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The association between objective sleep duration and diet. The CoLaus|HypnoLaus study

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SUMMARY

Background and aims: Sleep deprivation is frequently associated with an unhealthy diet. So far, most studies used reported sleep duration. We assessed the associations between objectively measured sleep duration and dietary intake.

Methods: Cross-sectional study conducted between 2009 and 2013 on 1910 participants (49.5% women, 58.3 ± 11.0 years) living in Lausanne, Switzerland. Total sleep time (TST) was assessed using polysomnography and categorized into <7, 7–9 and >9 hours/day. Total energy, macro and micronutrients intake, dietary adequacy scores and compliance to Swiss dietary recommendations were assessed.

Results: There were 60.6%, 37.2% and 2.2% of the participants in the categories <7, 7–9 and >9 h/day, respectively. Body mass index was higher in the >9 h/d sleep category. After multivariate adjustment, significant ($p < 0.05$) differences were found between sleep categories regarding total carbohydrates (46.6 ± 8.6, 46.0 ± 8.8 and 48.1 ± 8.0% of total energy intake for <7, 7–9 and >9 h/day, respectively), mono and disaccharides (22.7 ± 8.0, 22.4 ± 8.3 and 25.2 ± 8.8), and total fat (33.9 ± 6.4, 34.7 ± 6.9 and 34.2 ± 5.8). No association was found for total energy intake, other nutrients, dietary adequacy scores, dietary patterns or compliance to dietary guidelines. The differences in mono and disaccharides were found in women and the differences in total fat in men, although sex-diet intake interactions were not significant. Sensitivity analyses excluding participants with sleep apnea, using quartiles of TST or subjective sleep duration yielded similar conclusions.

Conclusion: Little if no associations were found between objectively measured TST and dietary intake in a Swiss general adult population. The associations with total carbohydrate, mono and disaccharide and total fat intake deserve further investigation.

1. Introduction

Short sleep has been associated with a series of chronic diseases such as obesity [1], diabetes, chronic inflammation, depression, cancer and decreased life expectancy [2]. A possible mediator is an unhealthy diet, as short sleepers tend to report a higher total energy intake and higher total fat intake [3]. Other hypotheses include timing of eating, short sleepers having more time to eat and also eating later in the night [4], or changes in metabolic pathways due to sleep restriction [5].

Sleep restriction has been associated with an increase in total energy intake compared to non-restricted controls [6], while no

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Abbreviations

AHEI	alternative healthy eating index
ANOVA	analysis of variance
BMI	body mass index
CI	confidence interval
CIRS	Centre for Investigation and Research in Sleep
MUFA	monounsaturated fatty acids
OR	odds ratio
PSG	polysomnography
PUFA	polyunsaturated fatty acids
SDB	sleep disordered breathing
SFA	saturated fatty acids
TEI	total energy intake
TST	total sleep time

association with energy expenditure or resting metabolic rate has been found [6,7]. Sleep restriction might increase fat relative to protein intake, with no effect on carbohydrate intake [6]. There are mechanisms by which sleep restriction might modify metabolism (for a review, see [8]): an increase in insulin resistance might lead to increased risk of diabetes [9]; an increase in ghrelin secretion paralleled with a decrease in leptin secretion [10] might increase appetite; an increased hypothalamic activation, with increased cortisol secretion, circadian disruption, and a correlated increase in appetite [11]. Finally, genes related to circadian rhythm such as CLOCK might regulate both sleep duration and body weight regulation [12,13]. Most studies assessing the associations between sleep and dietary intake have been conducted in the USA, and most used reported (not objectively measured) sleep duration. Using reported sleep duration might lead to estimation biases, as it has been shown that sleepers tend to underreport their total sleep time (TST) [14,15]. Most studies focused on nutrients, while subjects usually select foods rather than nutrients. Further, to our knowledge, few studies assessed the associations between TST and healthy eating scores [16–18] or compliance to dietary recommendations.

Thus, this study aimed to assess the associations between TST, dietary intake and eating patterns using objectively measured TST by polysomnography (PSG).

