

SHORT COMMUNICATION

Skin Barrier Recovery is not Associated with Self-Perceived Stress

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Abstract

The primary aim of the current study was to examine the association between self-perceived stress and skin-barrier recovery. From an initial sample of 410 students, 19 high-stress and 12 low-stress Hispanic women completed a behavioural survey and were assessed for recovery of skin barrier following a tape-stripping procedure. No association was found between self-perceived stress and skin barrier recovery at either the 30-min or 3.15-h recovery period. Supplemental analysis showed a positive correlation between skin barrier recovery and self-reported sleep quantity at both recovery periods. Barrier repair reflects a single, minimally invasive, measure of wound healing; thus, our findings do not necessarily contradict the notion that stress measures can be used to predict wound healing more broadly defined. Supplemental analysis demonstrated an intriguing relationship between barrier recovery and the number of hours slept, but these findings are considered tentative and will require replication with more rigorous measures of sleep quantity and quality. Copyright © 2015 John Wiley & Sons, Ltd.

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Researchers studying the impact of psychological factors on cutaneous wound healing have frequently relied on the creation of standardized wounds to the skin using punch biopsy or suction blisters (Gouin & Kiecolt-Glaser, 2012), but a number of recent studies have made use of a less invasive measure of cutaneous wound healing termed skin barrier recovery. The skin's epidermis is a multi-layered self-renewing structure that acts as a barrier to evaporative water loss and protects us from environmental pathogens. Damage to the epidermis, even the superficial wound of a carpet burn, results in a disruption of this barrier and triggers a cascade of complex cellular processes directed toward repair (wound healing). The assessment of skin barrier recovery relies upon associated changes in transepidermal water loss (TEWL), a measure of the amount of water vapor that diffuses through the skin's outer layer, the stratum corneum. Stripping the outer layers of the stratum corneum with adhesive tape disrupts the barrier, resulting in an increase in TEWL at that site. As an outcome variable, skin barrier recovery is based on the extent to which TEWL levels recover to pre-stripping baseline after a specified amount of time.

While baseline TEWL levels do not appear to be associated with psychological stress, there is evidence

from animal and human studies that both naturalistic and lab-induced stress delay skin barrier recovery (Altemus, Rao, Dhabhar, Ding, & Granstein, 2001; Fukuda, Baba, & Akasaka, 2015; Muizzuddin, Matsui, Marenus, & Maes, 2003; Robles, 2007). In two previous studies examining the effects of naturalistic chronic stress (extended exam periods and marital dissolution) on skin barrier recovery, researchers quantified stress using a well-established stress measure, the Perceived Stress Scale (PSS; Cohen, Spacapan, & Oskamp, 1988). The aim of the current study was to build upon these previous findings by examining whether self-perceived stress alone could be used to predict skin barrier recovery in a Hispanic student population, outside of defined naturalistic stress events.

Methods

Participants

Four hundred and ten undergraduates participated (mean age = 22.5, standard deviation (*SD*) = 5.4) in the screening phase of the study (92% Hispanic, 71% women). The students with the highest and lowest PSS scores were recruited for the study if they met the

following inclusion criteria: female, Hispanic, between 18 and 25 years of age, no diagnosed dermatological disorder, non-smoker. Complete session data were collected from a total of 29 participants. The study was approved by the Institutional Review Board.

Measures

The one-page questionnaire comprised demographic questions and questions about exercise and sleep such as 'Hours per week of exercise', 'On average, how many hours of sleep do you get a night?' and 'Generally speaking, do you feel rested when you wake up?'

The Perceived Stress Scale (Cohen et al., 1988) is a 10-item Likert-type scale that asks respondents 'In the last week, how often have you. . .' and includes items such as 'felt nervous and stressed?', 'felt that you were unable to control the important things in your life?' Response choices range from (0) 'never' to (4) 'very often'. The 10-item version of the scale, which is a revision of the originally published 14-item version, has been shown to provide a slight gain in psychometric quality over the longer version and is recommended over the 14-item version by the scale's authors (Cohen et al., 1988). The PSS has been reported as a better predictor of psychological symptoms, physical symptoms and health service utilization than life-event scales (Cohen, Kamarck, & Mermelstein, 1983). Possible scores range from 0 to 40, with higher scores representing greater stress, and were calculated by summing up the 10-item ratings (after reverse scoring specific items). Cronbach's alpha was 0.94 in the present study. Although norms are available for this scale (Cohen & Janicki-Deverts, 2012), there are no established low, medium or high cut-off scores for this measure (Cohen, 2014). Therefore, we recruited screening phase participants who had the highest and lowest PSS scores in order to establish the greatest differentiation between high-stress and low-stress subjects in our available sample.

