systeem, en ALPAMs (alternerende lage druk matrassen). APAMs en ALPAMs worden gekenmerkt door een enkelvoudige, snelle inflatie en deflatie cyclus van de luchtcellen.
ALPAMs zijn alternerende systemen die werden ontworpen door de medische industrie om een lagere druk te genereren in vergelijking met APAMs. Recentelijk werden deze ALPAMs aangepast om de overgang tussen inflatie en deflatie van een luchtcel meer gradueel of getrapt te laten verlopen. Aangezien complexere technologie niet noodzakelijk tot effectievere systemen leidt, was het doel van het onderzoek om na te gaan of er een verschil was in effectiviteit tussen een alternerende lage druk matras met een enkelvoudige, snelle inflatie en deflatie cyclus van de luchtcellen en de effectiviteit van een alternerende lage druk matras met een meer graduele, getrapte inflatie en deflatie cyclys van de luchtcellen. De ALPAM met een graduele/getrapte inflatie en deflatie cyclus resulteerde niet in een significant lagere incidentie van decubitus tegenover de ALPAM met een enkelvoudige, snelle inflatie en deflatie van de luchtcellen. Beide matrassen waren even effectief in de preventie van decubitus. De tijd om decubitus te ontwikkelen was vergelijkbaar in beide groepen.

Vervolgens werd de effectiviteit van een APAM oplegmatras vergeleken met de doeltreffendheid van zowel een ALPAM met een graduele/getrapte inflatie en deflatie van de luchtcellen als een ALPAM met een enkelvoudige, snelle inflatie

en deflatie van de luchtcellen. De incidentie van decubitus was significant lager in de ALPAM groep met een graduele/getrapte inflatie en deflatie van de luchtcellen vergeleken met de APAM oplegmatras groep. Er werden geen significante verschillen gevonden in incidentie van decubitus tussen de ALPAM met een enkelvoudige, snelle inflatie en deflatie van de luchtcellen en de APAM oplegmatras. De gemiddelde tijd om decubitus te ontwikkelen was vergelijkbaar in beide groepen.

Ondanks preventieve maatregelen in de effectiviteitsstudies, ontwikkelden een deel van de patiënten decubitus. De identificatie van deze hoog-risicopatiënten werd bestudeerd in het derde deel van het proefschrift en is van cruciaal belang om de kwaliteit van zorg verder te kunnen verbeteren. Het doel van dit onderzoek was identificeren van risicofactoren die de ontwikkeling van decubitus voorspellen bij patiënten die gestandaardiseerde preventieve zorg kregen. De aanwezigheid van niet-wegdrukbare roodheid, opname omwille van een urogenitale stoornis en een hogere lichaamstemperatuur bleken geassocieerd te zijn met de ontwikkeling van decubitus.

Het derde deel van dit proefschrift onderzocht de kost geassocieerd met de preventie en behandeling van decubitus. Internationale literatuur vermeldt kosten voor preventie van decubitus variërend van €2.65 tot €87.57 per dag per risicopatiënt. De kosten van de behandeling van decubitus varieerden tussen €1.73 en €812.92 per patiënt per dag. De methodologische heterogeniteit tussen de verschillende studies was aanzienlijk, in termen van gebruikte onderzoeksdesign, gekozen gezondheid, economisch perspectief, de geïncludeerde kost posten en de weergegeven uitkomstmaten.
In een vervolgonderzoek werd inzicht gegeven in de kost van preventie en de behandeling van decubitus in ziekenhuizen en woonzorgcentra in Vlaanderen, gebruik makend van een gecombineerd perspectief (patiënt, instelling en zorgverzekering). In ziekenhuizen bedroeg de kost voor decubituspreventie €7.88 per risicopatiënt per dag. In woonzorgcentra bedroeg deze €2.15 per bewoner met risico op het ontwikkelen van decubitus per dag. De kosten van

preventie van decubitus bij patiënten en bewoners zonder risico op de ontwikkeling van decubitus bedroegen €1.44 per dag in ziekenhuizen en €0.50 per dag in woonzorgcentra. De belangrijkste kostenfactor bleek de loonkost, eerder dan de materiaalkosten. De gemiddelde behandelingskost per patiënt per dag varieerde tussen €2.34 (decubitus categorie I) en €77.36 (decubitus categorie IV) in ziekenhuizen, en tussen €2.42 (decubitus categorie I) en €16.18 (decubitus categorie IV) in woonzorgcentra.