2. Participants and methods

2.1. Sampling procedure

The sampling procedure of the HypnoLaus Sleep Cohort study has been described previously [19]. Briefly, the HypnoLaus study is a random subset of the population-based CoLaus|PsyCoLaus cohort [20,21], which was designed to assess the clinical, psychological and genetic determinants of CVD; the baseline study was conducted between 2003 and 2006, the first follow-up was conducted between 2009 and 2012, and the second follow-up between 2014 and 2017. The HypnoLaus study was conducted between September 2009 and June 2013 and invited 3043 consecutive participants of the CoLaus|PsyCoLaus cohort to participate. No exclusion criteria were applied. Of the 3043 participants invited, 2162 accepted (71%) and had PSG data.

2.2. Dietary intake

Dietary intake was assessed using a self-administered validated semi-quantitative Food Frequency Questionnaire (FFQ) [22,23]. The FFQ queries the dietary intake of 97 different food items during the previous 4 weeks. For each food item, consumption frequencies ranging from “less than once during the last 4 weeks” to “2 or more times per day” could be selected, as well as the average serving size (smaller, equal or bigger) compared to a reference size. Conversion of the FFQ data into nutrients was performed using the French CIQUAL food composition table. Total energy intake (TEI) was computed in two ways: with and without alcohol consumption. The following items were expressed as percentage of TEI (alcohol excluded): total, animal and vegetable protein; total carbohydrate, mono and polysaccharides; total, saturated (SFA), mono- (MUFA) and polyunsaturated (PUFA) fatty acids. The validation study [23] showed that the FFQ assessed over 90% of the intake of calories, proteins, fat, carbohydrates, alcohol, cholesterol, vitamin D and retinol, and 85% of fibres, carotene, and iron. The day of the visit, FFQs were checked by trained interviewers for completion.

The self-reported food consumption frequencies were converted into daily values as follows: “never these last 4 weeks” = 0; “once/month” = 1/28; “2–3/month” = 2.5/28; “1–2/week” = 1.5/7; “3–4 times/week” = 3.5/7; “once/day” = 1 and “2+/day” = 2.5. Daily consumption frequencies for each food category (i.e. fruits, vegetables, meat …) were obtained by summing up all consumption frequencies of the food items in that category. Compliance with the dietary recommendations of the Swiss Society of Nutrition [24–26] was computed as previously [27]. The recommendations regarding food are ≥2 fruit portions/day; ≥3 vegetable portions/day; ≥3 portions dairy products/day; ≤5 portions meat/week and ≥1 portion fish/week. Compliance with the recommendation for fish was assessed in two ways: the first one considering all types of fish (including fried and canned), the second one considering fresh fish only. For each food recommendation, a binary variable (1 = yes, 0 = no) was computed, and the total number of recommendations complied to was summed up.

Three dietary scores were computed: two related to Mediterranean diet and a third related to healthy eating. The first Mediterranean dietary score (hereby designated as “Mediterranean score 1”) was derived from the one suggested by Trichopoulou et al. [28]. Briefly, a score of zero or one is assigned to each of seven food components using their sex-specific medians as cut-off. For vegetables, fruits, fish and cereal, consumptions above the median are assigned the value of one; conversely, for meat and dairy products, consumptions below the median are assigned the value of one. Two other items were considered: the ratio of monounsaturated to saturated fats and moderate alcohol consumption (between 5 and 25 g/day for women and 10–50 g/day for men). The final score ranges between zero and eight.

The second Mediterranean dietary score (hereby designated as “Mediterranean score 2”) adapted to the Swiss population was computed according to Vormund et al. [29]. It uses the same scoring system but considers nine types of beneficial foods: fruits, vegetables, fish, cereal, salads, poultry, dairy products and wine. Contrary to the previous score, dairy products are considered as beneficial. The score thus ranges between zero and nine.

The alternative healthy eating index (AHEI) developed by the Harvard School of Public Health was computed according to McCullough et al. [30], with some modifications. This score is composed of several items: vegetables, fruit, nuts & soy and alcohol consumption (all expressed as number of servings per day); ratio of white to red meat; cereal fibre (g/day); *trans* fat (% of energy); polyunsaturated to saturated fat ratio; and duration of multivitamin use. For each item, a value between 0 and 10 is given based on its consumption. In our study, the amount of *trans* fat could not be assessed, and we considered all participants taking multivitamins as taking them for a duration ≥5 years. Thus, the modified AHEI score ranges between 2.5 and 77.5 instead of 2.5

and 87.5 for the original AHEI score [30], higher scores representing healthier diet.

