Naif Arab University for Security Sciences
Arab Journal of Forensic Sciences and Forensic Medicine
المجلة العربية لعلوم الأدلة الجنائية والطب الشرعي
https://journals.nauss.edu.sa/index.php/AJFSFM

Quantifying the Relationship Between Skin Temperature and Skin Hydration Measured by Corneometry

قياس العلاقة بين درجة حرارة الجلد وترطيب البشرة المقاسة بقياس القرنية

Aurélien Partoune[1]*, Nadia Dardenne[2], Anne-Françoise Donneau[2], Philippe Boxho[1]

[1] Forensic institute, University of Liège, Liège, Belgium.

[2] Biostatistics unit, public health department, University of Liège, Liège, Belgium.

Received 21 Apr. 2025; accepted 16 Jun. 2025; available online 24 Jun. 2025.

Abstract

The role of the skin in forensic medicine is increasingly recognised, particularly in post mortem interval (PMI) determination through its electrical properties. This study investigates the relationship between stratum corneum hydration (SCH), measured by corneometry, and skin temperature (ST), as literature strongly suggests that variations in skin temperature can influence its electrical properties. Twenty-four (24) adult subjects with known cause of death and characteristics were selected and briefly removed from their mortuary cell. ST (°C) and SCH (a.u.) were measured immediately and then at 5-minute intervals for 20 minutes using the Skin-Thermometer ST 500® and Corneometer CM-825® (Courage & Khazaka electronic GmbH, Cologne, Germany) at 3 body sites (cheekbone, abdomen and index finger). The results show a significant inverse relationship between ST and SCH, with a unit decrease in SCH for each unit increase in ST (-1.21 ± 0.55, p=0.028). This relationship was site-dependent (p <0.0001) but not influenced by time since removal from the mortuary cell (RMCT) (p = 0.15), sex (p = 0.39) or PMI (p = 0.88). The results highlight the need for careful consideration of skin temperature when assessing skin hydration, in order to accurately interpret post mortem changes in skin electrical properties, particularly when determining the post mortem interval (PMI).

Keywords: Forensic sciences, post mortem interval, skin temperature, skin hydration, skin capacitance, corneometer CM-825®.

المستخلص

يتزايد الاعتراف بدور الجلد في الطب الشرعي، لا سيما في تحديد فترة ما بعد الوفاة (PMI) من خلال خصائصه الكهربائية. وتبحث هذه الدراسة في العلاقة بين ترطيب الطبقة القرنية (SCH)، التي تقاس بقياس القرنية، ودرجة حرارة الجلد (ST)، حيث تشير الأدبيات بقوة إلى أن الاختلافات في درجة حرارة الجلد يمكن أن تؤثر على خصائصه الكهربائية. تم اختيار أربعة وعشرين (24) شخصًا بالغًا (24) لديهم سبب وفاة معروف وخصائص معروفة وتم إخراجهم لفترة وجيزة من زنزانة الجثث. تم قياس درجة حرارة الجلد (درجة مئوية) و SCH (وحدة قياس درجة الحرارة) على الفور ثم على فترات زمنية مدتها 5 دقائق لمدة 20 دقيقة باستخدام مقياس حرارة الجلد ST 500® ومقياس القرنية CM-825® (شركة كوريج وخازاكا الإلكترونية GmbH، كولونيا، ألمانيا) في 3 مواقع من الجسم (عظم الوجنة والبطن والسبابة). أظهرت النتائج وجود علاقة عكسية كبيرة بين ST و SCH، مع انخفاض وحدة في SCH لكل وحدة زيادة في ST (-1.21 ± 0.55، p=0.028). كانت هذه العلاقة معتمدة على الموقع (p <0.0001) ولكنها لم تتأثر بالوقت منذ الإزالة من غرفة حفظ الجثث (RMCT) (p = 0.15) أو الجنس (p = 0.39) أو فترة ما بعد الوفاة (p = 0.88). تسلط النتائج الضوء على الحاجة إلى النظر بعناية في درجة حرارة الجلد عند تقييم ترطيب الجلد، من أجل تفسير التغيرات في الخصائص الكهربائية للجلد بعد الوفاة بدقة، خاصة عند تحديد الفترة الزمنية بعد الوفاة (PMI).

الكلمات المفتاحية: علوم الأدلة الجنائية، الفاصل الزمني بعد الوفاة؛ درجة حرارة الجلد؛ ترطيب الجلد؛ سعة الجلد؛ مقياس القرنية CM-825®.

