Short sleep duration is associated with a lower mean satiety quotient in overweight and obese men

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Abstract:

We examined satiety quotient (SQ) and energy intake (EI) according to sleep duration, quality and timing. Seventy-five overweight/obese men (age: 41.1±5.8 years; body mass index: 33.6±2.9 kg/m^2) completed visual analogue scales for appetite sensations before, immediately after and every 10 minutes for 1 hour following a standardized breakfast. The mean SQ (primary outcome of the study) was calculated from four appetite sensations. The Pittsburgh Sleep Quality Index identified short-duration (<7 h/night) and 'recommended sleep duration' (≥7 h/night) sleepers, poor (score ≥5)- and good (score <5)-quality sleepers and late (midpoint of sleep >0230 hours) and early (midpoint of sleep ≤0230 hours) sleepers. A 3-day food record and buffet-style meal assessed the EI. Short-duration sleepers had a lower mean SQ compared with recommended sleep duration sleepers (6.5±4.9 vs 8.8±4.3 mm/100 kcal; *P*=0.04). The mean SQ between poor and good (6.9±4.6 vs 8.7±4.6 mm/100 kcal; *P*=0.11) and that between early and late (8.99±5.10 vs 9.32±4.02 mm/100 kcal; *P*=0.78) sleepers were not significantly different. EI did not differ between the sleep groups. Thus, short-duration sleepers had a lower mean SQ compared with recommended sleep duration sleepers. However, this did not coincide with an increased EI.

Keywords: satiety quotient | sleep duration | sleep quality | sleep timing | energy intake

Article:

Introduction

Current evidence associates short sleep duration with the development of obesity.[1] The satiety quotient (SQ), expressed according to energy intake (EI), determines the extent to which a meal can reduce subjective appetite sensations.[2] A lower fullness SQ, or smaller changes in subjective fullness ratings in response to a meal, was associated with an increased EI in obese individuals.[2] It is, however, unknown whether changes in SQ may differ according to sleep parameters.

The present study evaluated the SQ in response to a standardized meal in overweight/obese men according to sleep duration, sleep quality and sleep timing. The mean SQ, based on responses to

four different appetite sensations, was the main outcome of this study. We hypothesized that a short sleep duration, poor sleep quality and a later bedtime would be associated with a lower mean SQ and a greater EI.

Methods

Participants

Seventy-five overweight/obese, healthy Caucasian men completed an in-laboratory assessment at Laval University (Quebec, Canada). The inclusion criteria were as follows: age between 30 and 50 years, body mass index between 28 and 40 kg/m^2, non-smokers, not taking medications that could influence appetite, non-diabetic with no insulin treatment, weight stable (±4 kg within the past 2 months), <3 × 30 min/week of physical activity and a low dietary restraint (score <10 on the Three-Factor Eating Questionnaire). This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures were approved by the Laval University ethics committee. Participants provided written informed consent.

Procedure and measurements

Participants arrived at the laboratory at 0800 hours following a 12-h overnight fast. They were instructed not to consume alcohol or engage in structured physical activity (for example, playing sports) for at least 24 h before testing and to follow their usual sleeping habits the previous night. Upon arrival, height, weight and waist circumference were measured according to standardized procedures[3], and fat mass was measured by dual-energy X-ray absorptiometry (GE Medical Systems Lunar, Diegem, Belgium).

A standardized breakfast and *ad libitum* lunch were served at 0830 and 1200 hours, respectively. The compositions of these meals are described in more detail in Appendix. The breakfast had a food quotient (global indicator of meal macronutrient composition) of 0.85 and was entirely consumed within 20 minutes. The participants' appetite sensations were recorded using visual analogue scales (VAS) before, immediately after, and at every 10 minutes for 1 hour following breakfast consumption. The 150-mm VAS were used to answer four questions that quantify subjective appetite sensations: desire to eat, hunger, fullness and prospective food consumption. The SQ was calculated for each appetite sensation using the following equation (2):

$$\mathrm{SQ(mm/100kcal)} = \frac{[\text{fasting appetite sensation(mm)} - \text{mean post meal appetite sentation(mm)}]}{\text{energy content of the test meal(kcal)}} \times 100$$