2.3. Dietary patterns

Naïve dietary patterns were derived using principal components analysis based on food consumption frequencies. Three dietary patterns were identified: “Meat & fries”, “Fruits & vegetables” and “Fatty & sugary”. Detailed description of assessment and characteristics of the dietary patterns is provided elsewhere [31].

2.4. Polysomnography

Certified technicians equipped the subjects with a PSG recorder (Titanium, Embla® Flaga, Reykjavik, Iceland) between 5 and 8 pm at the Centre for Investigation and Research in Sleep (CIRS, Lausanne University Hospital, Switzerland). All sleep recordings took place in the patients' home environment in accordance with the American Academy of Sleep Medicine 2007 recommended setup specifications [32]. Breathing was recorded using nasal pressure sensors. Subjects currently under treatment for sleep disordered breathing (SDB, N = 38) were asked to discontinue their treatment one week prior to the sleep recording. Two trained sleep technicians, blinded to the FFQ questionnaires' results, scored manually the PSG recordings using Somnologica software (Version 5.1.1, Embla® Flaga, Reykjavik, Iceland). Each recording was reviewed by an expert sleep physician and a second sleep expert performed random quality checks. Quality control for concordance rate between the 2 PSG scorers was implemented periodically to ensure at least a 90% agreement for sleep stages and respiratory events and an 85% agreement for arousals [33]. For analysis, participants were categorized into three groups of sleep duration: <7, 7–9 and >9 hours/day.

2.5. Other data

All participants attended the outpatient clinic of the Lausanne University Hospital in the morning after an overnight fast. Participants were seen during a single visit, which included an interview and physical assessment, among others. Trained field interviewers collected data in a single visit lasting about 60 min. Participants attending the examination were apparently free from an acute disease. If they presented an acute disease, another examination was scheduled. Participants had to restrain from heavy exercise and to maintain their usual diet the day before testing.

Nationality was categorized into Swiss and non-Swiss. Smoking status was categorized into never, former (irrespective of the time since quitting) and current. Body weight and height were measured with participants standing barefoot and in light indoor clothes. Body weight was measured in kilograms to the nearest 100 g using a Seca® scale (Seca, Hamburg, Germany), which was regularly calibrated. Height was measured to the nearest 5 mm using a Seca® height gauge. A body mass index (BMI) ≥25 and <30 kg/m^2 defined overweight and ≥30 kg/m^2 defined obesity.

Subjective assessment of sleep was assessed by questionnaire, where the participant reported his/her average sleep duration. The Spearman correlation between the objective and the subjective sleep duration was 0.158, $p < 0.001$, and participants overestimated their sleep by 17 ± 91 min. Physical activity was assessed by questionnaire [34], and participants were considered as sedentary if they spent less than 10% of their daily (non-sleep) time in physical activities with an energy expenditure >4 times their basal metabolism rate. Participants were considered to be on a diet if they reported any type of diet (to lose weight, antidiabetic, low salt, low fat).

2.6. Exclusion criteria

Participants were excluded from the main analysis if their total energy intake was <850 or >4500 kcal/day [35] or if they had no data regarding dietary intake or any other variable used in the analysis.

2.7. Statistical analysis

Statistical analyses were performed using Stata version 16.1 for Windows (Stata Corp, College Station, Texas, USA). Descriptive results were expressed as number of participants (percentage) for categorical variables or as average ± standard deviation for continuous variables. Bivariate analyses were performed using chi-square or Fisher's exact test for categorical variables and Student's t-test or analysis of variance (ANOVA) for continuous variables. For categorical variables, multivariate analysis was performed using logistic regression, and the results were expressed as Odds ratio (OR) and 95% confidence interval (CI). For continuous variables, multivariate analysis was performed using ANOVA. As the associations between sleep and dietary intake might change according to sex, analyses stratified by sex were also conducted, and a sex*sleep categories interaction was assessed.

Several sensitivity analyses were conducted: 1) using subjective (reported) sleep data; 2) using objectively measured TST as a continuous variable and performing linear and quadratic regressions; 3) excluding participants with SDB, defined by an apnea–hypopnea index greater than 15/h [36]; 4) including only participants aged ≥65 years, as the majority is retired and thus less constrained to limit their sleep time, and 5) using quartiles of objective sleep duration. As participants who had their PSG performed on a Friday night might sleep more, a further adjustment for day of PSG was performed. Statistical significance was assessed for a two-sided test with $p < 0.05$.

