Sweet dreams are not made of this: no association between diet and sleep quality

Diet and sleep quality

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All authors have seen and approved the manuscript.

All authors have no conflict of interest to declare

None of the authors received funding to conduct this work

Figures: 1

Tables: 5

Word count: 245 abstract, 107 brief summary, 2830 manuscript

Abstract

Background: Numerous studies have emphasized the significance of nutrition on the quality of sleep, but little have evaluated the effect of various coexisting dietary markers on middle-aged adults. We assessed the association between sleep quality and a large array of dietary markers among middle-aged, community-dwelling participants.

Methods: Data from the first, second and third follow-ups of CoLaus|PsyCoLaus, a population-based study in Lausanne, Switzerland, was used. Sleep quality was assessed by the Pittsburgh Sleep Quality Index (PSQI). Dietary intake was assessed by a validated food frequency questionnaire.

Results: data from 3857 (53% women, 57.2±10.4 years), 2370 (52% women, 60.7±9.5 years) and 1617 (52% women, 63.5±9.0 years) participants from the first, second and third follow-ups was used. Bivariate correlations showed fish, vegetables, fruit, and cheese intake to be associated with a better sleep quality (lower PSQI), while rusks, sugar, and meat intake were associated with a poorer sleep quality (higher PSQI). After multivariable adjustment, participants reporting poor sleep quality (PSQI>5) had a lower Mediterranean diet score and a lower likelihood of complying with the meat and fish recommendations, but the results were inconsistent between surveys. No association was found between sleep quality and macro- or micronutrients in the three surveys.

Conclusions: No consistent associations were found between a large panel of nutritional markers and sleep quality. Components of the Mediterranean diet such as dairy, fruits and vegetables might favour good sleep quality, while increased consumption of sugary foods or meat might favour poor sleep quality.

Key words: sleep quality; dietary intake; nutrients; cross-sectional study

Brief summary

Despite recent research emphasizing the link between diet and sleep quality and the significance of sleep quality to prevent cardiometabolic diseases, few studies have examined the association of various coexisting dietary markers on middle-aged adults. Our study assessed the association between a wide range of dietary markers and sleep quality as assessed by PSQI in a population-based sample.

Consumption of healthy foods such as fruits, vegetables, fatty fish, and dairy products was positively associated sleep quality, whereas consumption of sugary foods was negatively associated. As a result, patients with poor sleep quality should be encouraged to adopt a Mediterranean diet that includes dairy products.

Introduction

Poor sleep quality is a common issue reported by the adult population[1–3] and is a known risk factor for illnesses such as hypertension[4] and coronary heart disease.[5] Several studies have highlighted the importance of dietary intake on sleep quality.[6–9] Two large studies concluded a positive impact of fruits and vegetables on sleep quality among older adults[10] and university students.[11] Smaller studies found positive associations between sleep quality and other types of food such as milk,[8,12] cherries[8,9] and rice[13] in older adults. Other studies reported a positive impact of nutrients like protein[14,15] or even dietary patterns such as the Mediterranean diet[16,17] in middle aged and older participants. Conversely, no specific benefit has been reported for ketogenic diet[18] and the beneficial effect of omega-3 fatty acids has been questioned.[19]

Although multiple studies have studied the association between dietary intake and sleep quality, most studies assessed only a limited number of nutrients, foods or dietary patterns and only a few assessed them all simultaneously. In addition, most sample sizes were small and included mainly elderly people. There is a need for a larger sample sized study to evaluate the impact of multiple coexistent dietary markers on sleep quality in middle aged adults.

The objective of this study was to assess the cross-sectional associations between a wide range of dietary markers and sleep quality among middle-aged, community-dwelling people. We expect to confirm or not the previously published associations between dietary intake and sleep quality.

Methods

Participants

The CoLaus|PsyCoLaus study is a population-based study investigating the epidemiology and genetic determinants of psychiatric and cardiovascular disease in Lausanne, Switzerland.[20] Briefly, a representative sample was collected through a simple, non-stratified random sampling of 19,830 individuals (35% of the source population) aged between 35 and 75. The baseline study was conducted between June 2003 and May 2006 and included 6733 participants; the first follow-up was performed between April 2009 and September 2012 and included 5064 of the initial participants (75.2%); the second follow-up was performed between May 2014 and April 2017 and included 4881 of the initial participants (72.5%), and the third follow-up was performed between April 2018 and May 2021 and included 3751 of the initial participants (55.7%). As dietary intake was only assessed in the follow-ups, data from the follow-ups was included in this study.