Production and hosting by NAUSS

* Corresponding Author: Aurélien Partoune
Email: apartoune@uliege.be

doi: 10.26735/NAHQ5744

1. Introduction

The integumentary system is garnering increasing attention within the realm of forensic medicine, particularly concerning the assessment of postmortem interval (PMI) determination. Recent investigations have focused on the quantification of skin expression levels of various protein and RNA markers, including the immunohistochemical identification of HMGB1 and associated proteins (such as Beclin1 and RAGE) [1], the evaluation of mRNA concentrations pertaining to apoptosis-related proteins Bax and Bcl-2 [2], the analysis of the skin-specific mRNA marker late cornified envelope 1C (LCE1C) [3], the RNA quantification of matrix metalloproteinase-9 (MMP-9) alongside long non-coding fatty acid oxidation (lncFAO) [4], as well as skin clinical changes [5-7] and the delineation of skin histopathological alterations [8-11].

As an adjunct to research into PMI, the study of the electrical properties of skin, as an indirect, non-invasive, objective and quantitative measure of skin hydration levels [12-13], could be of interest for a better understanding of natural mummification, as well as and post mortem phenomenon of desiccation or maceration of the skin. Indeed, insufficient understanding of post-mortem desiccation processes may lead to inaccurate PMI estimations in forensic analysis [6,7,14,15], with existing terminologies like "mummification" and "desiccation" lacking precise definitions, as evidenced by contrasting descriptions of indoor desiccation patterns by Ceciliason et al. [14] compared to Galloway's first historical account [16].

In practice, in our previous study [17], we proposed the use of the Corneometer CM-825® (Courage & Khazaka electronic GmbH, Cologne, Germany) to better understand the skin desiccation process through the measure of the electrical properties of the skin at a depth of 30 to 45 μm, which is deemed to correspond to the average thickness of the stratum corneum [18]. This method, usually referred to as corneometry, would have several advantages for the study of skin desiccation process as it is non-invasive, validated in vitro and in vivo in multicentre studies [18-20] and potentially used wirelessly with a laptop "at the bedside" of the deceased by any examiner in forensic context [21]. However, like previous studies on the subject [22-23], we came up against the parameter of skin temperature, the exact influence of which on skin hydration and electrical properties remains to be determined.

Forensic literature suggests a link between post mortem interval (PMI) and the electrical properties of skin, both in non-human proxies [22] and, more recently, in human donor bodies placed in outdoor conditions [23], in the form of a progressive decrease in electrical impedance. In his paper, Querido [22] investigates the relationship between abdominal impedance and PMI, focusing on eliminating temperature change as a confounding factor. It employs a methodology that records deep abdominal temperature during impedance measurement, correcting values to a standard temperature of 40°C. The findings indicate that temperature-correction significantly improves the correlation between impedance and PMI. In their paper, Hansen et al [23] investigate the estimation of PMI using bioelectrical impedance analysis (BIA), hypothesizing that a cadaver behaves like a resistor-capacitor (RC) circuit whose impedance (Z) changes during decomposition. The study revealed a statistically significant parabolic relationship between impedance and PMI. However, they acknowledge that further research is needed to refine the technique and develop predictive models, especially as the effects of temperature, including skin temperature (ST), on BIA measurements were not fully addressed.

Berardesca [24] was the first one to our knowledge to discusses the relationship between skin conductance and skin temperature, indicating that skin conductance depends on both water content and skin temperature. It emphasizes that the electrical approaches to assessing skin hydration must consider skin temperature changes as a significant variable and suggests that effective standardization of skin temperature changes is essential for accurate measurements in studies [24], but he did not quantify the effect of skin temperature and did not mention it again in his later work on the use of skin capacitance as a non-invasive diagnostic technique [18].

Following the literature, the relationship between skin temperature and skin hydration, as measured by corneometry, seems thus to be very likely. However, the exact nature of this relationship does not appear to have been established. Therefore, we considered it essential to characterise and quantify this relationship in order to determine the extent to which skin temperature influences the apparent inter- and intra-individual variability of SCH [17] and the extent to which post mortem ST changes can explain a variation in skin electrical properties, regardless of PMI.

