

SHORT REPORTS

Physiological Skin Surface Water Loss Dynamics of Human Vulvar and Forearm Skin

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In order to estimate the influence of occlusion and sweating on forearm and vulvar skin surface water loss (SSWL), both were measured simultaneously and continuously for 30 min in 8 healthy women. Vulvar SSWL decreased significantly during the measuring period from $24.9 \pm 5.2 \text{ gm}^{-2}\text{h}^{-1}$ (mean \pm standard error of the mean) in the first 5 min, to $13.4 \pm 1.7 \text{ gm}^{-2}\text{h}^{-1}$ in the last 5 min ($p < 0.05$), whereas no significant changes were observed in forearm SSWL. The vulvar SSWL decay curve followed a logarithmic equation of the form $y = a * t^b$. Irregular SSWL increases ('bursts') were observed in vulvar (but not in forearm) skin of 7 out of 8 women. These SSWL bursts were considered to be caused by sweating. The study shows possible causes of systematic errors in vulvar irritation studies. Methods for error reduction are discussed. **Key words:** Skin physiology; TEWL.

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Transepidermal water loss (TEWL) measurement is increasingly used for the study of irritant dermatitis in man, since TEWL has been shown to be a sensitive indicator of epidermal barrier function, i.e. the ability of the stratum corneum to retain body water (1). Since vulvar irritant contact dermatitis may be difficult to diagnose with the naked eye and since irritation data from forearm skin cannot be simply extrapolated to vulvar skin (2, 3), it would be helpful if TEWL measurement could be used as a tool for the objective assessment of irritant dermatitis in vulvar skin. However, water loss measured at the skin surface (skin surface water loss, SSWL) is not equal to TEWL in all situations but may be influenced by other factors such as occlusion and sweating. Occlusion is not of usual concern on the forearm or the back where irritation studies are usually performed. It is of

concern, however, for irritation studies on vulvar skin (skin/skin occlusion and skin/garment occlusion). Since occlusion can be detected by measuring SSWL for a prolonged period of time (postocclusion SSWL decay curve), we studied time-dependent vulvar and forearm SSWL changes in 8 healthy female volunteers.

MATERIAL AND METHODS

Study population

Eight healthy female volunteers entered the study after giving informed consent. The study had been approved by the UCSF Committee for Human Research. The women were between 25 and 49 years old (mean 33.8, standard error of the mean (SEM) 2.8 years).

Measurements

All measurements were performed after the subjects had been physically inactive for at least 15 min. The measurements were taken in a quiet room under neutral environmental circumstances (room temperature 20-23°C, relative humidity 48-57%). For the time of the measurements, the women lay at rest on a gynecological examination chair in a relaxed position. One day before measurements were made on vulvar skin, labia majora hairs had been clipped. SSWL was measured on forearm and vulvar skin simultaneously with two evaporimeters (Servo Med Ep 1, Servo Med, Stockholm, Sweden) (4). The hand-held probe was fitted with a 1-cm tail cimney extension to reduce air turbulence around the hydro-sensors and the metallic shield (supplied by Servo Med) minimized the possibility of sensor contamination. For the time of the measurements (30 min) the evaporimeter probes were attached to the forearm and vulvar skin with adhesive tape. Causing any occlusion was carefully avoided. Skin temperature was monitored by placing a thermistor (Tele-Thermometer, Yellow Springs Instruments, Yellow Springs, Ohio) on the skin surface.

Forearm and vulvar skin SSWL were measured simultaneously and continuously for 30 min. The analog signals from the evaporimeters were digitized using an AD-converter board (MetraByte DAS 16, MetraByte Corp., Tautan, Mass.) installed in an IBM AT-compatible computer. The sampling rate was set at one measurement per second. The data were fed directly into a spreadsheet (Lotus 1-2-3™ with Lotus Measure™). SSWL values were converted to values at a standard reference temperature of 30°C as previously described (5).