Sleep quality

Sleep quality was assessed with the Pittsburgh sleep quality index (PSQI). The PSQI is used to assess sleep patterns over the past month and can be completed by the rater alone or with a sleeping partner. The score varies between 0 and 21; indicative of overall sleep quality, as well as subscale values, including self-reported sleep quality, sleep-onset latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. A score >5 indicates poor sleep quality.[21]

Dietary intake

Dietary intake was assessed using a self-administered, semi-quantitative food frequency questionnaire (FFQ) which also included portion size.[22] This FFQ has been validated in the Geneva population.[22,23] Briefly, this FFQ assesses the dietary intake of the previous 4 weeks and consists of 97 different food items that account for more than 90% of the intake of calories, proteins, fat, carbohydrates, alcohol, cholesterol, vitamin D and retinol, and 85% of fibre, carotene and iron. For each item, consumption frequencies ranging from “less than once during the last 4 weeks” to “2 or more times per day” were provided, and the participants also indicated the average serving size (smaller, equal or bigger) compared to a reference size.

Dietary intake was computed as follows: first, for each food item, the daily amount consumed was obtained by multiplying the daily frequency (converting monthly and weekly frequencies into fractions, for example “3-4 per week”=3.5/7=0.5 times per day) by the portion size (in grams or mL) indicated. The amounts of individual food items belonging to the same food group (i.e., dairy products or fruits) were added to obtain the total daily amount consumed. For dairy products, conversion of mL to gr of milk was performed. Conversion into calories and nutrients was performed based on the French CIQUAL food composition table considering each individual food item. Then, for each individual nutrient (i.e., total or animal-derived protein) the corresponding caloric intake was computed and divided by the total energy intake.

Dietary scores

Two dietary scores were computed based on the Mediterranean diet. The first Mediterranean dietary score (designated as ‘Mediterranean score 1’) was derived from Trichopoulou et al. .[24] The score uses consumption frequencies instead of amounts. Briefly, a value of 0 or 1 is assigned to each of seven foods using their sex-specific medians as cut-off. Participants whose consumption frequencies for “healthy” foods (vegetables, fruits, fish, cereal…) were above the median were given the value of 1, while for “unhealthy” foods (meat, dairy products), consumption frequencies below the median were given the value of 1. Two other items were considered: ratio of monounsaturated to saturated fats and moderate alcohol consumption (between

5 and 25 g/day for women and 10 and 50 g/day for men). The score ranges between 0 and 8. The second Mediterranean dietary score (designated as 'Mediterranean score 2') adapted to the Swiss population was computed according to Vormund et al. .[25] It used the same scoring system but considered nine types of "healthy" foods: fruits, vegetables, fish, cereal, salads, poultry, dairy products and wine. The score ranges between 0 and 9. For both scores, higher values represented a healthier diet.

Participants were dichotomized according to whether they followed the dietary recommendations for fruits, vegetables, meat, fish and dairy products from the Swiss Society of Nutrition.[26,27] The recommendations were ≥2 fruit portions/day; ≥3 vegetable portions/day; ≤5 meat portions/week; ≥1 fish portion/week and ≥3 dairy products portions/day. In this study, we did not use portion size to compute adherence, but relied on consumption frequencies. This was done as the portion sizes recommended by the Swiss Society of Nutrition do not take into account a subject's corpulence and caloric needs.[27] As the FFQ queried about fresh and fried fish, two categories of adherence to fish consumption were considered: one included and one excluded fried fish. For each participant, the number of guidelines complied to was computed. Two sums were computed: one used adherence to fish consumption using all types of fish preparation (i.e., including fried fish); the other used adherence to fish consumption using fresh fish only.