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Bachelor of Nursing, Katholieke Hogeschool voor Gezondheidszorg Oost-Vlaanderen, 2000, with great honour
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Advanced bachelor in Intensive and Emergency Care, 2005, with great honour

WORK EXPERIENCES

Nurse, Maria Middelares Hospital Ghent, 2000-2008
Hospital hygiene and infection control nurse, Maria Middelares Hospital Ghent, 2005-2008
Academic Assistant Staff member, PhD candidate at the Nursing Science and Midwifery Unit, Department of Public Health, Ghent University, 2008 – present

OTHER SPECIFIC TRAINING

Statistics

Introductory Statistics: Basics of Statistical Inference (Ghent University/ICES), Analyses of Variance (Ghent University/ICES), Advanced Statistical Analyses using SPSS (Ghent University), Survey Analysis (UGent/ICES), Health in Numbers: Quantitative Methods in Clinical & Public Health (HarvardX).

Management and communication skills

Project management - Feedback training - Personal effectiveness - Assistant training - Advanced Academic English Writing Skills (Doctoral Schools UGent)

Cost-effectiveness

Advanced methods of Cost-Effectiveness Analysis (University of Oxford)

INTERNATIONAL PEER-REVIEWED JOURNALS

Beeckman D., Defloor T., Verhaeghe S., Demarré L., Schoonhoven L., Vanderwee K. (2010). What is the most effective method of preventing and treating incontinence-associated dermatitis? *NursingTimes*, 10(38), 22-25.

Beeckman D, Vanderwee K, Demarré L, Paquay L, Van Hecke A, Defloor T. (2010) Pressure ulcer prevention: Development and psychometric validation of a knowledge assessment instrument. International Journal of Nursing Studies, 47 (4), 399-410

Beeckman D., Defloor T., Demarré L., Van Hecke A., Vanderwee K. (2010). Pressure ulcers: development and psychometric evaluation of the Attitude towards Pressure ulcer Prevention instrument (APuP). International Journal of Nursing Studies, 47(11), 1432-1441.

Vanderwee K., Defloor T., Beeckman D., Demarré L., Verhaeghe S., Van den Durme T., Gobert M. (2011). Assessing the adequacy of pressure ulcer prevention in hospitals a nationwide prevalence study. Quality & Safety in Health Care, 20(3), 260-267.

Demarré, L., Vanderwee, K., Defloor, T., Verhaeghe, S., Schoonhoven, L., Beeckman, D. (2012). Pressure ulcers: knowledge and attitude of nurses and nursing assistants in Belgian nursing homes. Journal of Clinical Nursing 21 (9-10), 1425-1434.

Demarré, L., Beeckman, D., Vanderwee, K., Defloor, T., Grypdonck, M., Verhaeghe, S. (2012). Multi-stage versus single-stage inflation and deflation cycle for alternating low pressure air mattresses to prevent pressure ulcers in hospitalised patients: A randomised-controlled clinical trial. International Journal of Nursing Studies, 49 (4), 416-426.

Demarré L., Verhaeghe S., Van Hecke A., Grypdonck M., Vanderwee K., Clays E., Beeckman D. (2013). The effectiveness of a conventional alternating air mattress versus two low pressure alternating air mattresses to prevent pressure ulcers in hospitalised patients: results of a comparative pooled database study. Journal of Research in Nursing and Health, 36(5),.439-452.

Demarré L., Verhaeghe S., Van Hecke A., Clays E., Grypdonck,M., Beeckman D. (2013). Factors predicting the development of pressure ulcers in an at risk population receiving standardised prevention: secondary analyses of a multicentre randomised controlled trial. Journal of Advanced Nursing. In Press. doi/10.1111/jan.12497.