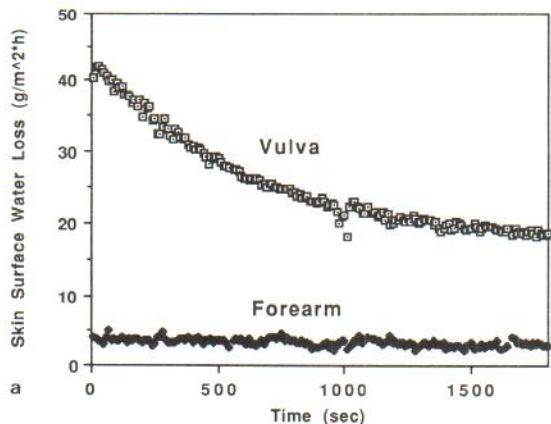
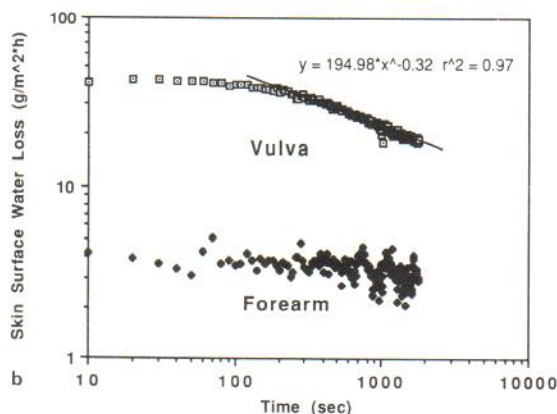


Fig. 1 (a, b). Typical skin surface water loss (SSWL) curves of forearm and vulvar skin monitored for 30 min (1800 s) from one volunteer (volunteer H). After taking the logarithm to the base 10 of both axes, the vulvar decay curve becomes linear



Statistical methods

For statistical analysis, data reduction (reduction ratio 1:10) was performed by calculating arithmetic means for 10-second intervals.

Statistical computations were performed with a statistical package (SPSS-PC+™, SPSS, Chicago, Ill.) on an IBM XT-compatible computer.

To calculate the means for the first 5 min and the last 5 min of the measuring period, the means of all observations in these periods were calculated for each volunteer first. From these data, $M \pm SE$ were calculated for the study population. Differences between means were checked for significance using the *t*-test for paired data.

For vulvar SSWL, the decay curves of each volunteer were transformed to a single- and a double logarithmic scale and fitted with a regression line using the least-square method. The intercept and the slope of the decay curves were computed using the procedure CORRELATION.

RESULTS

Whereas no significant time-dependent changes were noted for forearm skin SSWL, vulvar skin SSWL showed a significant decrease during the measuring interval (Table I). The decay curves were highly characteristic (Fig. 1a). Changing the ordinate to logarithmic scale did not linearize the decay curves, which was accomplished only after applying a double-logarithmic scale (Fig. 1b). The first 10 to 15 values, however, corresponding to a time frame of 100 to 150 s, did not fall on the line calculated from the rest of the data. This is probably due to the limitations of the measuring device, which responds slowly and gives inaccurately low readings at high SSWLs.

except for the first 150 s, when measured values are too low due to delayed sensor response and limited sensor sensitivity at high values.

The decay curve is best described by the following equation:

$$SSWL = a * t^b,$$

where *t* is time, *a* is a constant equalling SSWL at the time of 1 second and *b* is a constant and the slope of the linear decay curve which results after taking the log to the base of 10 of both sides of the equation:

$$\log_{10}(SSWL) = \log_{10}(a) + b * \log_{10}(t).$$

In addition to the gradual SSWL decay, sudden vulvar SSWL increases were noted which most probably corresponded to sweat bursts. On forearm skin, these bursts were not observed. Fig. 2 shows both SSWL decay and at least 4 SSWL bursts in one volunteer.

Table II summarizes the results. Except for volunteer D, who did not show a significant vulvar SSWL decrease and consequently had a small correlation coefficient, the data from the other volunteers correspond closely to the above equation. An average of 2

Table I. Changes in skin surface water loss (SSWL, $gm^{-2}h^{-1}$) of forearm and vulvar skin during a 30 minute observation period ($N=8$)

	First 5 min	Last 5 min	p-value
Vulva	24.9 ± 5.2	13.4 ± 1.7	<0.05
Forearm	4.4 ± 0.4	3.8 ± 0.7	n.s.
P-value	<0.01	<0.01	