Other covariates

Smoking was self-reported and categorized as never, former (irrespective of the time since quitting smoking) and current. Education was categorized into high (university), middle (high school) and low (apprenticeship + primary). Marital status was defined as living alone (single, divorced, widowed) or living with a partner.

Body weight and height were measured with participants barefoot and in light indoor clothes. Body weight was measured in kilograms to the nearest 100 g using a Seca® scale (Hamburg, Germany). Height was measured to the nearest 5 mm using a Seca® (Hamburg, Germany) height gauge. Body mass index was calculated and categorized as normal (<25 kg/m^2), overweight ≥25 and <30 kg/m^2) and obese ≥30 kg/m^2).

Blood pressure (BP) was measured using an Omron® HEM-907 automated oscillometric sphygmomanometer after at least a 10-minute rest in a seated position, and the average of the last two measurements was used. Hypertension was defined by a SBP ≥ 140 mm Hg or a DBP ≥ 90 mm Hg or presence of antihypertensive drug treatment.

Participants reported the medicines prescribed or bought over the counter. Medicines were further classified according to the WHO ATC criteria. Presence of sleep-inducing drugs such as benzodiazepines (ATC code starting with N05BA) and hypnotics or sedatives (ATC code starting with N05C) were considered.

Inclusion and exclusion criteria

All participants of the different surveys were considered as eligible for analysis. According to the PSQI scoring system, questions 1 to 9 are not allowed to be missing. Participants were excluded if they had 1) PSQI completely missing; 2) at least one answer missing for PSQI questions 1 to 9; 3) at least one answer missing in the PSQI questions 10 to 19; 4) no dietary data; 5) extreme total energy intake values (defined as <500 or >3500 kcal/day for women and <800 or >4000 kcal/day for men), or 6) missed any covariate.

Ethical statement

The institutional Ethics Committee of the University of Lausanne, which afterwards became the Ethics Commission of Canton Vaud (www.cer-vd.ch) approved the baseline CoLaus study (reference 16/03). The approval was renewed for the first (reference 33/09), the second (reference 26/14) and the third (reference PB_2018-000408) follow-ups. The approval for the entire CoLaus|PsyCoLaus study was confirmed in 2021 (reference PB_2018-00038, 239/09). The full decisions of the CER-VD can be obtained from the authors upon request. The study was performed in agreement with the Helsinki declaration and its former amendments, and in accordance with the applicable Swiss legislation. All participants gave their signed informed consent before entering the study.

Statistical analysis

Statistical analyses were conducted using Stata v.16.1 (Stata Corp, College Station, TX, USA). Descriptive results were expressed as number of participants (percentage) for categorical variables and as average±standard deviation or median [interquartile range] for continuous variables. Bivariate analyses were conducted using chi-square for categorical variables and student's t-test, analysis of variance (ANOVA) or Kruskal-Wallis test for continuous variables. Multivariable analyses were conducted using logistic regression for categorical outcomes, and results were expressed as odds ratio (OR) and (95% confidence interval). Multivariable analyses of continuous outcomes were conducted using ANOVA and results were expressed as multivariable-adjusted average±standard error. Multivariable analyses were adjusted on gender, age (continuous), education (high, middle, low), marital status (living with partner, living alone), smoking (never, former, current), presence of a diet (yes, no), BMI categories (normal, overweight, obese) and presence of sleep medicines (yes, no). As smoking might change dietary intake and increased BMI has been associated with poor sleep quality, the same analyses were conducted after stratifying by smoking and by BMI categories. The associations between the PSQI score (as a continuous variable) and the daily amounts of each food group were assessed using Spearman rank correlation.

Several sensitivity analyses were conducted. The first one used inverse probability weighting to take into account the percentage of excluded participants.[28] Briefly, logistic regression was used to estimate the likelihood of being included for each participant using covariates that were significantly different between included and excluded participants, i.e. age, gender, educational level, BMI categories, hypertension, diabetes and sleep medicines. The inverse of the predicted probability was then used for the analysis of dichotomous outcomes by logistic regression. The second sensitivity analysis used the data from all three follow-ups and assessed the association between dietary intake and sleep quality using mixed models with repeated measures for each participant. A third sensitivity analysis was conducted after excluding participants taking sleep medicines. Both weighted and unweighted mixed models were applied. All sensitivity analyses were adjusted for the same covariates as in the main analyses. Finally, a last sensitivity analysis was conducted including participants who had missing answers for the PSQI questions 10 to 19 (exclusion criterion 3).