It is important to note that the SQ calculation for fullness is reversed (the mean post meal rating−fasting rating). The mean SQ represents the mean value of the four individual SQ scores. This was selected as the primary outcome of the study as it provides a composite indication of the changes in appetite sensations in response to the meal. A lower SQ indicates a weaker satiety response to a meal.[3]

The Pittsburgh Sleep Quality Index[4] determined sleep duration (self-reported item), sleep quality (total score) and sleep timing (midpoint of sleep based on reported wake time and sleep duration) over the last month. The calculations for sleep timing are described elsewhere.[5]

Three-day food records and physical activity diaries, including 2 weekdays and one weekend day, assessed habitual EI and moderate-to-vigorous physical activity participation, respectively, following the in-laboratory assessment.

Statistical analyses

Independent *t*-tests compared variables between the sleep duration, sleep quality and sleep timing groups. Statistical significance was set at $P<0.05$. Statistical analyses were performed using JMP (version 10; SAS Institute, Cary, NC).

Results

Table 1 presents participants' characteristics according to sleep groups. There were no differences in these variables between groups, except for 3-day carbohydrate intake between sleep quality groups ($P=0.03$). There were no significant differences in specific SQ for desire to eat, hunger, fullness or prospective food consumption between groups (data not shown). Short-duration sleepers had a lower mean SQ compared to sleepers with recommended sleep durations, whereas no significant differences in the mean SQ between sleep quality and sleep timing groups were noted (Figure 1).

Table 1. Characteristics of participants according to sleep duration, sleep quality and sleep timing groups

	Sleep duration		**Sleep quality**		**Sleep timing**	
	Short-duration sleepers (<7 h/night) (n=34)	**Sleepers with recommended sleep durations (≥7 h/night) (n=41)**	**Poor sleepers (PSQI score≥5) (n=33)**	**Good sleepers (PSQI score<5) (n=42)**	**Late sleepers (midpoint of sleep >0230 hours) (n=37)**	**Early sleepers (midpoint of sleep ≤0230 hours) (n=38)**
Mean±s.d.	**5.7±0.9 h/night**	**7.5±0.5 h/night**	**PSQI score 6.6±1.9**	**PSQI score 2.9±1.2**	**0312 hours±36 min**	**0200 hours±30 min**
Range	**3–6.75 h/night**	**7–9 h/night**	**PSQI score 5–11**	**PSQI score 1–4**		
Age (years)	41.6±6.6	40.4±4.6	41.0±6.4	40.9±5	39.3±5.7	41.8±5.0
Height (cm)	174.0±5.7	174.6±7.0	174.2±5.3	174.3±7.3	175.3±7.2	173.0±5.6
Body weight (kg)	101.4±9.5	103.2±12.6	101.5±9.5	103.1±12.9	101.3±11.2	104.0±11.9
BMI (kg/m^2)	33.5±2.9	33.8±3.0	33.4±2.9	33.9±3.1	33.8±2.9	33.8±3.2
Fat mass (kg)	34.2±6.4	35.2±7.6	34.6±6.2	34.8±8.1	34.7±7.9	34.2±6.9
Fat mass (%)	33.8±4.8	34.2±4.7	34.2±4.7	33.8±4.9	33.4±5.1	33.8±4.4
Waist circumference (cm)	109.9±6.9	112.5±8.6	110.9±6.8	111.5±9.0	109.6±7.1	112.2±8.8
Lunch EI (kJ)	4987±1501	5323±1710	4984±1360	5411±1808	4891±1629	5580±1638
Carb intake (kJ)	2146±649	2265±766	2127±589	2304±811	2115±631	2344±841
Lipid intake (kJ)	2018±831	2153±907	1999±732	2214±980	1938±935	2290±812
Protein intake (kJ)	824±297	905±276	858±288	893±282	839±309	947±241
EI (kJ/day)	11 816±2335	11 715±2464	11 259±2251	12 029±2439	11 919±2653	11 610±2168
Carb intake (kJ/day)	5206±1368	5365±1212	4887±1357	5588±1146*	5397±1491	5255±1104