3. Results

3.1. Characteristics of the participants

Of the initial 2162 participants, 44 (2.0%) and 208 (9.6%) were excluded because of missing data for dietary intake or because their total energy intake was <850 or >4500 kcal/day, respectively. The socio-demographic characteristics of excluded and included participants are summarized in Supplementary table 1. Excluded participants were more frequently women, older, had a higher BMI, were more frequently sedentary and less frequently born in Switzerland than the included ones.

There were 60.6%, 37.2% and 2.2% of the participants in the categories <7, 7–9 and >9 h/day, respectively. Table 1 summarizes the main characteristics of the participants according to sleep category. Participants sleeping <7 h/day were less frequently men, obese or on a diet, were older, and more frequently former smokers or born in Switzerland. There were 156 participants with a TST <5 h/day, and 7 participants with a TST >10 h/day.

3.2. Associations between sleep duration and dietary intake

Dietary intake according to sleep duration is summarized in Table 2. On bivariate analysis, short sleepers (<7 h/day) had lower MUFA and alcohol consumption; after multivariate adjustment, long (>9 h/day) sleepers had a higher consumption of total carbohydrates, mono and disaccharides, and total fat (Table 2). Adjusting for day of PSG did not change the results (not shown). Conversely, no associations were found after multivariate adjustment between sleep categories and the three dietary scores

Table 1
Characteristics of the sample according to objectively assessed sleep duration categories, CoLaus/HypnoLaus study, Lausanne, 2009–2013.

	<7 h/day	7–9 h/day	>9 h/day	p-value
Sample size (%)	1157 (60.6)	710 (37.2)	43 (2.2)	
Men (%)	677 (58.5)	271 (38.2)	17 (39.5)	<0.001
Age (years)	59.2 ± 11.1	56.9 ± 10.8	57.5 ± 10.9	<0.001
Age group (%)				0.004
[40–50]	297 (25.7)	233 (32.8)	12 (27.9)	
[50–60]	350 (30.3)	223 (31.4)	14 (32.6)	
[60+]	510 (44.1)	254 (35.8)	17 (39.5)	
Body mass index (kg/m^2)	25.6 ± 4.3	25.4 ± 3.9	27.0 ± 4.8	0.023
Body mass index categories (%)				0.042
Normal	548 (47.4)	370 (52.1)	15 (34.9)	
Overweight	465 (40.2)	247 (34.8)	19 (44.2)	
Obese	144 (12.5)	93 (13.1)	9 (20.9)	
Smoking status (%)				0.003
Former	495 (42.8)	265 (37.3)	9 (20.9)	
Never	449 (38.8)	317 (44.7)	27 (62.8)	
Current	213 (18.4)	128 (18.0)	7 (16.3)	
Born in Switzerland (%)	785 (67.9)	431 (60.7)	26 (60.5)	0.006
On a diet (%)	368 (31.8)	229 (32.3)	20 (46.5)	0.129
Sedentary (%)	566 (53.1)	368 (57.1)	25 (73.5)	0.023

Results are expressed as average ± standard deviation or as number of participants and (percentage). Between-group comparisons performed using analysis of variance for continuous variables and chi-square for categorical variables.

Table 2
Daily nutrients' intake according to objectively assessed sleep duration categories, CoLaus/HypnoLaus study, Lausanne, 2009–2013.