2. Material & Method

2.1. Design

To investigate the relationship between skin temperature (ST) and stratum corneum hydration (SCH), 24 adult subjects who had died of natural causes and had not been autopsied were selected, irrespective of their individual characteristics and PMI. After setting up the equipment (see below), a stopwatch was started and the subject was removed from its mortuary cell for a total of 20 minutes. The cotton sheet covering the body (for ethical reason, according to usual morgue's protocol) in the open plastic body bag (to avoid excessive humidity, according to usual morgue's protocol) was removed. Any condensation on the skin surface was gently blotted with a cotton cloth. Skin temperature (1 measurement per site) and SCH (3 contiguous iterative measurements per site) were then measured for the first time at 3 body sites (cheekbone, abdomen, index) in less than one minute (T0 = 0 min), and then repeated (in less than one minute) at 5-minutes intervals for a total of 20 minutes after the subject was removed from its mortuary cell (T1 = 5 min, T2 = 10 min, T3 = 15 min, and T4 = 20 min after removal of mortuary cell). The cotton sheet initially covering the subject was then replaced and the subject was finally returned to its mortuary cell.

2.2. Probes

The wireless Corneometer CM-825® (Courage & Khazaka electronic GmbH, Cologne, Germany) is a 22 cm surface probe with a flat surface of 49 mm2 inside which is a capacitor subjected to an alternating current of 0.9 to 1.2 Mhz. When the skin is attached to this capacitor as a dielectric, it changes its capacitive reactance depending on its dielectric constant (K), which in turn is a function of the skin's moisture content [25]. This instrument does not generate galvanic current, performs a measurement in 1 second and has an inaccuracy rate of ±3% following manufacturer [21]. The maximal measurement depth over 30 μm according to the producer [21] and up to 45 μm according to in vitro measurements by independent source [12]. The level of hydration is not given in absolute electrical capacitance units (Farads (F)), but indirectly, in arbitrary units (a.u.) on a scale from 0 to 120, from the driest to the most hydrated (18). A skin is considered as normally hydrated >40 a.u., as dry between 30 and 40 a.u. and as "very" dry <30 a.u. [18]. The probe is reputed to be very sensitive for dry and very dry skin conditions, but

less sensitive for high levels of skin hydration [18]. The device is factory calibrated by an in vitro method with a reference pad impregnated with a calibration solution (saturated aqueous NaCl solution). The maximum reference hydration value of 120 a.u. is obtained by measuring the hydration level of this impregnated filter pad. The minimum hydration value is determined by covering the surface of the impregnated pad with a layer of 15 μm thick polyurethane foil [25].

The wireless Skin-Thermometer ST 500® (Courage & Khazaka electronic GmbH, Cologne, Germany) measures the surface temperature of the skin. The measurement is based on the non-contact infrared detection of its emission from the skin by a sensor. In living humans, skin temperature is mainly determined by microcirculation: the less blood circulates in a given area of skin, the lower the temperature. It allows very fast measurements (1 s). The resolution is 0.1°C and the measurement uncertainty for absolute temperature measurements is ± 0.8° C. The non-contact measurement ensures that the subject's skin is not affected. The temperature is expressed in °C.

The wireless probes transmit the measurement data by radio and via a receiver unit RR-200 (connected to the computer via USB) to the MPA WLplus software (Courage & Khazaka electronic GmbH, Cologne, Germany). The values can be transmitted from a distance of 5 to 10 meters.

2.3. Body sites

Three specific body sites were chosen for this study: the cheekbone (at the highest point of the underlying zygomatic relief), the abdomen (a finger's breadth above the umbilicus) and the index finger (at the pad of the finger).

The choice of these anatomical sites is the result of the following reasoning. Body sites that were difficult to access were excluded for practical (the need to take all the measurements in less than 1 minute) and ethical reasons (to avoid turning the bodies over). Sites located on the back of the body were therefore excluded. For the same practical reasons, we have chosen to limit ourselves to 3 different locations.

In accordance with the results of our previous study [17], which shows that the segments that do not differ from each other are the anterior aspect of the abdomen from the lower limb and the posterior abdomen from the head and upper limb. As a result, we chose one body site for the head, one for the upper limb and one for the anterior aspect of the abdomen.

The pad of the index finger seemed particularly appropriate as this site is often subject to early post mortem desiccation [26]. The choice of the cheekbone for the head segment was justified by the fact that this site appears to be subject to less inter-individual variability than adjacent sites at cephalic level [17]. The choice of the umbilicus for the abdomen segment was justified by the fact that this site appears to be subject to less inter-individual variability than adjacent sites at abdominal level [17].