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Range	**3–6.75 h/night**	**7–9 h/night**	**PSQI score 5–11**	**PSQI score 1–4**		
Lipid intake (kJ/day)	4238±1136	3986±1084	3938±989	4131±1129	4179±1187	3969±962
Protein intake (kJ/day)	2000±425	1924±445	1954±390	1945±472	1972±403	1936±465
Alcohol intake (kJ/day)	385±469	530±826	516±525	425±802	418±522	497±818
MVPA (min/day)	12.6±22.7	22.2±69.8	12.2±23.8	23.6±71.8	13.3±21.3	23.1±76.5

Abbreviations: BMI, body mass index; EI, energy intake; MVPA, moderate-to-vigorous physical activity; PSQI, Pittsburgh Sleep Quality Index.
All variables were not significantly different between groups with the use of independent *t*-tests, except for daily carbohydrate intake between good and poor sleepers (indicated by the *).

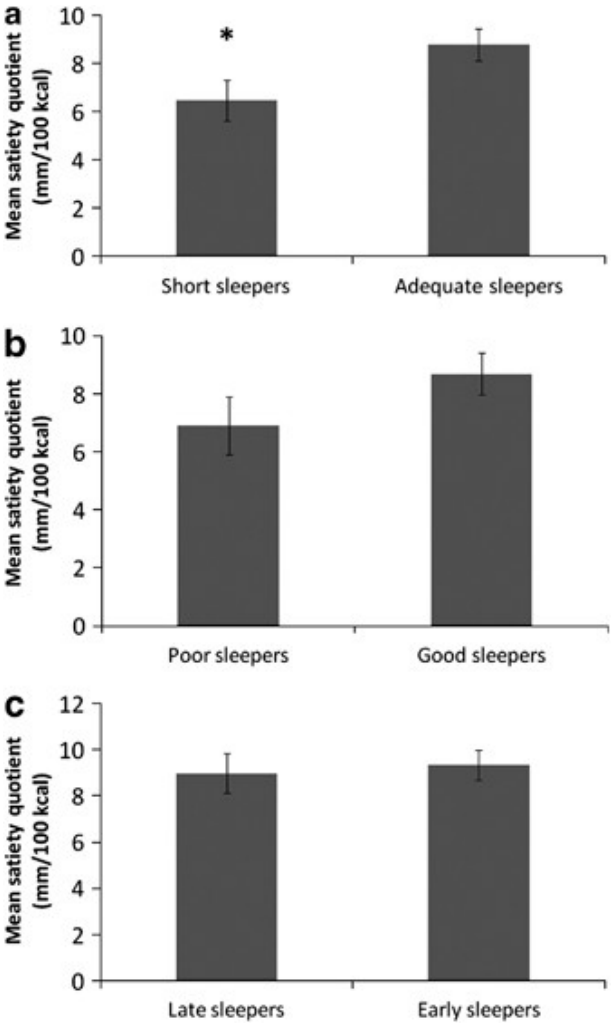

Figure 1. The mean satiety quotient between (**a**) short-duration sleepers (<7 h of sleep/night) and sleepers with a recommended sleep duration (≥7 h of sleep/night, **b**), between poor sleepers (PSQI score <5) and good sleepers (PSQI score ≥5, **c**) and between late sleepers (midpoint of sleep >0230 hours) and early sleepers (midpoint of

sleep ≤0230 hours). Values are presented as means for 75 participants with standard errors of the mean represented by vertical bars. *P=0.04 when compared with recommended sleep duration sleepers. P=0.11 between poor and good sleepers. P=0.78 between early and late sleepers. PSQI, Pittsburgh Sleep Quality Index.

