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Biophysical skin properties of grade 1 pressure ulcers and unaffected skin in spinal cord injured and able-bodied persons in the unloaded sacral region

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ABSTRACT

Aim of the study: To examine biophysical skin properties in the sacral region in spinal cord injury (SCI) patients suffering from a grade 1 pressure ulcer (PU) defined as non-blanchable erythema (SCI/PU), SCI patients in the post-acute phase (SCI/PA) and able-bodied participants (CON). Also, for SCI/PU patients, both the affected skin and healthy skin close to the PU were examined.
Study design: An experimental controlled study with a convenience sample.
Setting: A Swiss acute care and rehabilitation clinic specializing in SCIs.
Materials and methods: We determined hydration, redness, elasticity and perfusion of the unloaded skin in the sacral region of 6 SCI/PU patients (affected and healthy skin), 20 SCI/PA patients and 10 able-bodied controls. These measures were made by two trained examiners after the patients were lying in the supine position.
Results: The affected skin of SCI/PU patients showed elevated redness: median 595.5 arbitrary units (AU) (quartiles 440.4; 631.6) and perfusion: 263.0 AU (104.1; 659.4), both significantly increased compared to the healthy skin in SCI/PA patients and CON ($p < 0.001$). Similarly, healthy skin of SCI/PA patients showed elevated redness ($p = 0.016$) and perfusion ($p < 0.001$) compared to CON. On the other hand, differences in redness and perfusion between the affected and unaffected skin in SCI/PU patients were not significant. The results for skin hydration and skin elasticity were similar in all groups.
Conclusions: Skin perfusion and redness were significantly increased in grade 1 PUs and for healthy skin in both SCI/PA patients and CON participants; thus, these are important in understanding the pathophysiology of PUs and skin in SCI.

1. Introduction

Changes in biophysical skin properties have been increasingly examined to understand pressure ulcer (PU) development [1–6]. Skin properties including hydration [1], perfusion [4,7,8], temperature [2], elasticity [9,10] and redness [11,12] have been discussed regarding their ability to predict the risk of developing PUs or to explain the susceptibility to PUs. In patients with a spinal cord injury (SCI), the altered autonomic vegetative nervous system affects skin physiology and contributes to the increased risk for PU development [3,5,13,14]. The time to normalization for perfusion after a standardized pressure load differs in able-bodied people compared to those with SCIs [5,7,15], which might explain the increased PU incidence rates in SCI patients [16,17].

The sacral region is one of the most affected regions for PU development in SCI patients [16,18,19] because of its anatomical prominence and physiological consequences [20–24]. This body region is particularly subjected to pressure, shear and friction during lying, sitting and the transition between different positions [25]. The susceptibility of the sacral region for PU formation has been examined in different positions and findings indicate that the combination of mechanical loads and microclimatic changes at the skin surface influence tissue blood flow and skin temperature [26].

Two cascades of pathophysiology are discussed for PU

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formation. One cascade includes the development of superficial lesions in the epidermis as non-blanchable redness leading to profound lesions according to the European Pressure Ulcer Advisory Panel (EPUAP/NPUAP) classification grades 1 to 4 [25]. The other cascade is initiated by muscle necrosis and deep tissue injury [21,25,27]. A PU generally arises as a result of sustained pressure on the soft skin tissue layers over bony prominences. While tissues can withstand large pressures for brief periods, sustained pressures above the arterial pressure can impair the perfusion and thus, the supply of nutrients and oxygen to the tissues [21,27]. Similarly, sustained forces above the venous pressure closing pressure impedes the return of blood flow and leads to the accumulation of metabolites, lymphatic stasis and tissue damage [21]. Concomitant reactive capillary dilatation, increased vascular permeability, oedema, blistering and thrombosis lead to a downward spiral of tissue necrosis and ulceration [21]. The first phase of ulceration is characterized by paleness of the affected skin followed by a second phase with increased hydration level leading to a change in skin elasticity, increased skin temperature and redness [21].

Over the last decade, these biophysical skin properties have been examined with various procedures and technical devices [22,28–30]. Challenges still exist because of missing examination standards [7], the pilot character of the study designs [26] and the moderate reproducibility of skin assessments [29,31,32].

