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Skin conductance response during sleep and the contribution of the stratum corneum

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Electrodermal activity is observed through fluctuations in the skin's electrical conductance and has been used as an indicator of sympathetic nervous activity. Although electrodermal activity during sleep has been suggested to correlate with different sleep stages, its underlying mechanisms remain unclear. Previous studies have reported that skin conductance responses (SCR) occur frequently during deep sleep (N3) [1], but the mechanisms and contributing factors have not been sufficiently elucidated. In addition, while the removal of the stratum corneum (the outermost layer of the skin) is known to rapidly increase skin conductance [2], its effect on SCR during sleep is not fully understood.

The purpose of this study was to characterize the fluctuations in skin conductance during sleep and clarify the contribution of the stratum corneum to SCR in deep sleep.

To measure skin conductance, we used nanomesh electrodes composed of gold nanowires and polyvinyl alcohol, which are illustrated in Figure 1(a). These nanomesh electrodes function as dry electrodes capable of adhering to the skin while maintaining breathability, enabling continuous measurement during sleep with a compact skin conductance meter attached to the forearm. Figure 1(a) depicts both the electrode design and the overall measurement setup. To evaluate the effect of the stratum corneum, we performed tape stripping for its removal and compared SCR before and after the removal. Data analysis involved calculating the number of SCR occurrences in 30-second intervals and examining differences among sleep stages.

Our results showed that SCR frequency during N3 was significantly higher than in other sleep stages. Moreover, Figure 1(b) shows that after removing the stratum corneum, the baseline skin conductance rose, while Figure 1(c) indicates that the amplitude of SCR during deep sleep tended to decrease.

These findings suggest that the high insulating property of the stratum corneum increases fluctuations in electrodermal activity. In other words, when the stratum corneum is intact, its insulating nature appears to amplify electrodermal activity fluctuations, whereas its removal suppresses these fluctuations. Consequently, maintaining the stratum corneum in its natural state seems necessary when using SCR as an indicator of deep sleep.

In addition, because many previous studies measured electrodermal activity at the wrist, we compared our forearm-based measurements to published wrist-based data. Despite the change in measurement site, a very high correlation coefficient (r = 0.98) was observed between our forearm-based SCR results and those obtained via wrist-based methods. This finding suggests that measuring from the forearm with our miniaturized system effectively reproduces the characteristic electrodermal activity patterns during deep sleep, even though the forearm is a different anatomical site than the traditionally used wrist.

The skin conductance measurement system developed in this study may help more accurately identify deep sleep stages, which have been challenging to classify with conventional wearable devices. By integrating this system with existing wearables, it may be possible to achieve higher-precision sleep monitoring at home. Looking ahead, longer-term measurements and large-scale data collection are expected to further enhance sleep assessment technologies.

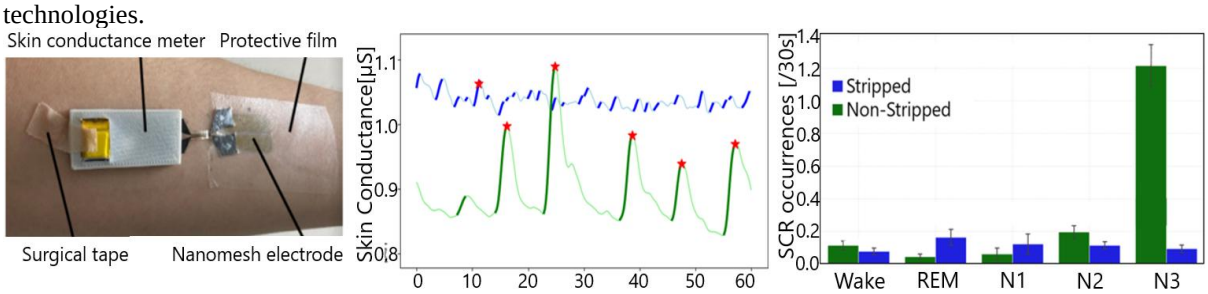

Figure 1. (a) Skin resistance measurement system (b) Illustration of how skin conductance responses are counted (c) SCR frequency for each sleep stage. (Error bars indicate the standard error)

1) Sano A et al., Quantitative analysis of wrist electrodermal activity during sleep, *Int J Psychophysiol*, 94, 3, (2014)
2) Tagami H et al., Evaluation of the skin surface hydration in vivo by electrical measurement, *J Invest Dermatol*, 75, 6, (1980)