Transepidermal water loss was measured using an evaporimeter (Tewameter 300, Courage and Khazaka, Cologne, Germany), which calculates evaporation rate ($\text{g}/\text{m}^2/\text{h}$). Basal TEWL ($\text{g}/\text{m}^2/\text{h}$) was assessed on the volar (underside) surface of the forearm at a distance of 10 cm below the antecubital fossa (elbow crease). The site was then disrupted by sequential applications of tape (D-squame; CuDerm, Dallas, TX) until a TEWL level of at least $20 \text{ g}/\text{m}^2/\text{h}$ was reached. TEWL was measured 30 min and 3.15 h later; the timing of the second measurement allowed the total study participation time to be kept under 4 h, thereby minimizing time demands placed on the participants. Skin barrier recovery was calculated as the percentage of TEWL recovery to baseline levels.

Procedures

Individual sessions were scheduled by a research assistant, and the researcher was kept blind as to whether

the subject had scored high or low on the PSS.¹ Each participant was called the day before the scheduled session and instructed not to apply creams or lotions to the forearms on the day of the appointment, to avoid exercise and to refrain eating or drinking anything but water 1 h prior to the appointment. To reduce time-dependent variation in barrier recovery (Denda & Tsuchiya, 2000), all individual sessions were scheduled to start between 12:00 and 13:30 h and were conducted in a sound-attenuated room. The individual appointments involved two lab sessions, as follows:

Session 1. After 15 min of quiet sitting, baseline TEWL was obtained from both of the participant's arms. Tape stripping was performed on the left arm until TEWL of at least $20 \text{ g}/\text{m}^2/\text{h}$ was obtained or until 50 tape strippings had been conducted. The mean post-stripping TEWL value was 20.66 [$SD = 3.69$]. Following IRB-approved protocol, and in keeping with previously published research (e.g. Robles, 2007), tape stripping was halted at 50 strips and was therefore discontinued in six participants prior to reaching a value of $20 \text{ g}/\text{m}^2/\text{h}$. After 30 min quiet sitting, during which subjects completed the PSS and questionnaire again, TEWL was reassessed. The participant was then instructed to refrain from smoking, consuming caffeinated drinks or exercising, and to return exactly 2.5 h later for a follow-up assessment.

Session 2. After 15 min quiet sitting, TEWL was recorded for the fourth time. Participants were paid \$20, debriefed and excused.

Results

Stress and subject variables

In our original sample of 410 students, self-perceived stress was higher in women and significantly lower in those who reported exercising regularly (Table I). Smoking, being married, having children and working were not associated with stress. Our undergraduate sample slept an average of approximately 6.5 h per night; subjective stress levels were higher in those who reported not feeling rested upon awakening and negatively correlated with self-reported sleep duration ($r(408) = -0.19, p < 0.001$).

Stress and skin barrier recovery

For those subjects attending the individual skin barrier recovery sessions, self-perceived stress was significantly correlated with stress scores obtained during the screening phase, $r(29) = 0.86, r^2 = 0.74, p < 0.001$. Based on the stress measures taken during the

¹To verify that the researcher remained blind to stress classification, a high/low guess was recorded during the first session. The researcher guessed at chance levels, correctly identifying group assignment 50% of the time.

Table 1. Summary statistics and subject variable comparisons for original sample of 410 students

Variable		N	Perceived Stress Scale			p-value
			M	SD	t-value	
Sex	M	118	16.88	6.65	3.30	0.001
	F	289	19.29	6.70		
Do you exercise regularly?	Y	211	17.44	7.18	3.56	<0.001
	N	197	19.78	5.95		
Do you feel rested when you wake up?	Y	136	15.68	6.70	6.52	<0.001
	N	274	20.09	6.31		
Do you smoke?	Y	63	18.94	6.46	0.39	0.70
	N	347	18.57	6.82		
Are you married?	Y	51	19.59	7.02	1.08	0.28
	N	359	18.50	6.72		
Do you have children?	Y	68	18.79	6.48	0.22	0.82
	N	342	18.60	6.82		
Do you work?	Y	241	18.66	6.62	0.12	0.90
	N	169	18.58	6.96		

individual sessions, 12 subjects were classified as low-stress ($M = 8.58$, $SD = 4.38$) and 19 were classified as high-stress ($M = 25.88$, $SD = 4.17$). The mean stress score for low-stress and high-stress participants was below/above one SD from the mean stress score of the original 410 students ($M = 18.63$, $SD = 6.76$), respectively.