2.4. Subjects and environment characteristics

The study involved 24 subjects. Given the exploratory nature of the study, as the exact relation between the variables was not yet known, the sample size was empirically estimated on the basis of our preliminary study (unpublished data) and by comparison with the sample sizes used in studies of this parameter in living subjects in literature [17-19].

Selection criteria were the following: adults, no previous autopsy, natural death, no dermatological pathology at measurement site. In this case, our subjects were recruited during one summer

in Belgium, as some studies mention seasonal variations in SCH (20-22).

All subjects were selected from the mortuary of the local University Hospital and studied in the controlled environment of the mortuary's fridges. In accordance with the hospital's internal procedure, the deceased is placed in a refrigerated mortuary cell within 3 hours of death. The refrigerated mortuary system measures 240 cm x 210 cm x 204 cm and involves 4 individual mortuary cells, where each deceased person is placed in an open plastic body bag on a stainless-steel tray measuring 210 cm x 60 cm, then covered with a white cotton sheet. Cooling is provided by means of a conventional condensation/expansion/evaporation refrigeration cycle, with an evaporator located in the cell providing cooling by capturing heat and transferring it to a refrigerant, while the heat is extracted via a ventilated air-cooled condenser located above the cell. The stability of the environment is controlled on the basis of temperature only, not humidity, using an electronic temperature controller which is given minimal and maximal reference values of 1 and 6 °C respectively. In practice, the average temperature is between 3.79 and 3.95°C and the average relative humidity (RH) is between 83 and 87% [17]. In the event of an anomaly, an audible alarm alerts the staff of the mortuary. No incident was reported during the study period and no alarm was triggered for the subjects recruited.

2.5. Measurements

The probes heads are cleaned after each subject. As a result of the Corneometer CM-825® operating principle, there is an influence of probe application pressure and any interposed substance (including hairs) between the studied skin and the probe. The influence of probe application pressure is supposed to be cancelled by means of a spring system theoretically enabled with a force between 1.1 and 1.8 Newton, with measurement realization indicated by an acoustic signal [21]. To obtain the most repeatable values possible while eliminating the influence of the operator hand pressure, the measurements were carried out using a low and increasing pressure until the minimum threshold for obtaining the acoustic signal from the device was reached. To avoid influence of any interposed substance, skin at measurement site is cleaned and dried before and between measurement(s) by gently dabbing it with a soft towel [24]. Influence of excessive hairiness could have be cancelled out by gentle shaving with a non-electric razor [27], but was not necessary in practice. Measurements were performed outside of the mortuary fridge in a room with ambient conditions of 19-23°C and 40-60% relative humidity (RH). No measurement was made under direct sunlight or any heating device. To avoid occlusion phenomenon, the repeated measurements were made using adjacent skin areas. The SCH value retained, for each body site and for each interval, is the average of three consecutive measurements made on one site at one second interval. The calibration of the device was checked before and after the study was carried out, in accordance with the manufacturer's instructions.

2.6. Statistics

Quantitative parameters were summarised using the mean and standard deviation (SD). Qualitative parameters were expressed in terms of numbers and frequencies.

The association between stratum corneum hydration (SCH) and skin temperature (ST) was investigated and analysed using a generalized linear mixed model (GLMM) to allow both fixed and random effects, with the assumption that there was non-independence in the concerned

parameters. This model, adjusted for biological sex and PMI, also examined the effect of location and time since removal of the body from the mortuary cell. The models were compared using the Akaike Information Criterion (AIC). The normality and homoscedasticity of the residuals were verified. The variance-covariance structure was compound symmetry (CS).

The uncertainty level was set at 5% ($p < 0.05$). The software used was SAS (version 9.4).

The graphical representations were produced using Julius (Julius AI©, San Francisco, California, United States), an AI-powered large language model [Computer software] trained for data science and analysis tasks, with capabilities including data analysis and visualization, document processing and text analysis, image analysis, code execution and debugging and statistical analysis.

2.7. Ethical considerations

The study has been performed with agreement of the local Ethics Committee. The data collection was strictly non-invasive, did not interfere with the normal funeral process or with usual morgue's protocols. Informed consent was not sought from the family of the deceased. Measurements were strictly made outside of visiting hours. Measurements outside the mortuary cell took about 20 minutes, a time that does not result in any alteration to the body. The absence of ante-mortem opposition to the experiment was verified in the national register before recruitment into the study. Each patient has been anonymized. All data have been numerically stored and managed in a GDPR (General Data Protection Regulation of the European Union) compliant manner.

