The effects of partial sleep restriction on olfactory performance

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Abstract:

Olfaction can increase the drive to eat and may partially explain the consistent increases in energy intake (EI) following sleep restriction. We investigated the effects of 50% sleep restriction with altered sleep timing on olfactory performance. We also evaluated whether changes (Δ) in olfactory performance were associated with Δ24 h EI. Twelve men and six women (age: 23±4 years; BMI: 23±3 kg/m^2) completed three randomized cross-over conditions: habitual sleep duration, 50% sleep restriction with advanced wake-time, and 50% sleep restriction with delayed bedtime. Sleep was measured in-laboratory (polysomnography). Olfactory performance ('sniffin sticks') and 24 h EI (food menu) were evaluated the next day. A trend for a significant condition*sex interaction was noted for threshold-discrimination-identification (TDI) scores (P=0.09); TDI scores were lowest in women and highest in men, following sleep restriction with advanced wake-time. Δolfactory performance were not associated with Δ24 h EI. The impact of sleep restriction on olfactory performance may differ between sexes. Changes in olfactory performance were not associated with changes in 24 h EI. Studies investigating prolonged effects of sleep loss on the relationship between olfactory performance with EI are needed.

Keywords: sleep deprivation | olfactory performance | energy intake

Article:

The orbitofrontal cortex is hypothesized to be the processing site of information linked to appetite and olfaction.[1] Findings suggest that activities in food-sensitive processing sites of the prefrontal cortex, including the orbitofrontal cortex, are enhanced in response to visual food cues following partial[2] and 24 h[3] sleep restriction. These results may partly explain the consistent increases in EI reported following imposed sleep restriction.[4] Only one study has investigated the effects of total sleep deprivation (24 h wakefulness) on olfactory performance, reporting declines in olfactory performance following 24 h of sleep restriction.[5] No study has assessed the effects of partial sleep restriction with altered sleep timing on olfactory performance and its association with EI. We examined the effects of 50% sleep restriction during the first or second half of the night on olfactory performance and whether changes (Δ) in olfactory performance were related to Δ24 h EI between sessions.

Twelve men and six women (age: 23 ± 4 years; BMI: 23 ± 3 kg/m^2) completed all measurements. Participant inclusion criteria and study measurements are described elsewhere.[6] Only women taking monophasic oral contraceptives were included in this study. All procedures were approved by the University of Ottawa ethics committee. Participants provided written informed consent. Participants completed three randomized cross-over sessions: control, 50% sleep restriction with advanced wake-time, and 50% sleep restriction with delayed bedtime. Individualized bed- and wake-times were based on 2 weeks of sleep–wake monitoring with accelerometry and diaries. In-laboratory sleep was assessed with polysomnography (Medipalm 22 with the Pursuit Sleep Software, Braebon Medical Corporation, Kanata, Ontario, Canada) during all conditions. Olfactory performance was measured with the 'sniffin sticks' kit (Burghart Instruments, Wedel, Germany) the following morning. This kit includes three tests of odorized pens that measure odor threshold, discrimination and identification, which added together forms a total odor score (TDI).[7] Finally, participants had *ad libitum* access to foods selected from a validated menu for the remainder of the day.[8]

SPSS (version 19.0; SPSS Inc, Chicago, IL) was used to conduct statistical analyses. One-way repeated measures ANOVA assessed the effects of sleep condition (within-participant factor) and sex (between-participant factor) on olfactory performance (Threshold, Discrimination, Identification and TDI). Linear regression models assessed associations between Δolfactory performance and Δ24 h EI between sessions. These models included sex, age and Δsleep duration as covariates. Results are presented as means ± standard deviations. Differences with *P*-values <0.05 indicated statistical significance.

A trend for a statistically significant condition*sex interaction was noted for TDI scores; TDI scores were lowest in women and highest in men, following sleep restriction with advanced wake-time (Table 1). No statistically significant associations were noted between Δolfactory performance with Δ24 h EI (data not shown).

This study investigated the acute effects of partial sleep restriction with altered bed- and wake-times on olfactory performance and its association with 24 h EI. Ambient food odors and increased olfactory performance have a functional role in EI by helping to locate food sources and stimulating the drive to eat.[9] Increased olfactory performance could therefore be associated with increased EI reported following imposed sleep restriction.[4] A trend was noted for decreased olfactory performance following sleep restriction with advanced wake-time vs control in women, whereas an increase was noted in men. However, there were no significant changes in 24 h EI between men and women across conditions nor were Δolfactory performance related to Δ24 h EI between control and sleep restriction with advanced wake-time conditions. Markwald *et al.*[10] reported that men had ≈70%, and women ≈20%, greater EI than needed to maintain body weight following sleep restriction vs control. Additionally, naturally cycling women had greater odor performance scores when presented with musk-like odors, compared with women taking monophasic oral contraceptives.[11] Although only women taking monophasic oral contraceptives were recruited in this study, it is possible that this trend for sex differences following sleep restriction with advanced wake-time may be influenced by hormonal modulations of olfactory performance.

