Effect of chronic sleep deprivation on skin status in healthy young women

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Abstract. The majority of the studies conducted on sleep deprivation has been dedicated to the consequences on the psychomotor performances. However, the impact of a debt of sleep on the skin has never been studied to date. Fourteen Caucasian females subjects (30-40 years) were included in this study that consisted in 3 sessions: baseline session (2 days), chronic partial sleep deprivation session (6 days, 4 hours of sleep allowed) and sleep-recovery session (4 days). Polysomnography recordings, assessments of mood and psychomotor vigilance, and measurements of biophysical skin properties have been collected from these women. The variations of these data during the study have been first described using descriptive analysis methods and graphs. Then, Multiple Factor Analyses (MFA) and Partial Least Square (PLS) approaches were used to highlight possible correlations and causal links. A significant reduction of capacitance (reflect of skin hydration) and an increase of skin pH were found between the baseline and the end of deprivation sessions. MFA showed that during the deprivation session, SWS (Slow Wave Sleep) was correlated to these two biophysical skin properties. Furthermore, PLS approach demonstrated that the shorter the time passed in NREM sleep (Non Rapid Eye Movement), the lower the capacitance and the higher the skin pH. Partial sleep deprivation provoked slight modifications of biophysical skin properties, which returned to their baseline values during the sleep-recovery session.

Keywords: Biostatistics, Multiple Factor Analysis, PLS approach.

1. Introduction

An impact of sleep disorders on skin color has been reported recently (Robert and Vorona [11]), but until now no study has explored the effect of a sleep deprivation on biophysical skin properties. Thus, the CE.R.I.E.S. conducted a study in collaboration with FORENAP Pharma to assess on the one hand, the effects of this chronic partial sleep deprivation on mood and cognitive functions, and on the other hand, to investigate its possible effect on the skin.

2. Population and methods

Fourteen healthy Caucasian women, between 30 and 40 years old, participated in this study. The duration of the study period was 12 days divided in three sessions:

- A baseline session of 2 days,
- A sleep deprivation session of 6 days (4 hours of sleep allowed),
- A sleep-recovery session of 4 days (10 hours of sleep allowed).

The subjects have to remain in the study center from the begining of the study to day 12. At the end of the study, they were allowed to leave the center only if their physical examinations did not reveal any clinically-relevant abnormality, as judged by the investigator.

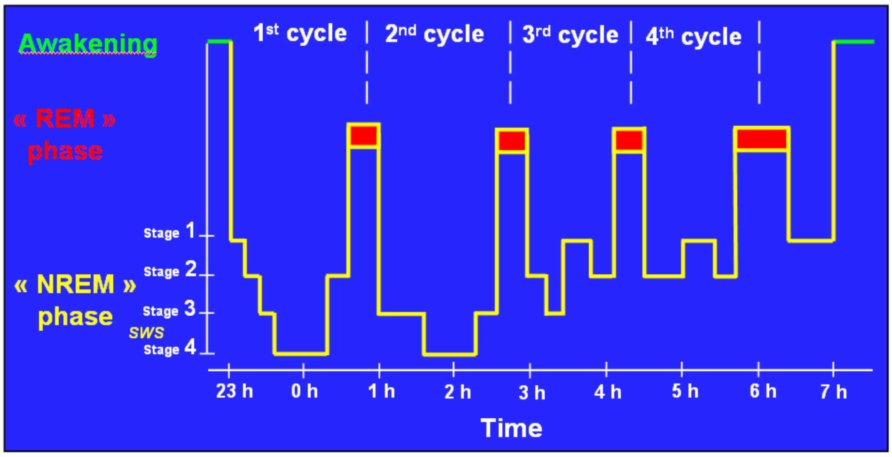
Sleep: polysomnography

Polysomnographic recordings have been done to watch over the different stages of sleep of each subject (fig. 1): at baseline, from 11:00 pm to 7:00 am, during the deprivation session, from 3:00 to 7:00 am and during the recovery session, from 9:00 pm to 7:00 am.

For analysis purposes, the parameters retained are the followings: Total Sleep Time (TST), Sleep Onset Latency (SOL), Wake After Sleep Onset (WASO), time in Rapid Eye Movement sleep (REM), time in Non-REM sleep (NREM) and time in Stage 1, in Stage 2 and in Slow Wave Sleep (SWS), (Patil [9]).

Furthermore, the mood of the subjects has been assessed by means of a questionnaire: the Profile of Mood Scale (POMS); and their psychomotor and cognitive functions with two different tests: the Word Pair Associates Task (WPAT) and the Psychomotor Vigilance Task (PVT).