Low-stress participants demonstrated a mean recovery of 36.45% ($SD = 9.40$) at the 30-min mark, increasing to 45.50% ($SD = 12.67$) at 3.15 h. High-stress participants demonstrated a mean recovery of 38.25% ($SD = 13.04$) at the 30-min mark, increasing to 42.50% ($SD = 13.50$) at 3.15 h. A Mann-Whitney U test demonstrated no significant difference between the groups for either the 30-min recovery period, $U = 85.0$, $Z = 0.75$, $p > 0.05$, $r = 0.14$, or the 3.15-h recovery period, $U = 82.0$, $Z = 0.54$, $p > 0.05$, $r = 0.10$ (Figure 1).²

Supplemental analysis: Sleep quantity and skin barrier recovery

We examined the association between self-reported sleep quantity ('On average, how many hours of sleep do you get a night') and barrier recovery values. Our data demonstrated a statistically significant positive correlation with skin barrier recovery at both the 30-min recovery period, $r(29) = 0.66$, $r^2 = 0.43$, $p < 0.001$ and the 3.15-h recovery period, $r(28) = 0.40$, $r^2 = 0.16$, $p = 0.017$ (Figure 2).

Discussion

The primary aim of this study was to determine whether self-perceived psychological stress could be used to predict skin barrier recovery following a tape-stripping procedure. Our study differs from prior research in

that low-stress/high-stress groups were established based on self-perceived stress rather than specific naturalistic (e.g. marital dissolution) or laboratory stressors (e.g. the Trier social stress test). Although stress levels were assessed via a well-established self-report measure and the resultant low-stress and high-stress groups demonstrated significantly different levels of stress, the present study found no relationship between self-perceived stress and barrier recovery. It is important to recognize that barrier repair reflects a single, minimally invasive, measure of wound healing. As such, these findings do not necessarily contradict the notion that PSS scores can be used to predict wound healing more broadly defined. The PSS has, for example been shown to predict punch biopsy wound healing in healthy adult men (Ebrecht et al., 2004). Perhaps our failure to find an effect is because of our participants not being as stressed as those experiencing defined naturalistic stressors, such as marital dissolution. However, based on the same 10-item PSS measure, our high-stress group scores are similar to those obtained from caregivers of mothers/husbands with dementia who showed delayed punch-biopsy wound healing (Kiecolt-Glaser, Marucha, Malarkey, Mercado, & Glaser, 1995), suggesting that these null findings are not simply a consequence of insufficiently stressed participants.

Our data revealed some interesting supplemental findings. Based on our original pool of 410 students, those who smoked did not experience higher stress, a finding that runs contrary to previously published research (Mackey, McKinney, & Tavakoli, 2008). Prior studies provide mixed evidence regarding the association between stress and exercise; in our sample, stress was significantly lower amongst those who reported exercising regularly. Additionally, although being married, having children and working were each unrelated to stress levels, those who felt rested upon awakening reported significantly lower stress.

²Although room temperature increased during Session 1, supplemental analyses using a temperature-corrected formula for skin barrier recovery (Halkier-Sørensen, Thestrup-Pedersen, & Maibach, 1993) produced equivalent results.

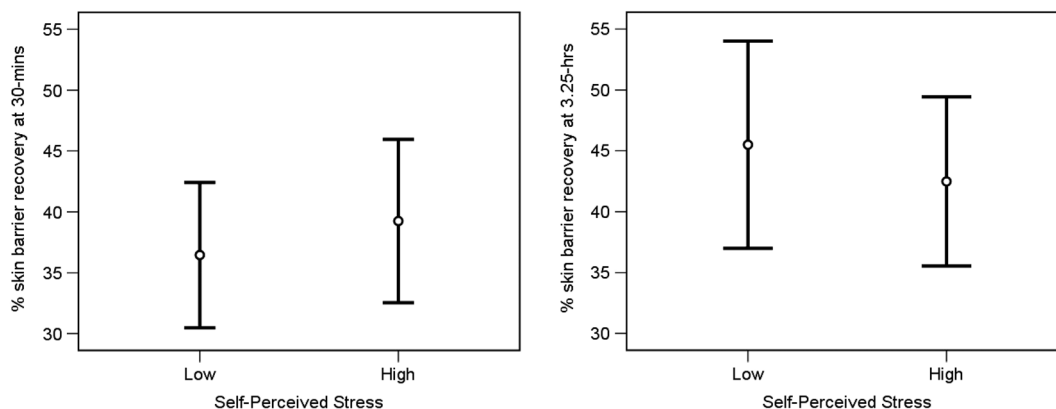


Figure 1 Ninety-five percent Confidence Interval (CI) error bars showing skin barrier recovery at 30-min and 3.15-h post-tape stripping for low-stress and high-stress participants.