3. Results

The sample consisted of 9 (37.5%) men and 15 (62.5%) women. Mean age is 64,8±12,2 years. Mean post mortem interval (PMI) is (15-38.5) hours (Appendix 1).

Table 1 shows the main parameters: stratum corneum hydration (SCH) and skin temperature (ST) as a function of the site and the time elapsed since removal from the mortuary cell (RMCT).

The relationship between RMCT and ST is a gradual warming of the skin, which varies from one part of the body to another: index finger: +5.64°C mean temperature in 20 minutes, compared with +3.49°C on the abdomen and +2.89°C on the cheekbone (Table 1).

The relationship between the RMCT and the

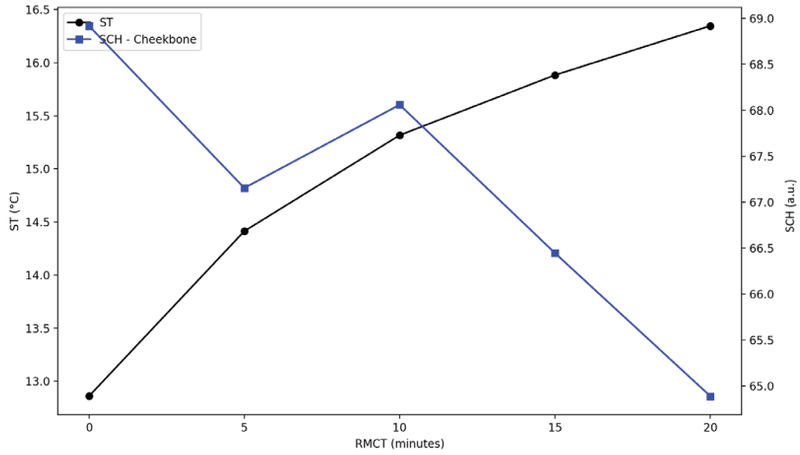

Figure 1- *Mean skin temperature (ST) and mean stratum corneum hydration (SCH) vs removal from mortuary cell time (RMCT) at cheekbone level.*

Table 1- *Description of SCH and ST according to RMCT and Body Site (n=24)*

RMCT (min)	Body Site	Variable	N	Mean (±SD)
0	Cheekbone	ST	24	12.86°C (±2.94)
		SCH	24	68.92 a.u. (±23.82)
	Abdomen	ST	24	14.44°C (±4.12)
		SCH	24	37.93 a.u. (±22.58)
	Index Finger	ST	24	11.66°C (±2.91)
		SCH	24	43.79 a.u. (±18.15)
5	Cheekbone	ST	24	14.41°C (±2.87)
		SCH	24	67.15 a.u. (±23.74)
	Abdomen	ST	24	15.75°C (±3.89)
		SCH	24	38.52 a.u. (±21.77)
	Index Finger	ST	24	13.77°C (±2.54)
		SCH	24	44.47 a.u. (±16.20)
10	Cheekbone	ST	24	15.32°C (±2.69)
		SCH	24	68.06 a.u. (±24.95)
	Abdomen	ST	24	16.54°C (±3.72)
		SCH	24	38.46 a.u. (±22.58)
	Index Finger	ST	24	15.48°C (±2.47)
		SCH	24	41.95 a.u. (±15.25)
15	Cheekbone	ST	24	15.88°C (±2.60)
		SCH	24	66.45 a.u. (±23.17)
	Abdomen	ST	24	17.00°C (±3.69)
		SCH	24	36.97 a.u. (±22.09)
	Index Finger	ST	24	16.69°C (±2.29)
		SCH	24	40.96 a.u. (±14.47)
20	Cheekbone	ST	24	16.35°C (±2.48)
		SCH	24	64.89 a.u. (±23.10)
	Abdomen	ST	24	17.33°C (±3.66)
		SCH	24	33.97 a.u. (±20.56)
	Index Finger	ST	24	17.30°C (±2.30)
		SCH	24	38.63 a.u. (±12.87)

SCH, on the other hand, shows a progressive decrease of SCH at each body site, which also varies from one part of the body to another: index finger: -5,16 a.u. of mean SCH in 20 minutes, compared with -4,03 a.u. on the cheekbone and -3,96 a.u. on the abdomen (Table 1).

The graphic representations of the relationship between skin temperature (ST) and stratum corneum hydration (SCH) according to time elapsed since removal from the mortuary cell (RMCT) shows that there is an inverse relationship between ST and SCH, regardless of the body site chosen (Figures 1 to 3).