Fig. 1. Stages of sleep. Sleep is composed of two phases: the Rapid Eye Movement sleep (REM), which is marked by intense brain activity, and the Non-REM sleep (NREM). The NREM phase consists of four stages: Stage 1, which is the time of drowsiness or transition from being awake to falling asleep; Stage 2, the period of light sleep during which the eyes movements stop, and Stages 3 and 4, which are also called Slow Wave Sleep (SWS).



Mood status

The mood has been appreciated thanks to the Profile Of Mood Scale (POMS) every day at 5:00 pm from day 2 to the end of the study. The POMS is a 5-point self-administered scale aimed to assess general psychopathology mood states (McNair *et al.* [7]). The POMS consists in 65 items investigating six different entities:

- Tension/Anxiety (10 items)
- Depression/Dejection (15 items)
- Anxiety/Hostility (12 items)
- Fatigue/Inertia (7 items)
- Vigor/Activity (8 items)
- Confusion/Bewilderment (7 items)

Cognitive functions

The Psychomotor Vigilance Task (PVT) is a brief, sustained attention, visual reaction time task sensitive to sleepiness (Dinges *et al.* [3], Dinges [4]). During each 10-minute performance trial, the subjects are asked to press as quickly as possible a button, when a stimulus appears on screens, making an effort to keep response times as short as possible throughout the task. The mean Reaction Time (RT, in ms), the mean duration of the 10% slowest Reaction Time (Maximum RT), and the mean duration of the 10% fastest Reaction Time (Minimum RT) have been analysed: an increase of these measurements indicating an impaired ability to sustain attention.

Furthermore, the Word Pair Associates Test (WPAT) has been used to test the memory of the subjects (Plihal and Born [10], Ferrand and Alario [6]). WPAT is a computerized learning and memory task, which requires the subject to learn a list of 40 pairs of semantically related words. Afterwards, immediate recall is tested. Learning and immediate recall have been performed in the evening two hours before going to sleep. The delayed recall was tested in the morning two hours after awakening. In order to assess the sleep-related memory consolidation efficiency, the variation between immediate recall and delayed recall has been calculated for the mean response time for correct recalled pairs (in ms). Furthermore, the number of trials necessary to succeed (24 pairs of correct recall) has been recorded.

Biophysical skin properties

Five biophysical skin properties have been measured: Trans-Epidermal Water Loss (TEWL), which is a measurement of the quantity of water that passes through the skin (Tewameter® TM300), skin temperature (Thermometer® ST500), skin pH (skin pH905 pH-meter®), sebum casual level (Sebumeter® SM810 PC) and capacitance, reflect of skin hydration (Corneometer® CM825). All these devices have been developed by Courage and Khazaka Electronic, GmbH, Cologne in Germany.

Statistical analysis

The measurements performed the last day of each session (day 2 for baseline, day 8 for deprivation and day 11 for recovery) have been retained in the analyses.

The variations of each parameter between the sessions have been studied using Wilcoxon signed ranks test (Siegel [12]) and described by graphs (SAS® software, release 9.11). Then, causal linkages between groups of variables have been investigated for each session with Multiple Factorial Analysis method (MFA) (Escofier and Pagès [5]), (SPAD® software, release 7.0). Four groups of variables have been used for each MFA:

- **Sleep**: time in NREM, in REM, in WASO, in Stage 1, in Stage 2, in SWS, in SOL, and total sleep time,
- **Skin**: TEWL, skin temperature, skin pH, sebum causal level and capacitance,
- **Mood**: tension, depression, anxiety, fatigue, vigor and confusion,
- **Cognition**: mean reaction time, maximum reaction time, minimum reaction time, number of trials to succeed, delta response time between immediate recall and delayed recall.

As the correlations between the groups of variables can not establish causal links, Partial Least Squares (PLS) approach has been used (Tenenhaus *et al.* [13]), (XSTAT® software, release 2010.3.06). To answer to the main objective of the study, i.e. the investigation of the possible links between the sleep and the skin, a model with 3 groups of variables describing the sleep and 3 groups of variables describing the skin has been tested.

- Sleep at baseline
- Sleep in deprivation
- Sleep in recovery
- Skin at baseline
- Skin in deprivation
- Skin in recovery

To describe the sleep, only two variables have been used in this analysis: "percentage of time passed in NREM" and "percentage of time passed in REM". Moreover, each variable has been categorised into three equal size groups using the quantile method (Milton [8]).