	<7 h/day	7–9 h/day	>9 h/day	p-value§	p-value§§
Sample size	1157	710	43		
Total energy intake (kcal)	1892 ± 626	1839 ± 633	1987 ± 750	0.103	0.223
Macronutrients (% TEI)					
Total protein	15.4 ± 3.0	15.6 ± 3.4	15.1 ± 3.3	0.190	0.108
Vegetable protein	4.7 ± 1.2	4.7 ± 1.1	4.6 ± 1.2	0.703	0.299
Animal protein	10.7 ± 3.4	10.9 ± 3.8	10.4 ± 3.9	0.217	0.079
Total carbohydrates	46.6 ± 8.6	46.0 ± 8.8	48.1 ± 8.0	0.130	0.013
Mono and disaccharides	22.7 ± 8.0	22.4 ± 8.3	25.2 ± 8.8	0.093	0.018
Polysaccharides	23.8 ± 7.7	23.4 ± 7.6	22.8 ± 7.9	0.409	0.661
Total fat	33.9 ± 6.4	34.7 ± 6.9	34.2 ± 5.8	0.052	0.034
SFA	12.7 ± 3.3	12.8 ± 3.3	12.1 ± 3.0	0.412	0.089
MUFA	13.5 ± 3.3	14.0 ± 3.7	14.0 ± 3.5	0.008	0.080
PUFA	4.8 ± 1.4	4.9 ± 1.5	5.0 ± 1.5	0.135	0.249
Micronutrients					
Dietary fibre (g)	16.6 ± 8.4	16.2 ± 8.9	19.1 ± 11.5	0.095	0.217
Cholesterol (mg)	311 ± 144	305 ± 153	307 ± 116	0.718	0.540
Alcohol (g)	79 ± 106	67 ± 96	53 ± 88	0.023	0.593
Calcium (mg)	1080 ± 549	1053 ± 562	1062 ± 451	0.586	0.532
Iron (mg)	10.9 ± 3.7	10.6 ± 3.9	11.4 ± 4.7	0.133	0.969
Retinol (μg)	536 ± 565	534 ± 725	409 ± 263	0.422	0.202
Carotene (μg)	4060 ± 3284	3996 ± 2630	4819 ± 4738	0.238	0.105
Vitamin D (μg)	2.60 ± 1.89	2.59 ± 1.92	2.61 ± 1.66	0.993	0.992

TEI, total energy intake; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. Results are expressed as average ± standard deviation or as number of participants and (percentage). Between-group comparisons performed using analysis of variance: § unadjusted; §§, adjusted on sex, age (continuous), body mass index (other, overweight, obese), smoking status (never, former, current), country of birth (Switzerland/other) and sedentary status (yes/no).

considered (Table 3); the three naïve dietary patterns (Table 3), or the compliance to the Swiss dietary recommendations (Table 4).

Stratifying the analyses by sex showed a higher consumption of mono and disaccharides among women who slept >9 h/day but not in men; and a higher total energy intake, total fat and SFA intake in men who slept >9 h/day but not in women (Supplementary tables 2 and 3). Women who slept <7/day had a lower score for the Fatty & sugary dietary pattern, while men who slept >9 h/day had higher scores for the Mediterranean diet 2 and the Fruits & vegetables dietary pattern (Supplementary tables 4 and 5). No differences were found regarding compliance to dietary recommendations between both genders (Supplementary tables 6 and 7). Still, only the sex*sleep categories interaction for the Mediterranean score 2 was statistically significant (p = 0.002).

3.3. Sensitivity analyses

The characteristics of the participants according to subjective sleep duration categories are indicated in Supplementary table 8. Long sleepers tended to be older and more frequently current smokers, while short sleepers had a higher BMI. The associations between subjective sleep duration and dietary intake are summarized in Supplementary tables 9–11. After multivariate adjustment, short and long sleepers consumed more animal protein (Supplementary table 9), while no association was found with the three dietary scores (Supplementary table 10), the naïve scores (Supplementary table 10) or the compliance to the Swiss dietary recommendations (Supplementary table 11).

Stratifying the analyses by sex showed that, in men, short sleepers to consumed more calories, had a higher AHEI score and

Table 3
Dietary adequacy scores and dietary patterns according to objectively assessed sleep duration categories, CoLaus/HypnoLaus study, Lausanne, 2009–2013.

	<7 h/day	7–9 h/day	>9 h/day	p-value§	p-value§§
Sample size	1157	710	43		
Diet quality scores					
Mediterranean diet[a]	4.04 ± 1.49	3.91 ± 1.50	3.84 ± 1.66	0.147	0.388
Mediterranean diet[b]	4.72 ± 1.89	4.71 ± 1.90	4.91 ± 2.21	0.801	0.512
AHEI	32.3 ± 9.7	32.6 ± 9.8	32.3 ± 9.7	0.760	0.892
Dietary patterns					
Meat & chips	−0.03 ± 1.09	−0.01 ± 1.27	0.13 ± 1.33	0.669	0.729
Fruits & vegetables	−0.04 ± 1.51	0.12 ± 1.56	0.47 ± 1.92	0.021	0.090
Fatty & sugary	0.00 ± 1.32	0.05 ± 1.35	0.07 ± 1.29	0.793	0.543

AHEI, alternative healthy eating index. Mediterranean diet scores: [a], according to Trichopoulo et al; [b], according to Vormund et al. Results are expressed as average ± standard deviation. Between-group comparisons performed using analysis of variance: § unadjusted; §§, adjusted on sex, age (continuous), body mass index (other, overweight, obese), smoking status (never, former, current), country of birth (Switzerland/other) and sedentary status (yes/no).

