

Research Article

Skin Capacitance Mapping of Eccrine Sweat Gland Activity during Pregnancy

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Abstract. Skin capacitance mapping is a real-time non-invasive method useful in the assessment of eccrine gland activity. We presently revisit and explore the sweat gland production in pregnant women. Sprouts of sweat vapour are progressively increased during pregnancy by recruiting increasing numbers of active sweat pores. An overall moisturization of the stratum corneum ensues in absence of increased liquid sweat production. These aspects are conveniently assessed using skin capacitance mapping. The sweat duct opening could represent an increased way for percutaneous penetration of some xenobiotics during pregnancy.

Keywords: eccrine sweat gland; skin capacitance mapping; pregnancy; imperceptible perspiration

1. Introduction

Eccrine sweat glands (ESG) are dispersed in the deep dermis over the vast part of the body. In general, men sweat more than women do in similar conditions (approximately 800 mL/h for men vs. 450 mL/h for women during physical exercise). When corrected for body surface area, the sweat rate was reported to be about 30–40% higher in men [1].

Eccrine sweating is the response to a set of thermal, emotional and gustatory stimuli. It is under the control of acetylcholine from the cholinergic sympathetic innervation. The resulting increased intracellular Ca^{2+} stimulates loss

of cellular K^+ , Cl^- , and H_2O responsible for eccrine gland cell shrinkage [2]. The volume-activated transcellular and paracellular fluxes of Na^+ , Cl^- , and H_2O , lead to net flux of isotonic NaCl solution into the glandular lumen.

The physiological ESG activity plays an essential role in regulating body temperature. Such a function is altered by a variety of systemic diseases [3, 4]. Fine-tuning objective analytical assessments of discrete aspects of ESG dysfunction has been seldom explored using recent sensitive biometrological methods [1, 4]. However, considering the impact of ESG activities in a variety of physiopathological

conditions, diverse methods are available for recording ESG numbers and assessing their functional status [3].

In the past, ESG activity was commonly reported to be progressively increased during the whole duration of pregnancy [5–8]. Alterations in adrenal gland activity and in autonomic nervous system function produce symptoms and signs of increased vasomotor activity, resulting in excess sweating except on the palms.

Over the past decade, an innovative progress afforded the skin capacitance mapping method representing a specific type of nonoptical skin surface imaging [1, 9–14]. This method relied on fine-tuned electrometric measurements of the skin surface properties. Other electrometric assessments of the upper layers of the epidermis [15] represented a convenient noninvasive way for assessing the stratum corneum hydration. Such properties are conveniently related to a series of specific stratum corneum structures and functions.

In physiological conditions, water is distinctly lost by minimal evaporation through both the interadnexal epidermis [12] and ESG. Basically, three distinct conditions are encountered regarding aspects of skin capacitance mapping of ESG activity [1, 4, 9]. The Moisture Map HM100 device (CK Technology, Visé, Belgium) operates through a multisensor probe generating detailed capacitance measurements at $50\mu\text{m}$ resolution over the stratum corneum. The skin capacitance mapping picture is displayed in a range of gray levels according to each capacitance value. Thus, a nonoptical capacitance map of the skin surface is created. The darker pixels represent high capacitance spots, while the clear ones correspond to lower capacitance values. Skin capacitance is considerably influenced by sweat. Any prolonged contact time beyond about 5 seconds between the stratum corneum and the probe increases the density in darker pixels owing to accumulation of sweat, transepidermal water loss (TEWL), and water saturation of the stratum corneum [1, 15].

Sweating is initially stimulated when acetylcholine is released from periglandular cholinergic nerve endings in response to thermal or emotional stimuli. Acetylcholine binds to cholinergic receptors on the clear cell plasma membrane, stimulating intracellular Ca^{2+} release and influx, and increasing cytosolic Ca^{2+} concentrations [2]. Such condition opens Ca^{2+} -sensitive Cl^- and K^+ channels in the clear cells. Any decrease in cell volume with H_2O release initiates a cascade of cell signalling events. The final product of glandular secretion is the net movement of Na^+ , Cl^- , and H_2O into the glandular lumen to form the isotonic NaCl precursor of sweat. Acetylcholine sweating, which constitutes the bulk of sweat production, appears to be mediated by intracellular Ca^{2+} [2]. In contrast, adrenergic-induced sweating appears to be mediated by increased intracellular cyclic adenosine monophosphate.

The aim of the present study was to revisit the effect of pregnancy on sweating using the method of skin capacitance mapping.

2. Materials and Method

2.1. Design. The study was approved by the Ethic Committee of the University Hospital (B70720084875), and it was performed in accordance with the Declaration of Helsinki. A total of 50 healthy Caucasian pregnant women aged 21–34 years, were enrolled. The volunteers signed an informed consent after the entire procedure of the study had been fully explained. The study started on Spring, 2014 and lasted for 18 months.

2.2. Procedure. At inclusion, the volunteers first rested for 30 min in the dedicated room controlled at $21 \pm 1^\circ\text{C}$ and $53 \pm 2.4\%$ relative humidity. Each volunteer performed a 10-min moderate physical exercise on a cycloergometer aiming at stimulating discrete sweat production without any visible sweat running at the skin surface. Biometrological measurements were carried out before (at rest) and at completion of the physical exercise. Skin temperature was measured using a Skin Thermometer[®] ST500 (C + K electronic, Cologne, Germany). TEWL was measured using a Tewameter[®] TM300 (C + K electronic).