3. Results

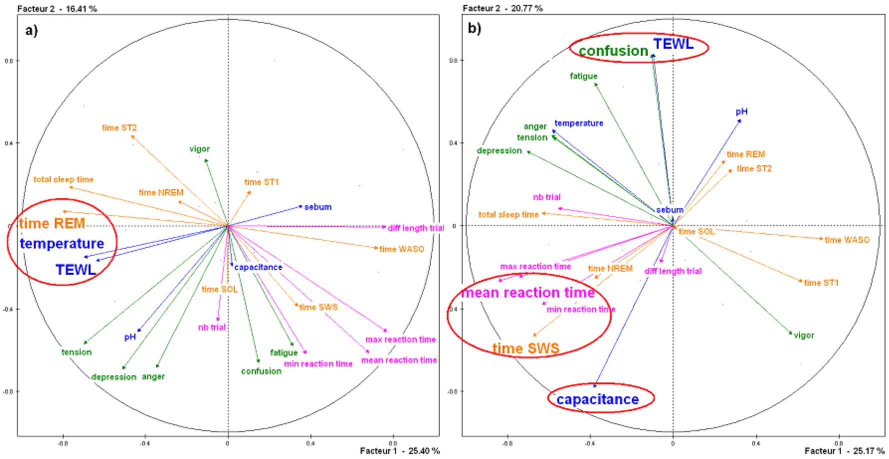
During sleep deprivation session, a significant decrease of the percentage of time passed in Stage 2 and a significant increase of the percentage of time passed in SWS have been found (50.4 ± 6.4% at baseline vs 36.6 ± 9% in deprivation, and 23.9 ± 7.7% vs 40.5 ± 8.7%, respectively). In parallel, a significant decrease of cognitive functions (mean reaction time 297.5 ± 45.9 vs 342.7 ± 64.7 ms), and significant increases of tiredness, tension and confusion have also been revealed (1.9 ± 2.2 vs 15.4 ± 5.9 points, -1.9 ± 3.2 vs -0.9 ± 3.8 points and -0.4 ± 2.7 vs 4.5 ± 4.5 points, respectively). Furthermore, some modifications of the biophysical skin properties have been found: significant decreases of capacitance and TEWL (34.1 ± 10.1 vs 27.5 ± 10.1, 14.0 ± 4.2 vs 11.9 ± 3.2 g/m^2h, respectively), and a significant increase of skin pH (5.3 ± 0.3 vs 5.7 ± 0.6). At the end of the recovery session, the cognitive functions and the mood have returned at their baseline values, as well as the biophysical skin properties, except the skin pH which stayed slightly higher.

The results of the MFA showed noticeable correlations:

- At baseline between skin and sleep (fig. 2a): skin temperature, TEWL and the time passed in REM are positively correlated.
- In deprivation between skin and mood (fig. 2b): capacitance is negatively correlated with confusion whereas TEWL is positively correlated with confusion; between sleep and cognitive functions: time passed in SWS is positively correlated with mean reaction time.
- In recovery between skin and sleep (figure not shown): skin temperature and time passed in REM sleep are positively correlated (i.e. the same links that those found at baseline).

Using PLS approach, sleep at baseline has a significant effect on sleep in deprivation and sleep in recovery, and the same kind of links has been established for the biophysical skin properties. However, the link between skin and sleep has only been found significant during the sleep deprivation session: the latent variable "sleep at baseline" is summarized by a low time passed in NREM sleep; and the latent variable "skin in deprivation" by a low capacitance and a high pH. It can be deduced that during the sleep deprivation session, the lesser the time passed in NREM sleep, the lower the capacitance and the higher the pH.

Fig. 2. Links between sleep (in orange), skin (in blue), mood (in green) and cognition (in pink): a) at baseline and b) in deprivation



4. Conclusion

This study confirmed that this experimental scheme and the process of sleep deprivation, that is to say 4 hours of sleep during 6 nights and 4 days of recovery was efficient (Cornette *et al* [1]). Indeed, this process led to a deeper sleep characterized by a longer time passed in SWS and a shorter time passed in Stage 2 (Diekelmann and Born [2]). Besides, the expected impact on the mood and on the cognitive functions has been found.

This study also showed that a partial sleep deprivation provoked significant modifications of some biophysical skin properties: the shorter the time passed in NREM sleep, the lower the capacitance and the higher the pH; these parameters returning to their baseline values at the end of the sleep recovery session. Moreover, the PLS approach highlighted some links between the sleep and the biophysical skin properties during the sleep deprivation session.

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