Table 4
Compliance to Swiss dietary guidelines according to objectively assessed sleep duration categories, CoLaus/HypnoLaus study, Lausanne, 2009–2013.

	<7 h/day	7–9 h/day	>9 h/day	p-value§
Sample size	1157	710	43	
Univariate analysis				
Fruits ≥2/day	492 (42.5)	289 (40.7)	19 (44.2)	0.707
Vegetables ≥3/day	86 (7.4)	52 (7.3)	6 (14.0)	0.272
Meat ≤5/week	701 (60.6)	418 (58.9)	25 (58.1)	0.743
Fish ≥1/week[1]	749 (64.7)	484 (68.2)	31 (72.1)	0.223
Fish ≥1/week[2]	475 (41.1)	292 (41.1)	18 (41.9)	0.994
Dairy products ≥3/day	84 (7.3)	72 (10.1)	4 (9.3)	0.090
≥3 recommendations[1]	272 (23.5)	165 (23.2)	11 (25.6)	0.938
≥3 recommendations[2]	201 (17.4)	126 (17.8)	9 (20.9)	0.827
Multivariate analysis				**p-value§§**
Fruits ≥2/day	1.19 (0.96–1.46)	1 (ref.)	1.24 (0.60–2.54)	0.226
Vegetables ≥3/day	1.14 (0.78–1.66)	1 (ref.)	1.71 (0.57–5.16)	0.285
Meat ≤5/week	1.11 (0.90–1.37)	1 (ref.)	0.88 (0.43–1.81)	0.846
Fish ≥1/week[1]	0.86 (0.69–1.07)	1 (ref.)	1.33 (0.61–2.92)	0.976
Fish ≥1/week[2]	1.05 (0.85–1.29)	1 (ref.)	1.20 (0.60–2.43)	0.537
Dairy products ≥3/day	0.72 (0.51–1.02)	1 (ref.)	1.31 (0.44–3.87)	0.583
≥3 recommendations[1]	1.12 (0.88–1.42)	1 (ref.)	1.27 (0.57–2.84)	0.367
≥3 recommendations[2]	1.08 (0.82–1.40)	1 (ref.)	1.33 (0.55–3.21)	0.450

Fish consumption: [1], all types of fish, including fried and canned; [2], fresh fish only. Results are expressed as number of participants and (percentage) or as multivariate-adjusted odds ratio and (95% confidence interval). Between-group comparisons performed using chi-square (unadjusted) and logistic regression adjusted on sex, age (continuous), body mass index (other, overweight, obese), smoking status (never, former, current), country of birth (Switzerland/other) and sedentary status (yes/no). §, p-value for chi-square; §§, p-value for quadratic trend.

had a higher odds of complying with the fish recommendation (Supplementary tables 12–14) while no difference was found for women (Supplementary tables 15–17). Only the sex*sleep categories interactions for cholesterol and the meat & chips score were statistically significant ($p < 0.001$ and $p = 0.015$, respectively).

The associations between objective sleep duration as a continuous variable and dietary intake are summarized in Supplementary tables 18–20 and in Supplementary Figs. 1 and 2. For vegetable protein, mono and disaccharides and polysaccharides, the quadratic model fitted better the data than the linear one, and significant coefficients were found for the quadratic component of TST. A linear association with total carbohydrate was also found, while neither linear nor quadratic association was found for all other nutrients (Supplementary table 18). No association was found with the three dietary scores or the naïve dietary patterns (Supplementary table 19). A linear association was found between TST and compliance to fish consumption, while no association was found with the compliance to the other recommendations (Supplementary table 20).

The associations between objective sleep duration and dietary intake after exclusion of participants with sleep apnea are summarized in Supplementary tables 21–23, and the associations between objective sleep duration and dietary intake among participants aged ≥65 years old are summarized in Supplementary tables 24–26. After multivariate adjustment, no significant associations were found for all dietary intake.

The associations between quartiles of objective sleep duration and dietary intake are summarized in Supplementary tables 27–29. Only an inverse association between quartiles of sleep duration and alcohol consumption was found (Supplementary table 27), while no association was found with the three dietary scores or naïve dietary patterns (Supplementary table 28), or the compliance to the Swiss dietary recommendations (Supplementary table 29).