Table 1. Individual (threshold, discrimination and identification, 1–16) and combined (TDI, 1–48) olfactory performance scores, 24 h energy and macronutrient intakes (kilojoules) and sleep stage durations (minutes) across conditions, between sexes and sex*condition interactions

	Control		***SR with advanced wake-time***		***SR with delayed bedtime***		***Condition effect***	***Sex effect***	***Sex* condition interaction***
	Men Mean±s.d.	***Women Mean±s.d.***	***Men Mean±s.d.***	***Women Mean±s.d.***	***Men Mean±s.d.***	***Women Mean±s.d.***			
Olfactory performance									
Threshold scores	8.7±2.1	9.5±1.2	9.5±2.0	8.5±1.6	8.6±3.4	8.6±1.5	F(2)=0.26,*P*=0.77	F(1)=0.01,*P*=0.92	F(2)=0.91,*P*=0.41
Discrimination scores	12.4±1.7	13.3±2.1	13.2±1.9	12.2±2.6	12.3±2.0	13.2±1.8	F(2)=0.09,*P*=0.91	F(1)=0.12,*P*=0.73	F(2)=2.35,*P*=0.11
Identification scores	13.1±1.6	14.5±1.2	13.3±1.4	14.0±1.7	13.3±1.8	14.3±0.8	F(2)=0.09,*P*=0.92	F(1)=2.77,*P*=0.12	F(2)=0.57,*P*=0.57
TDI scores	34.2±3.3	37.3±2.1	36.0±2.4	34.6±3.9	34.1±5.4	36.1±2.0	F(2)=0.21,*P*=0.82	F(1)=0.82,*P*=0.38	F(2)=2.64,*P*=0.09
Energy and macronutrient intakes [a]									
Energy intake	12 627±1941	8693±3632	13 431±2402	8188±2280	13 134±2075	9636±3485	F(2)=1.12, *P*=0.34	F(1)=13.52, *P*=0.002	F(2)=1.59, *P*=0.22
Carbohydrate intake	7192±1397	4674±1456	7657±1464	4263±745	7623±1552	5263±1987	F(2)=1.43, *P*=0.26	F(1)=18.64, *P*=0.001	F(2)=1.34, *P*=0.28
Fat intake	3941±895	2900±1653	4100±1117	2845±1335	3904±732	3151±1289	F(2)=0.12, *P*=0.89	F(1)=3.97, *P*=0.07	F(2)=0.66, *P*=0.53
Protein intake	1807±385	1247±736	1933±272	1201±623	1879±289	1418±741	F(2)=1.48, *P*=0.24	F(1)=6.47, *P*=0.02	F(2)=1.77, *P*=0.19
Sleep stage durations[a,b]									
Stage 1 sleep	18±9	17±10	6±4	8±4	5±3	3±3	F(2)=28.10, *P*=0.0001	F(1)=0.15, *P*=0.71	F(2)=0.49, *P*=0.62
Stage 2 sleep	254±26	228±47	113±18	113±46	102±28	98±40	F(2)=283.94, *P*=0.0001	F(1)=0.51, *P*=0.49	F(2)=2.28, *P*=0.12
SWS	88±26	99±44	76±24	75±50	83±23	74±45	F(2)=5.23, *P*=0.01	F(1)=0.00, *P*=0.99	F(2)=1.52, *P*=0.23
REM sleep	107±28	111±15	35±8	32±6	48±20	57±9	F(2)=148.89, *P*=0.0001	F(1)=0.19, *P*=0.67	F(2)=0.79, *P*=0.46

Abbreviations: M, mean; REM, rapid eye movement; s.d., standard deviation; SWS, slow-wave sleep; TDI, threshold-discrimination-identification.

[a]Data adapted from McNeil *et al.*[6]

[b]For within-session analyses, pair-wise comparisons indicated statistically significant differences between all sessions, except for SWS between the control and SR with delayed bedtime conditions (*P*<0.05).

This study had a small sample size of 12 men and six women. One-day measurements of the interventions and outcomes were performed, which does not account for variability across time or additive effects. Olfactory threshold was assessed with n-butanol, which is not a food-related odor. The use of food odors may yield different results. Finally, causality cannot be inferred through correlations. However, olfactory preceding EI measurements takes into account potential temporal effects. These results suggest that the impact of sleep restriction on olfactory performance may differ between sexes. However, changes in olfactory performance were not associated with Δ24 h EI. Studies are needed to investigate the prolonged effects of sleep loss on the relationship between olfactory performance with EI.

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