Various statistical models were performed and then compared using the Akaike Information Criterion (AIC). Full results are shown in Appendix II. There was a significant decrease of SCH with each unit increase in skin temperature (-1.21 ± 0.55, p=0.028) at each body site chosen and regardless

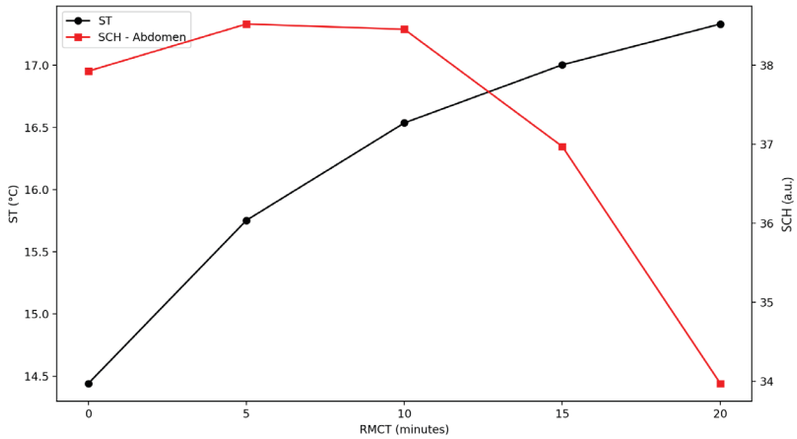

Figure 2- *Mean skin temperature (ST) and mean stratum corneum hydration (SCH) vs removal from mortuary cell rime (RMCT) at abdomen level.*

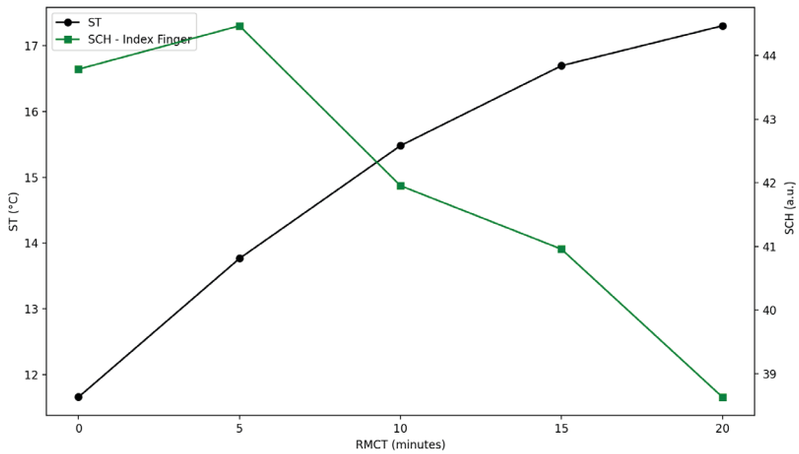

Figure 3- Mean skin temperature (ST) and mean stratum corneum hydration (SCH) vs removal from mortuary cell time (RMCT) at index finger level.

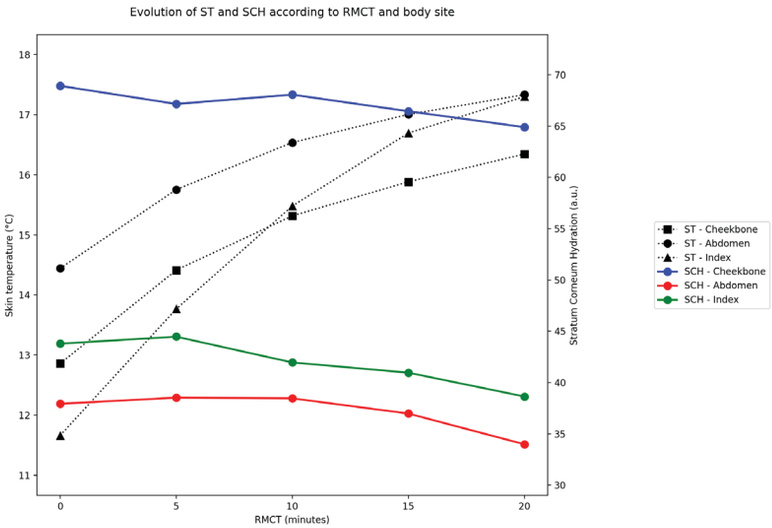

Figure 4- Relationship between mean ST and mean SCH at the level of the three body sites considered.