Discussion

To our knowledge, this is the first study to examine measures of SQ according to sleep duration, sleep quality and sleep timing in overweight/obese men. Short sleep duration was associated with a weaker mean SQ, despite no significant differences in body weight, fat mass and EI between sleep duration groups. There were no differences in the mean SQ between sleep quality and sleep timing groups, despite a greater 3-day carbohydrate intake in good vs poor sleepers. The SQ is a more valid indicator of potential changes in subjective appetite ratings in response to a standardized meal compared with 1 h post-prandial area under the curve calculations because it considers pre-meal appetite sensations and meal caloric content.[3]

The greater mean SQ in short-duration sleepers did not coincide with greater EI in this study. These results suggest that appetite ratings may not be consistently related to measured or reported EI.[6] Furthermore, despite noting a greater EI following imposed sleep restrictions,[7, 8] one study found no differences in appetite ratings between sleep conditions,[7] whereas another only noted increased pre-prandial hunger ratings following sleep restriction.[8] Taken together, changes in appetite ratings, or SQ, may not be consistently related to changes in EI and *vice versa*.

Studies have also shown that a later sleep timing may lead to an increase in EI after 2000 hours,[9] as well as a greater total EI[5] in adults and obese children/adolescents, respectively. Conversely, the current study did not observe a significant difference in the mean SQ and EI between sleep timing groups. This lack of association may be due to differences in participant characteristics and calculated sleep timing midpoints between this study and others.[5, 9]

Finally, reductions in stage 2, rapid eye movement and slow-wave sleep were associated with greater hunger ratings and EI,[10] whereas the occurrence of sleep fragmentation led to a lower fullness and greater desire to eat ratings compared with a non-fragmented sleep condition.[11] These results suggest that alterations in specific sleep stages following imposed sleep fragmentation, rather than self-reported habitual sleep quality, may alter appetite ratings.

The present findings are limited to a small sample size of overweight/obese men, which limits generalizability to other populations. The cross-sectional design used does not allow for causal relationships to be drawn. Finally, the use of self-reported measurements and the possibility of residual confounding factors cannot be overlooked (for example, we are unable to determine whether differences in sleep timing are related to biological predispositions or social circumstances).

Although exploratory, we observed a lower mean SQ in short-duration sleepers. The mean SQ between sleep quality and sleep timing groups was not statistically different. Finally, no difference in EI was noted between sleep groups. Future studies are needed to confirm these preliminary findings.

Acknowledgements

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Ethics declarations

Competing interests: The authors declare no conflict of interest.

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Appendix

Table A1. Characteristics pf participants according to the sleep duration, sleep quality and sleep timing groups

	Quantity provided (grams)	**Energy content (kJ)**
Standardized breakfast		
White bread	100	1092
Butter	12	371
Peanut butter	16	429
Cheddar cheese	40	688
Orange juice	250	486
Total	418	3066
	Initial quantity provided (grams)	**Energy content (kJ/kg)**
Ad libitum lunch		
Sliced turkey	130	3930
Sliced ham	150	5480
Salmon mousse	90	10 833
Liver pâté	70	13 350
Gruyere cheese (28% fat)	100	17 286
Mozzarella cheese (17% fat)	100	11 718
Cottage cheese (2% fat)	100	3384
White bread	150	11 300
Whole-wheat bread	150	10 170
Soda crackers	100	18 400
Butter	40	29 990
Mayonnaise	60	30 630
Ketchup	40	4350
Italian dressing	60	26 110
Mustard	30	3140
Lettuce	60	670
Tomatoes	100	880
Carrots	150	1800
Butter biscuits	70	20 840
Chocolate fudge cookies	100	19 700
Strawberry yoghurt (1.5% fat)	250	4050
Regular crisps	60	23 214
Apples	100	2470
Oranges	100	1970
Milk (2% fat)	1000	2095
Orange juice	1000	1826
Coca cola	355	1720
7-Up	355	1674
Water	1000	0