4. Discussion

Several studies have suggested an association between sleep duration and dietary intake [4,37,38], but most if not all have relied on subjectively assessed TST [4,37,38]. Our results, based on objectively measured TST, suggest that the associations between TST and dietary intake either do not exist or are too small to be detected using the current sample size. Thus, the associations between TST and different chronic diseases might not be (or at most little) mediated by diet.

4.1. Characteristics of the participants

Elderly participants tended to sleep less, a finding in agreement with the literature [39]. BMI was higher in long sleepers, while BMI levels were similar between short and normal sleepers. Our results do not replicate those of a recent systematic review [1], where short sleep duration was associated with the risk of future obesity, while long sleep duration was not. Still, heterogeneity was high and non-significant associations were obtained in the systematic review after considering potential confounders [1]. Indeed, the association between short sleep and obesity is not consistent between studies [40]. A likely explanation is that long sleepers have lower physical activity levels, as observed in this study and in the literature [41]. Overall, our results suggest that long sleepers present with higher BMI levels, and that this association appears to be independent of dietary intake; thus, other mechanisms such as changes in metabolic status [5], decreased physical activity [41] or sleep quality [42] should be further explored, although the quality of the data on the association between diet and sleep quality is low [42].

4.2. Total energy intake and nutrients

No association was found between sleep duration and TEI, a finding in agreement with several studies [4,17,38,43] but not with others [3,44]. Hence, and as indicated previously, it is possible that sleep is associated with obesity independently of dietary behaviour [45].

The associations between sleep duration and macro or micronutrient intake are inconsistent and vary according to survey. For instance, a study based on participants of the 2007–2008 National Health and Nutrition Examination Survey (NHANES) found an association between short sleep and lower dietary fibre intake, and between long sleep and a decreased intake of protein, carbohydrates, sugars, dietary fibre, fat and alcohol [37], while no such associations or even opposite trends were found in other studies [17,43]. In this study, an association between long sleep and increased total carbohydrate, mono and disaccharide and total fat intake was found, a finding contradicting a previous study [43]. Interestingly, the differences for total carbohydrate, mono and disaccharide intake were stronger in women and the difference for total fat was stronger in men, although no significant interactions between sex and dietary intake were found ($p = 0.392$, 0.686 and 0.308 for total carbohydrate, mono and disaccharide, and total fat, respectively). Conversely, when using TST as a continuous variable, mono and disaccharide decreased with TST. A recent systematic review suggested that manipulating carbohydrate intake for at least 24 h appears to alter sleep outcomes among healthy individuals, but the strength of the evidence was low [46]. Interestingly, using TST as a continuous variable showed a significant U-association between TST and mono and disaccharide intake, and an inverse U-association between TST and polysaccharide, suggesting that both short and long sleepers tend to replace complex carbohydrates by simple ones (Supplementary table 18 and Supplementary Fig. 1). Nevertheless, the coefficients of the quadratic regression were very small, indicating that the impact of TST on carbohydrate preference might not be of clinical importance. Overall, our results suggest that there is little if no association between objectively measured sleep duration and macro- or micronutrient intake in the general population of Lausanne, and that those associations are similar between sexes. Still, the associations with total carbohydrate, mono and disaccharide and total fat intake should be further explored.

4.3. Dietary scores and naïve dietary patterns

No association was found between sleep duration and the three dietary quality scores considered irrespective of the model used. These findings are in agreement with a previous study on AHEI in a large cohort of 11,888 participants using reported sleep duration [17], but not in smaller (<1000 participants) studies [16,47]. In fact, there is little agreement between studies, as a worse healthy eating index has been reported either among long [47] or short [16] sleepers. Similarly, no association was found between the Mediterranean diet scores and sleep duration. Our results do not replicate those conducted in the US, where a higher Mediterranean diet score was associated with adequate sleep duration and less insomnia symptoms [48]. Possible explanations include the calculation of the Mediterranean score itself, which relies on sample-derived medians rather than on absolute values. Interestingly, men who slept >9 h/day scored higher the Mediterranean score 2, while no differences were found in women. Those findings contradict a study of Swedish men, where no association between the Mediterranean diet and sleep parameters was found [49]. Conversely, no sex differences in the association between the Mediterranean diet and sleep duration were found in a Greek study [50]. Still, the sex*Mediterranean score interaction term was not significant ($p = 0.393$). Overall, our results using both objective and subjective TST suggest that there is no consistent association between sleep duration and dietary quality, although differences between sexes should be further explored.