Table 2- *Model of SCH according to ST, site and RMCT (n = 24).*

Factor	Coefficient ± SE	p-value
Skin Temperature (ST)	-1.21 ± 0.55	0.028
ST × Cheekbone (vs. Index)	-1.64 ± 0.55	0.003
ST × Abdomen (vs. Index)	-1.71 ± 0.48	0.0019
RMCT	0.19 ± 0.13	0.15
Sex	—	0.39
PMI	—	0.88

of the fact that the hydration of skin was significantly higher at the level of the cheekbone than at the level of the other two body sites, as in our previous study (17). Graphical representation of this comparison is given in Figure 4.

In addition, this relationship was significantly dependent on site ($p < 0.0001$) but not on time since removal from the mortuary cell (RMCT) ($p = 0.15$). There was no effect of sex ($p = 0.39$) or PMI on SCH ($p = 0.88$). The results are summarized in Table 2.

The compound symmetry variance (248.78) suggests significant correlation between repeated measurements and the residual variance (157.59) indicates substantial variation that isn't explained by the fixed effects. Obtained values indicate that the model structure explains about 61.2% of the total variance.

4. Discussion

Provided that the size of our sample remains relatively small, skin temperature seems to significantly influence the SCH, independently of the PMI, with a decrease of about one SCH unit for each 1°C increase in skin temperature.

The theoretical model of the Corneometer CM-825® implies that the stratum corneum is considered as a dielectric placed in parallel with a capacitor (the probe), to which an alternating current (AC) is applied in order to determine the level of skin hydration as a function of its impedance (28). The electrical capacitance of the skin is therefore a function of its impedance. Impedance quantifies the resistance to electric current flow through the skin, which is notably influenced by its dielectric constant (also referred as its permittivity) (29). Dielectric constant is the resultant of the polarizability of the atoms and molecules constituting it, and therefore this value is a function of its temperature, as thermal energy amplifies atomic and molecular agitation (following Arrhenius and Van 't Hoff Laws) (24). Therefore, an increase in temperature leads to an increase in the thermal agitation of the molecules, which disturbs the electric dipoles (polar molecules or ions) and makes them less able to realign quickly with the applied electric field. As a result, the polarisation of the medium decreases, leading to a reduction in the dielectric constant.

The electrical capacitance of a capacitor is given by the formula : $C = (\varepsilon 0 \, . \, \varepsilon r \, . \, A) / D$ where : C is the capacitance ; $\varepsilon 0$ is the permittivity of vacuum, εr is the dielectric constant of the medium (or relative permittivity) ; A is the surface area of the capacitor plates and D is the distance between the plates. If the dielectric constant εr decreases, the capacitance C also decreases, because capacitance is directly proportional to εr. In other words, the lower the dielectric constant of a medium, the lower the capacity of a capacitor to store

energy. The observed relationship between skin temperature (ST) and stratum corneum hydration (SCH) was thus physically predictable. However, it was interesting to determine empirically the link between SCH and ST insofar as we could fear the occurrence of intercurrent phenomena.

Firstly, Corneometer CM-825® actually measures the level of free-water in the SC (30), and not its absolute level of hydration, which include free-water and protein-bound water (31). And free-water content of the SC increases with rising temperatures, particularly at lower relative humidity (RH) levels. For instance, a temperature increase from 20 to 35 °C can lead to a 50% increase in SC water content at RH below 60% (32). At higher RH levels, the temperature's impact on water content diminishes, indicating that temperature effect is not linear and more pronounced in drier conditions (32).

Furthermore, our methodology requires the body to be moved from the artificially refrigerated environment of mortuary cell (mean T° = 3,95°C, mean RH = 83%) to the warmer and moister environment of mortuary room (mean T° = 20°C, mean RH = 50%). Calculating the the amount of water in the air in terms of actual vapour pressure difference between the two environments, we find that it is 6.37 hPa in the mortuary cell compared with 11.69 hPa in the mortuary room, i.e. almost twice the humidity. This is not insignificant when the literature tells us that the SC reacts rapidly to an increase in ambient humidity, with an average thickness doubling in 90 minutes when 120 microlitres of distilled water is applied, through a 6 x 6 mm cotton patch, to stratum corneum (33). This led us to consider a potential passive increase in SCH linked to the acclimatisation of the SC to its new environment.

And indeed, our results suggest that while ST and body site are important predictors of SCH, there are other factors contributing to SCH variation that aren't captured by our current linear model. Sources of unexplained variance could be individual-specific characteristics, measurement error, other unmeasured environmental factors that could influence SCH and a possible non-linear relationship between SCH and ST.