Demarré L., Verhaeghe S., Van Hecke A., Grypdonck M., Lemey J., Annemans L. & Beeckman D. A systematic review of the cost of prevention and treatment of pressure ulcers. *Under review.*

Demarré L., Verhaeghe S., Van Hecke A., Grypdonck M., Annemans L. & Beeckman D. The cost of prevention and treatment of pressure ulcers in hospitals and nursing homes in Flanders. *Under review.*

ARTICLES IN NATIONAL JOURNALS

Demarré L. (2004) Als chemotherapie geen optie is. Een exploratief onderzoek naar de beleving bij ongeneeslijke kankerpatiënten die geen chemotherapie (meer) krijgen. Ligament, 35(2): 17-22.

Beeckman D., Defloor T., Demarré L., Vanderwee K. (2010). De effectiviteit van de Australische Medische Schapenvacht: een reactie op Mistiaen ea. (2009). *Tijdschrift voor Verpleegkundigen* (TvZ), 7/8, 62.

BOOK CHAPTERS

Defloor T., Demarré L., Beeckman D. (2010). Pressure Ulcer Classification. In: G.Cherry, M. Hughes (Eds.), The second Oxford European Wound Healing Course Handbook. Oxford Wound Healing Foundation, Positif Press, Oxford, pp. 141-147. ISBN 978 0 906894 51 4

ORAL PRESENTATIONS

Demarré L., Beeckman D., Bauwens P., Borms F., Defloor T. (2009). Decubitus in rust- en verzorgingstehuizen: Wat is de houding en kennis van zorgverleners? Paper presented at the Wondtopic "Decubitus… Observeren en voorkomen" in Gent, Universitair Ziekenhuis Gent, Belgium.

Demarré L., Vanderwee K., Beeckman D., Defloor T. (2009). Pressure ulcers: Knowledge and attitudes of nurses in Belgian nursing homes. Paper presented at the 12th Annual European Pressure Ulcer Advisory Panel Meeting in Amsterdam, Amsterdam Medical Centre, The Netherlands.

Demarré L. (2009). Behandeling van decubitus. Nieuwe richtlijnen EPUAP-NPUAP. Paper presented at the Hill-Rom D-day 2009 in Vianen, The Netherlands.

Demarré L. (2010). Behandeling van decubitus. Nieuwe richtlijnen EPUAP-NPUAP. Paper presented at the symposium of Stichting Transmurale zorg: Decubitus" nieuwe inzichten in de praktijk toegepast" in Den Haag, The Netherlands.

Demarré L., Vanderwee K., Beeckman D., Defloor T. (2010). Pressure ulcer prevention: Randomized Controlled Trail comparing the effect of a standard alternating pressure air mattress and an alternating low pressure air mattress with gradual inflation and deflation. Paper presented at the 20th Conference of the European Wound Management Association in Geneva, Geneva Palexpo, Switzerland.

Demarré L., Vanderwee K., Beeckman D., Defloor T. (2010). The effectiveness of a multistage low pressure air mattress in pressure ulcer prevention: a RCT. Paper presented at the 13th Annual European Pressure Ulcer Advisory Panel Meeting in Birmingham, University of Birmingham, England.

Demarré L., Vanderwee K., Beeckman D., Defloor T. (2010). The effectiveness of a multistage low pressure air mattress in pressure ulcer prevention: a RCT. Paper presented at the Fourth European Nursing

Congress Older Persons: the Future of Care, Rotterdam, The Netherlands.

Demarré L., Beeckman D., Defloor T. (2010). Pressure ulcers: Knowledge and attitudes of nurses in Belgian nursing homes. Paper presented at the Fourth European Nursing Congress Older Persons: the Future of Care, Rotterdam, The Netherlands.

