EFFECT OF PASSIVE BODY HEATING AT VARIOUS TIMES OF DAY ON SUBSEQUENT SLEEP

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INTRODUCTION

Body heating during the day, whether passive[1,2,3] or active[4], is reported to alter subsequent nocturnal sleep. In particular, an increase in the amount of slow wave sleep (SWS) has been observed, though the effect of body heating on periods of sleep other than at night, when circadian influences would need to be considered, has not been studied. The present study has examined effects of passive body heating, at various times of the day, on subsequent sleep.

METHODS

Eight males took part in a total of 8 experiments each. They slept before @re-exposure sleep), and 1.25 h after (post-exposure sleep), a 2h exposure in an environmental chamber with a relative humidity of 25% and a wind speed of 1.5m s^{-1}, under either control (21°C) or hot (40°C) conditions, at 4 (schedules) different times of day (Schedule 1:1500-1700h; 2:2100-2300h; 3:0300-0500h; 4:0900-1100h).

Pre-exposure sleep, which ended 2h before exposure to thermal environments, ensured subjects were equally well-rested at the start of the post-exposure sleep period. The required duration for sleep was calculated theoretically using the sleep-regulating variable S[5]. Subjects slept in the sleep laboratory used for post-exposure sleep, except that for chamber exposure starting at 0900h, pre-exposure sleep occurred overnight in the subject's home.

For post-exposure sleep only, electroencephalographic (EEG) activity, together with submental myographic and bilateral electro-oculographic activity, were recorded and scored in 30s epochs according to conventional criteria. Rectal temperature (Tre) was recorded at 1 min intervals preceding and during exposure to thermal environments, and at 4 min intervals from approximately 30 min before and throughout the sleep period. Subjects completed 100mm visual analogue scales for subjective assessment of sleep and well being.

STATISTICAL ANALYSES

Sleep variables derived from the data for post-exposure sleep, pre- and post-exposure subjective assessments of sleep and well being, and data for rectal temperature were analysed using a three factor repeated measures analysis of variance, with 8 subjects, 2 thermal environments (control and hot), and 4 periods of sleep (3 for pre-exposure subjective assessments).

As total sleep time was dependent on the time of day of sleep, further analyses were concerned with consecutive (100 min) intervals of sleep period time, and with the period before the first occurrence of rapid eye movement (REM) sleep. Tre was analysed before and at the end of exposure to thermal environments (means over 10 min), and at "light's out", sleep (stage 2) onset, slow wave sleep (SWS, stage 3) onset, and onset of REM sleep.

RESULTS

Sleep - Changes in sleep after heating were limited. For sleep from 0600h in the hot environment, % stage 1 sleep during the 1st non-REM period was reduced compared with that in the control environment ($p<0.05$). REM sleep in the first 200 min of (combined) overnight and early morning sleep was reduced ($p<0.05$). There were no effects related to thermal environment on stage 2 sleep or on stages 3 and 4 (SWS). Paradoxically, though subjects felt they slept better following exposure to the hot environment ($p<0.05$), they felt more tired having awoken from sleep following exposure to the hot compared with the control environment ($p<0.05$).

Rectal temperature - There were no differences between hot and control environments within schedule and so values were combined. Tre over the last 10 min in the hot environment was 0.45°C higher than for the same period in the control environment ($p<0.001$) and remained higher (0.20°C) at the subsequent interval of "light's out" ($p<0.05$). Thereafter, Tre continued to decline, though remained higher after exposure to the hot compared with the control environment at onsets of stage 2 and SWS (difference 0.19°C and 0.14°C, respectively, $p<0.05$), though the difference was not significant later, at REM sleep onset.

DISCUSSION

The changes in stage 1 and REM sleep observed after heating were limited and mainly confined to sleep commencing in the early morning. Increased nocturnal SWS after heating during the day that has been observed in previous studies was not observed in this study in which the duration of heating was relatively long and which occurred near to the sleep period However, the propensity for SWS may have been reduced by sleep obtained in the pre-exposure sleep period as SWS shows little, if any, relation to circadian phase but is influenced by duration of prior wakefulness. Thus, while the small rise in rectal temperature in the present study may have been an insufficient stimulus alone to increase SWS, it may have been particularly so in conjunction with an already reduced drive for SWS.

Body temperature during the sleep period itself may be important in this respect, particularly in view of hypotheses relating the quantity of SWS to body temperature at, or shortly after, sleep onset[6,7]. A previous study' reported an increase in SWS, 4h after a heat-induced rise in rectal temperature of 1.47°C. Temperature was higher than control, at "lights out" (0.19°C), at sleep onset (0.18°C) and at onset of SWS (0.19°C), and these differences were of the same order of magnitude as in the present study (0.20, 0.19 and 0.14°C, respectively) in which heating ended 1.25h before sleep. Possibly, the discrepant findings between these *two* studies with regard to SWS may relate to the differences in the magnitude of the initial heating-induced increase in body temperature, as increased SWS has only been observed after increases in body temperature in excess of 1°C[4].

However, circadian effects normally observed with sleep measures, subjective assessments and rectal temperature were evident and serve to illustrate the sensitivity of methodology used in the present study. It would appear, therefore, that a short-term thermal stress that increases core temperature by approximately 0.5°C, is unlikely to bring about any major change in subsequent sleep.

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