It is also interesting to note that the link between ST and SCH varies depending on the anatomical site considered. This may be explained by the specific morphological and functional characteristics of the skin at these different sites and in particular by variations in stratum corneum thickness (SCT). Indeed, SCT may be measured at less than 45 μm. In our case, the mean SCT at the cheekbone has been reported to be approximately 16.8 micrometers in healthy subjects, using confocal Raman spectroscopy (33), compared to 173 µm at the thenar eminence, which is likely similar to the fingertips due to similar mechanical stress exposure (17) and 12 μm at the abdominal region (34). This variability has the potential to affect the results of the measurements, as the water content (expressed as a percentage of mass relative to 100 grams of wet tissue) tends to increase from the surface towards the deeper layers of the epidermis, exhibiting a fluctuating rate of 20 to 40% at the surface (stratum corneum), and a consistent rate of 70% within the basal stratum granulosum (regardless of anatomical site) (35). Consequently, the values obtained through corneometry may reflect – contingent upon the selected anatomical location – either the most superficial layer of the stratum corneum (at index level) or an entire segment of the epidermis, which is estimated to range in thickness from 61 to 84 μm at the umbilicus (34) and from 59 to 95 μm at the cheek (36).

5. Conclusion

In conclusion, this study successfully quantified the relationship between skin temperature (ST)

and stratum corneum hydration (SCH) using the Corneometer CM-825® at various body sites, in a post mortem context. The findings indicate a significant inverse relationship between ST and SCH, with an increase in skin temperature corresponding to a decrease in hydration levels. This relationship was found to be site-dependent, highlighting the importance of anatomical variations in skin properties.

The results underscore the necessity for careful consideration of skin temperature when assessing skin hydration, particularly for postmortem interval (PMI) determination. Overall, this study contributes valuable insights into the interplay between skin temperature and its electrical properties, enhancing the forensic community's ability to interpret post mortem skin electrical properties changes accurately.

Future research should focus on the evolution of SCH as a function of PMI after the temperature has reached stable equilibrium with a stable ambient temperature.

Conflict of interest

The authors declare no conflicts of interest.

Source of funding

The authors received no financial support for the research, authorship or publication of this paper.

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Appendix I- *Subjects characteristics (n = 24)*

Variable	N	Mean	SD	P25	P50	P75	Min	Max
Age (years)	24	64,83	12.18	52.00	69.50	72.50	43.00	89.00
PMI (hours)	24	36.96	43.47	15.00	20.50	38.50	9.00	170.00

Appendix II- *Generalized linear mixed modelling of SCH according to ST, site and RMCT (n = 24) with models comparison using the Akaike Information Criterion (AIC).*

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6*
Variables	**Coef ± SE (p)**	**Coef ± SE (p)**	**Coef ± SE (p)**	**Coef ± SE (p)**	**Coef ± SE (p)**	**Coef ± SE (p)**
ST	-2.61 ± 0.42	-1.80 ± 0.32	-0.73 ± 0.42	-3.60 ± 0.53	-3.07 ± 0.60	-1.21 ± 0.55
	(<0.0001)	(< 0.0001)	(0.086)	(<0.0001)	(<0.0001)	(0.028)
Site		(< 0.0001)	(< 0.0001)			(<0.0001)
Cheekbone vs Index		25.1 ± 1.65	49.6 ± 8.37			49.6 ± 8.35
		(< 0.0001)	(<0.001)			(<0.0001)
Abdomen vs Index		-2.57 ± 1.70	23.78 ± 7.66			21.8 ± 7.75
		(0.14)	(0.0032)			(0.0073)
ST*Site			(0.0009)			(0.0021)
Cheekbone vs Index			-1.64 ± 0.55			-1.64 ± 0.55
			(0.0031)			(0.0030)
Abdomen vs Index			-1.71 ± 0.48			-1.71 ± 0.48
			(0.0005)			(0.0019)
RMCT				0.50 ± 0.17	1.80 ± 0.66	0.19 ± 0.13
				(0.0035)	(0.0066)	(0.15)
ST*RMCT					-0.082 ± 0.040	
					(0.043)	
AIC	3162.0	2923.5	2908.6	3155.3	3155.7	2905.1
CS	234.68	235.21	231.75	261.24	371.27	248.78
Residual	326.12	164.14	158.43	316.89	313.22	157.59

*Adjusted by gender and PMI