A group of 47 pregnant women aged 23–33 year-old completed the exploratory study. They were healthy and out of drug intakes. Skin capacitance mapping was assessed at various gestational ages. The examinations were performed on the volar aspect of the forearms when volunteers were sitting at rest in a temperature-controlled room ($21 \pm 1^\circ\text{C}$) with stable relative humidity ($53 \pm 2.4\%$). A similar procedure was applied to 28 healthy non-pregnant women of similar ages. All participants were not allowed to use skin care products on the forearms for at least 2 h before testing. Irritant products were also forbidden. Group values of darker skin capacitance mapping areas (%) were given as mean (SD). Differences between groups of different gestational ages were tested with two-sample t tests. A p-value lower than 0.05 was considered statistically different.

3. Results

At the skin capacitance mapping examination, the initial sweat quiescent stage did not show any obvious manifestation. Second, ESG became discretely active in absence of visible sweating, when they emitted only discrete amounts of water vapour (Figure 1).

Skin capacitance mapping combined two major functional aspects affecting the ESG activity and the stratum corneum hydration [4]. On the one hand, a large number of tiny black dots revealed the presence of awaken ESG. Their size and distribution over the skin surface were quite uniform. Some larger dark spots corresponded to both the enlargement and merging of the tiny black dots. On the other hand, the overall skin capacitance mapping background appeared darker, indicating an increased stratum corneum moisture.

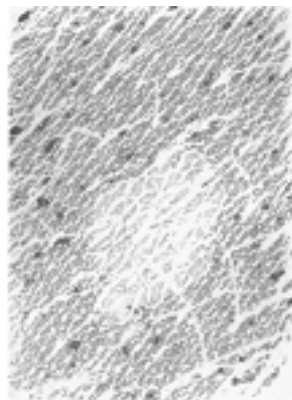


Figure 1: Discrete ESG activity outside a lesion of pityriasis versicolor serving as a negative control.

Table 1: SCM of ESG activity during pregnancy.

Gestation trimester	Area of ESG-SCM	<i>P</i>
1	26.8±10.8	
2	51.9±8.9	0.05
3	83.2±14.7	0.05

These features were reported to be particularly present in the early months of pregnancy.

A progressive increase in ESG activity was observed during pregnancy (Table 1). Significant differences ($P < 0.05$) were found between successive gestation trimesters. The numbers of active ESG was increasing while the black dot sizes were little enlarged.

4. Discussion

Skin capacitance mapping is the simplest procedure to have access to the early and versatile phase of eccrine sweat gland activation. The method is sensitive enough for detecting early signs of activity under various stimulations. It must be stressed that some hyperkeratotic disorders interfere with sweat excretion. Tinea (pityriasis) versicolor and psoriasis represent such conditions where the sweat output is largely curbed [10, 13].

The virtue of this method is its simplicity. The present study did not consider the effects of increased external temperature [16] alterations in desquamations [17] and physical exercise [18–21] on ESG production in pregnant women.

However, this is only achieved when the skin surface is devoid of any material occluding the sweat pores. The aspect of the imperceptible (insensible) perspiration through sweat pores [4] is conveniently observed using skin capacitance mapping when the subject is in a quiet condition without any overheating. Tiny black dots mark the joining up of each discretely active eccrine sweat glands at the stratum corneum surface. Such tiny black dots correspond either to open ESG

ducts or to soft cornified and moisturized caps of stratum corneum [17] cuffing the sweat pores. Such structures likely exhibit a sweat-holding capacity capturing the sweat vapor. There is no perceptible running sweat at that stage of the ESG activity. In such a condition, sweat vapor is apparently emitted in minimal sprouts and the casual TEWL nearly remains unaffected. However, this condition is similarly present in association with an overall increase in interadnexal stratum corneum moisturization. In such instance, TEWL is commonly increased. Third, watery sweat is poured out through active ESG, implying that the skin surface water loss (SSWL) reaches much higher values than the regular vapor TEWL. When sweating is increasing, the black dots of the skin capacitance mapping enlarge, and some of them merge to form irregular black “puddles”. This aspect is more closely related to the skin surface water less than to TEWL. Because sweat appears as black dots, it is possible to measure its contribution to the mean skin capacitance mapping derived gray level by thresholding the values under consideration.

Terminology exerts a confounding influence on the meaning of the tests focused on eccrine sweat gland activity. Obviously, the initial trivial stage of activity without sweat production is difficult to perceive by most usual methods. Both for the purposes of research and for any drug and cosmetic developments, it is important to perceive the nature and extent of eccrine sweat gland response in the physiological range and beyond. A careful study based on controlled environmental condition is warranted.

A whole range of cell functions are regulated by the free cytosolic Ca^{2+} concentration [22].

The functional biology of eccrine sweat glands and their regulatory mechanisms are complex [23] and associated with a variety of immunohistological expressions [5, 24]

Any subtle increase in eccrine sweat gland activity will probably increase the stratum corneum hydration and open some percutaneous penetration pathways [25]. The intra-epidermal duct could be a possibly penetration pathway. Since the sweat gland opens directly to the skin surface, even simple diffusion into the lumen and the surrounding tissue is possible, which is possibly prohibited by the counter-current sweat flow. A possible mechanism relies on changes in the Ca^{2+} intraglandular concentration [2, 22, 26–28].

Whatever risk associated with mild changes in eccrine sweat gland activity, it exists and is extremely small, but not zero. It is possibly linked to possible versatile barrier functions of the skin. All practical steps reducing the risk to the smallest acceptable level of eccrine sweat gland activity must be considered, particularly during scorching heat episodes skin capacitance mapping provides a sensitive method for the direct measurement of subtle eccrine sweat gland activity. Tracking the progress of such activity is now possible using skin capacitance mapping.

Elevation of intracellular Ca^{2+} concentration in epidermal keratinocytes delays barrier recovery IP3 receptor and ryanodine receptor (RyR) are the major Ca^{2+} channels [29].

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