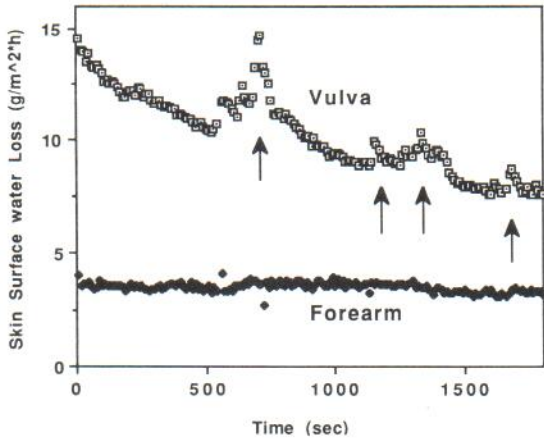


Fig. 2. Skin surface water loss (SSWL) curves of forearm and vulvar skin monitored for 30 min (1800 s) (volunteer C). SSWL bursts (episodes of sweating) are indicated by arrows.

sweat bursts were noted per volunteer (range 0 to 5 bursts). A SSWL burst is defined as a transient SSWL increase of >2 units lasting for a minimum of 30 s. SSWL bursts are attributed to episodes of sweating. Table II shows that up to 5 SSWL bursts were seen in 7 out of 8 women. No correlation between the frequency of sweat bursts and the absolute SSWL was observed.

DISCUSSION

The SSWL time curves of untreated vulvar skin strikingly resemble the SSWL decay curves seen in the plastic occlusion stress test (6). This test is performed by occluding a skin area for a defined period and measuring the SSWL decay after removal of the patch. It allows to evaluate irritant-related changes in stratum corneum water holding capacity.

The observation of a significant SSWL decay at the vulva confirms our previous findings that occlusion is a constant physiological factor influencing vulvar SSWL, but that even allowing for occlusion, vulvar SSWL is significantly higher than forearm SSWL (7). In contrast to the plastic occlusion stress test curves, however, we could not fit the data with an exponential decay curve but found the data to be described best by a logarithmic equation. Whether this indicates a biological difference cannot yet be decided.

Under non-occluded conditions and in the absence of sweating, stratum corneum water content is an equilibrium between body water diffusing into the stratum corneum from lower epidermal layers and

water evaporating from the skin surface (SSWL). In this situation, SSWL equals the influx of body water into the stratum corneum and the transcorneal water flux (TEWL).

This equilibrium is disturbed by occlusion which reduces the outflow of water and leads to an accumulation of water in the stratum corneum. After the occlusion is removed, the previous equilibrium is reached again by a transient increase in water outflow corresponding to an SSWL increase. In this situation, SSWL exceeds the transcorneal water flux (TEWL).

After removal of an occlusion, the total SSWL can be described as the sum of the basal TEWL, which is the indicator of the barrier function, and the time-dependent SSWL induced by occlusion:

$$SSWL_{\text{tot}} = TEWL + SSWL_{\text{occl}}$$

where

$$SSWL_{\text{occl}} = f(t).$$

Our results clearly show that we can disregard the occlusion variable in forearm skin; then SSWL equals TEWL, and irritation-induced changes in TEWL will be appropriately reflected in the measured SSWL.

In vulvar skin, however, the occlusion variable must be taken into account. Then the value of TEWL can be found in two ways, either by waiting for the SSWL reading to stabilize, which according to our results will take a minimum of 20 min, or by measur-

Table II. Skin surface water loss decay curve constants and SSWL bursts at vulvar skin

Volunteer	<i>a</i>	<i>b</i>	<i>r</i> ²	No. of SSWL bursts
A	3 630.78	-0.72	0.96	1
B	37.15	-0.20	0.93	4
C	158.49	-0.39	0.94	1
D	18.20	-0.04	0.10	1
E	133.97	-0.36	0.91	5
F	44.67	-0.18	0.74	3
G	34.67	-0.12	0.61	1
H	194.98	-0.32	0.97	0
Mean	531.61	-0.29	0.77	2.00
SEM	443.36	0.07	0.11	0.63

a is the intercept and *b* is the slope of the line. Furthermore, $a = SSWL$ for $t = 1$. r^2 = square of correlation coefficient *r*, SEM = standard error of the mean.

ing the SSWL decay for a shorter period and calculating the endpoint as the SSWL value at a given time point, e.g. 60 min.

However, there remains the influence of sweating on vulvar SSWL measurements. The only way to eliminate the sweating factor would be to suppress sweat gland activity with anticholinergic agents locally or systemically. Since this is not practical in irritation studies, a higher variance of SSWL measurements must be anticipated in contrast to the forearm. In order not to overlook existing differences between treatments (type II error), the number of subjects may have to be higher in irritation studies on vulvar skin compared to forearm studies.

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