Demarré L. (2010). Decubituspreventie = samen op weg met de richtlijn! Paper presented at the symposium of The University Medical Centre of Groningen: Huidverzorging een kunst op zich, Groningen, The Netherlands.

Beeckman D., Van Hecke A., Vanderwee K., Defloor T., Demarré L., Schoonhoven L., Verhaeghe S. (2012). Knowledge and attitudes of nurses on pressure ulcer prevention: a cross-sectional multicentre study in Belgian hospitals. Abstract accepted for oral presentation at the 4th Congress of the World Union of Wound Healing Societies WUWHS2012, Yokohama, Japan.

Beeckman D., Demarré L., Verhaeghe S., Vanderwee K., Defloor T, Van Hecke A. (2012). The effectiveness of a multistage low pressure air mattress in pressure ulcer prevention: a randomized- controlled trial. Abstract accepted for oral presentation at the 4th Congress of the World Union of Wound Healing Societies WUWHS2012, Yokohama, Japan.

Beeckman D., Van Hecke A., Vanderwee K., Defloor T., Demarré L., Schoonhoven L., Verhaeghe S. (2012). Multi- facet tailored implementation to improve pressure ulcer prevention: development and evaluation of a strategy to implement a patient-tailored pressure ulcer prevention protocol in nursing homes. Presentation and Panel Discussion in the Scientific Stream on Pressure Ulcers at the 4th Congress of the World Union of Wound Healing Societies WUWHS2012, Yokohama, Japan.

Beeckman D., Verhaeghe S., Danckaert H., Boudt D., Van Hecke A., Annemans L., Demarré L. (2012). A cost- effectiveness analysis of pressure ulcer prevention in Belgian hospitals – Phase 1: direct time

observations and a Delphi procedure to develop standard nursing times for activities related to pressure ulcer prevention. Abstract accepted for an oral presentation at the 15th Annual European Pressure Ulcer Advisory Panel Meeting, Cardiff, England.

Demarré L., Verhaeghe S., Van Hecke A., Beeckman D. (2012). The effectiveness of a conventional alternating air mattress versus two low pressure alternating air mattresses to prevent pressure ulcers in hospitalized patients: results of a comparative pooled database study. Abstract accepted for an oral presentation at the 15th Annual European Pressure Ulcer Advisory Panel Meeting, Cardiff, England.

Demarré L., Verhaeghe S., Van Hecke A., Clays E., Beeckman D. (2013). Factors predicting the development of pressure ulcers in an at risk population receiving prevention: a multicentre cohort study. Oral presentation at the 16th Annual European Pressure Ulcer Advisory Panel Meeting, Vienna, Austria.

Beeckman D., Vanhuyse C., Heyman H., Verhaeghe S., Van Hecke A., Demarré L. (2013). Cost-effectiveness analysis of 3-in-1 disposable wash cloths impregnated with dimethicone 3% compared with standard care in the prevention and treatment of IAD in older patients. Oral presentation at the 16th Annual European Pressure Ulcer Advisory Panel Meeting, Vienna, Austria.

POSTER PRESENTATIONS

Demarré L., Vanderwee K., Beeckman D., Defloor T. (2010). Decubitusprevalentie en adequaatheid van decubituspreventie in Belgische ziekenhuizen. Poster presentatie, Samen bouwen aan een veilige zorg, Katholieke Universiteit Leuven, Belgium.

Demarré L., Verhaeghe S., Van Hecke A., Vanderwee K., Bouzegta N, Gobert M., Defloor T., Beeckman D. (2012). Decubitusprevalentie en adequaatheid van decubituspreventie in Belgische ziekenhuizen. Poster presentatie, Wetenschapsdag Universiteit Gent, Gent, België.

Demarré L., Verhaeghe S., Van Hecke A., Beeckman D. Pressure ulcer prevalence and compliance with pressure ulcer prevention: Phase 1 of a cost- effectiveness analysis in nursing homes in Flanders (Belgium). Abstract accepted for a poster presentation at the 15th Annual European Pressure Ulcer Advisory Panel Meeting, September 19-21, Cardiff, England.

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