No association was found between sleep duration and naïve dietary patterns. Our results do not replicate those of a Polish study, where both the “fruits & vegetables” and the “fast food & sweets” were negatively associated with short sleep [51]. A study conducted in the UK found a positive association between long sleep and unhealthy dietary patterns, but this association varied according to weekday or weekend [52]. In this study, the association between naïve dietary patterns and sleep duration differed according to sex; women sleeping <7 h/day scoring lower in the Fatty & sugar pattern and men sleeping >9 h/day scoring higher in the Fruits & vegetables pattern, while no association was found for the Meat & chips pattern. Those findings should be compared to those of a German study that found no association between a “traditional” dietary pattern and sleep duration in women, and a negative association in men [53]. Still, as this “traditional” pattern differed between genders (high loading of vegetables, fruits, berries, fish, and nuts for women and more vegetables, root vegetables, fruits, beef, and whole-grain foods for men), identification of the foods most associated with sleep duration is difficult. As for dietary quality scores, our results suggest that there is no consistent association between sleep duration and dietary patterns, although differences between sexes should be further explored.

4.4. Compliance with recommendations

No difference was found between sleep categories regarding compliance to most dietary guidelines for food intake. Contrary to previous findings [54,55], no association was found between objectively or subjectively assessed TST and vegetable intake. A possible explanation is the low compliance rate regarding adequate vegetable intake observed in our study, which might have decreased statistical power. Notwithstanding, our results suggest that, similar to dietary quality scores, TST is not associated with a better or worse compliance to dietary guidelines.

4.5. Strengths and limitations

The main strength of this study is that it relied on objectively assessed TST via polysomnography, whereas most studies relied on subjective data [4,16,17,37,38].

This study also has several limitations worth acknowledging. Firstly, dietary intake and TST assessment were conducted approximately one year apart; hence, associations might have been lost due to changes either in dietary intake or sleep between assessment periods. Still, studies in nearby Geneva have shown that dietary intake changes little with time [56–58]. Secondly, TST was recorded on a single occasion, so it might not be representative of the usual sleep duration of a participant. Still, similar findings were obtained when subjective sleep duration was used. Thirdly, and contrary to other studies [37,38], it was not possible to assess the impact of very short (<5 h/day) or very long (>10 h/day) sleepers, as the number of very long sleepers was too small to allow proper statistical power. Still, using quartiles of TST led to similar findings. Fourthly, associations were adjusted for BMI, and it could be argued that this would lead to an overadjustment; still, most studies that assessed the associations between sleep duration and diet also adjusted for BMI [4,37,38], and not adjusting for BMI did not change the results (not shown). Fifthly, the study was conducted in Switzerland, and sleep characteristics might differ relative to other countries such as the USA, where the percentage of short sleepers is considerably higher and dietary intake also different. Hence, the associations might differ, but we lack data from PSG in USA studies to assess the issue of generalisability. Finally, we did not consider the possibility for people to take a nap during the afternoon since only nocturnal sleep was recorded [59]; thus, TST might be underestimated. As participants aged ≥65 years old are often retired and more likely to have daytime naps we performed an analysis in this subgroup which yielded similar results.

5. Conclusion

In a sample of the Swiss general adult population, little if no associations were found between objectively or subjectively assessed TST and dietary intake. The associations with total carbohydrate, mono and disaccharide and total fat intake deserve further investigation.

Author contribution

RS made part of the statistical analyses and wrote part of the manuscript; PMV collected data, made part of the statistical analysis and wrote part of the manuscript; PV, RH and JH-R collected data and revised the manuscript for important intellectual content; IG and GW revised the manuscript for important intellectual content. PMV had full access to the data and is the guarantor of the study. All authors have read and approved the current version of the manuscript.

Data availability

The study participants of CoLaus have not provided consent to publicly share the individual level data underlying this study. Information related to data access is available to qualified, interested researchers at https://www.colaus-psycolaus.ch/professionals/how-to-collaborate/. All responses to data sharing requests must comply with the ethical and legal constraints of Switzerland.

Declaration of competing interest

The authors report no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2022.01.028.

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