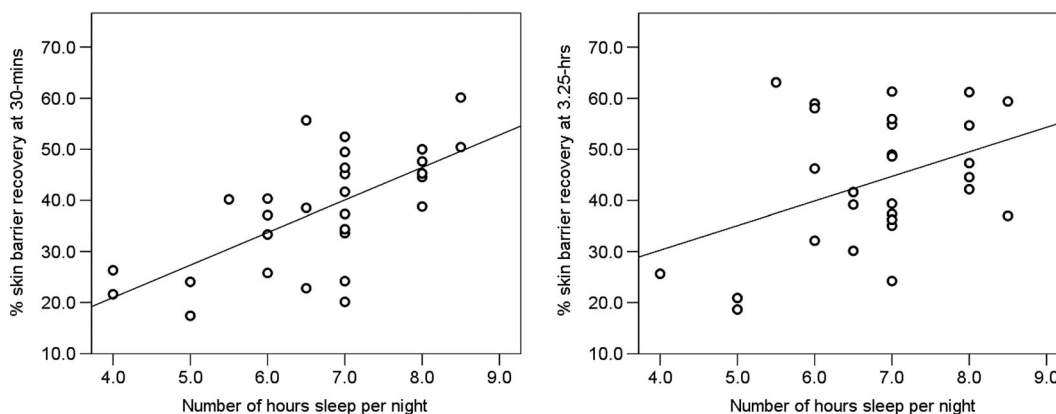


Figure 2 Scatterplots showing relationship between self-reported sleep quantity and skin barrier recovery at 30-min and 3.15-hours post-tape stripping.

We also examined whether skin barrier recovery was associated with self-reported sleep quantity. Researchers have increasingly emphasized the role of insufficient sleep (Barber, 2014; Benham, 2010; Hagger, 2014; Mullan, 2014), recognizing it not only just as a consequence of stress and poor health but also as a contributing factor to both. Our preliminary findings indicate a statistically significant association: sleep quantity accounted for 43% of the variance in barrier recovery at 30 min and 16% of the variance at 3.15 h. In keeping with our findings, recent research suggests that naturally occurring sleep debt similarly slows barrier recovery (Oyetaquin-White et al., 2015). However, our findings should be interpreted cautiously, given the limited measure of sleep used in this supplemental analysis (a single question about the average number of hours slept per night). We present the data as a tentative finding for the reader’s consideration; a finding that needs verification using substantially more refined measures of sleep (including an assessment of sleep *quality* in addition to sleep *quantity*). These results provide a small steppingstone from which researchers might consider

further inquiry. It is interesting to note, for example, that a substantial proportion of recovery to baseline TEWL is observed at the 30-min mark. Although there is evidence that barrier recovery occurs within 30 min of disruption through the formation of intercellular lipid bilayer structures (Denda, Sokabe, Fukumi-Tominaga, & Tominaga, 2006), the mechanism through which inadequate sleep quantity might impair this process is currently unknown.

In addition to sleep measurement limitations, our sample had limited diversity: although the homogeneity of our sample was purposeful, consisting of 18 to 25-year-old non-smoking Hispanic female college students, it necessarily limits the generalizability of the findings. This limitation can be balanced against having provided important data regarding a traditionally underrepresented demographic.

Conclusions

The notion that psychological stress adversely affects health is supported by a large body of literature that includes diverse outcome measures. Our study failed to

support the hypothesis that psychological stress, as assessed by a standardized and widely used self-report measure, is associated with impaired skin barrier recovery. Our findings do not contradict the well-supported notion that psychological stress is a major contributor to allostatic load nor that stress has an important role to play in the development of illness and disease. However, in the limited context of skin barrier recovery after the removal of epidermal cells by a tape-stripping procedure, self-ratings of stress were found to be inconsequential. Supplemental analysis demonstrated an intriguing relationship between barrier recovery and the number of hours slept, but these results were limited by a rudimentary self-report measure of sleep quantity. Future research will need to examine whether these preliminary findings are replicable with more rigorous measures of sleep.

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Conflict of interest

The author reports no conflicts of interest. The author alone is responsible for the content and writing of the paper.

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