Therefore, the aim of this study was to measure baseline data of biophysical skin properties in the sacral region in SCI patients over PU grade 1 and the healthy skin close to the PU, in SCI patients without PU and in able-bodied participants. We hypothesized that there would be significant differences between skin properties between these groups. Our results provide new knowledge to understand the susceptibility for PUs in different populations and to measure the potential effects of preventive strategies.

2. Materials and Methods

2.1. Study design, participants and setting

An experimental controlled study in a convenience sample was conducted in an acute care and rehabilitation clinic that specializes in SCIs and treatment of all stages of PUs. Three groups of participants were recruited as outlined below.

- Group 1: inpatients with SCI and a hospital-acquired PU grade 1 (SCI/PU)
- Group 2: inpatients with SCI during the post-acute phase of initial inpatient rehabilitation without a PU (SCI/PA)
- Group 3: able-bodied volunteers from the hospital staff were selected as a reference group (CON). Data from these participants were published for reproducibility testing of the measurement procedure in another publication [29].

Participants with skin lesions or scarring at the sacral region, severe comorbidities (diabetes, coronary heart disease, kidney failure), tumours or progressive diseases, severe brain injuries, or severe infections were excluded.

2.2. Procedures and methods

Measurements were systematically taken following a standardized procedure [29]. All participants reclined for half an hour in the supine position in a standard hospital bed with a standard mattress (DUO, Senectovia, Urdorf, Switzerland) and bed sheet (Typ Romanit, 3071, colour yellow, 80% cotton, 20% polyester, Pfeiffertextil AG, Schindellegi, Switzerland). The room temperature was 24 °C (±4 °C). Patients with a sacral PU grade 1 were examined with the same procedure both directly at the PU and in another healthy skin region (at a maximal distance of 5 cm). For SCI/PA and CON participants, biophysical skin parameters were examined both in the sacral region [29].

For the measurements, participants turned from the supine position onto the lateral position (Figs. 1 and 2). In case of paraplegia and a reduced ability to move independently, patients were turned onto a standard side position by the examiner. The sacrum was detected by manual palpation. To minimize the effects of the circadian rhythm on the biophysical skin properties and skin function, all measurements were carried out between 7 and 11 a.m. To prevent mechanical or chemical irritation, no cleaning procedures were performed. Two trained examiners conducted all measurements.

2.3. Instruments and assessments

The detailed measurement procedure was described before [29] and the methods, devices and times are summarized in Table 1. The sequence for the four examinations was designed with respect to the expected changes of the skin after turning from the supine onto the lateral position and the possible skin irritation after each method [29]. The approximate time line for the complete assessment of the four skin parameters was about 15 min.

2.4. Analysis

Descriptive statistics (i.e. frequencies or median and quartiles, where appropriate) were used for participant characteristics of sex, age, weight, height, smoking, completeness of and time since the lesion development, and biophysical skin properties including redness, hydration, elasticity and perfusion. Comparisons of the

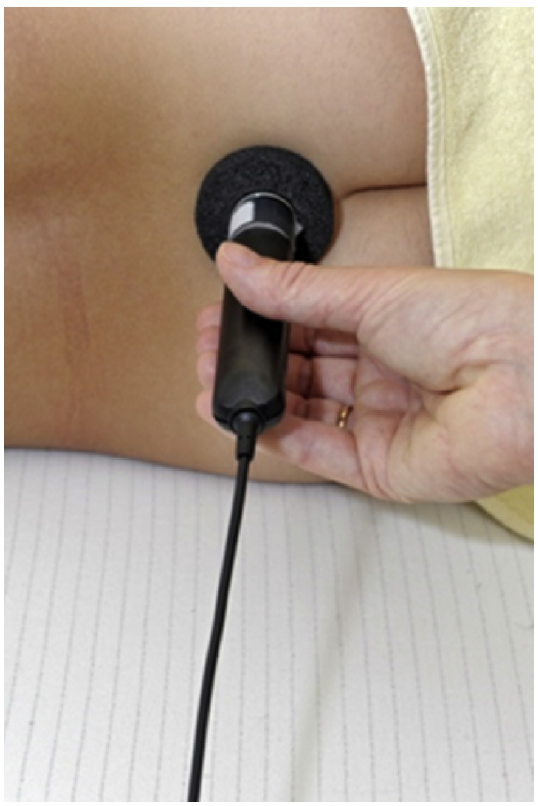

Fig. 1. Illustration of measurement for skin hydration, redness, elasticity exemplified with Mexameter MX 18, Courage + Khazaka.

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