Statistical significance was considered for a two-sided test with $p<0.05$.

Results

Study population

Of the 5064, 4894 and 3751 participants in the first, second and third follow-ups, 3857 (76.2%), 2370 (48.4%) and 1617 (43.1%) were included, respectively. The reasons for exclusion are summarized in **supplementary figure 1**. The main reason for exclusion was absence of sleep data.

The characteristics of included and excluded participants in each follow-up are summarized in **Table S1**. Excluded participants were more frequently women, were older, of a lesser educational level, more frequently obese, presenting with hypertension or diabetes, and taking more frequently sleep medicines.

The characteristics of the participants according to sleep quality and stratified by study period are summarized in **table 1**. Participants with a lower sleep quality were more frequently women, older, lived more frequently alone, and took sleep medicines more frequently.

Associations between dietary intake and poor sleep quality

The bivariate and multivariate associations between sleep quality and dietary intake, stratified by study period, are summarized in **tables 2 and 3**, respectively. No consistent statistically significant associations were found between the three follow-ups for any of the dietary variables studied (**table 2**). Participants reporting poor sleep quality had a lower Mediterranean diet score as defined by Vormund et al. in the first and second follow-ups, and a similar trend was found for the Mediterranean diet score as defined by Trichopoulo et al. (**table 2**).

Multivariate analysis confirmed the lack of consistent associations between sleep quality and dietary intake (**table 3**). Participants reporting poor sleep quality had a lower likelihood of complying with the meat recommendation in the first and third follow-ups, and a similar, non-significant trend was found in the second follow-up. Participants reporting poor sleep quality also had a lower likelihood of complying with the fish recommendation in the second follow-up. Finally, participants reporting poor sleep quality tended to present lower Mediterranean diet scores, but the differences did not reach statistical significance (**Table 3**). Slightly similar results for adherence to guidelines were found after weighting for non-inclusion (**Table S2**). Including all follow-ups in a single analysis and taking into account repeated measurements for each participant led to similar findings (**Table S3**). Excluding participants taking sleep medicines led to results close to those using the whole sample or applying inverse probability weighting (**Table S4**).

Stratifying the analysis by smoking status (**Tables S5 to S7**) or BMI category (**Tables S8 to S10**) did not reveal any consistent association. At most, a higher Mediterranean diet score among non-smokers reporting good sleep quality for study period 2014-2017 (**Table S6**) and a lower compliance to dietary guidelines among overweight participants reporting poor sleep quality for study periods 2014-2017 and 2019-2021 (**Tables S9 and S10**) was found.

The results of the sensitivity analysis including participants with missing data for the PSQI questions 10 to 19 are summarized in **Tables S11 to S12**. Overall, results were comparable to those restricted to participants with full PSQI data, a higher consumption of fruits, vegetables and fish, a lower consumption of meat and a higher compliance to at least three guidelines being associated with a lower likelihood of poor sleep quality.

Associations between selected food items and poor sleep quality

The correlations between the 97 food items of the FFQ (expressed as daily consumption in gr or mL) and sleep quality for the three follow-ups are depicted in **Figure 1**. Significant, albeit non-consistent negative associations were found for fish, vegetables, and cheese, while positive associations were found for rusks, sugar, and milk in coffee. Restricting the analysis to more generic food groups showed a negative association with fish, vegetables and fruit, and a positive association with meat (**Table 4**). Including participants with missing data for the PSQI questions 10 to 19 led to similar findings (**Table S13**).

Discussion

Main findings

In this population-based study, we found few associations between a large array of dietary intake markers and sleep quality. Overall, the results suggested that Mediterranean diet, fruits, vegetables and fish were negatively associated with poor sleep quality, while meat was positively associated with poor sleep quality. Still, the associations were inconsistent between surveys.

Associations between dietary intake and poor sleep quality

No association was found between sleep quality and macro- or micronutrient intake. Those findings do not replicate other studies reporting an inverse association between sleep quality and carbohydrate intake[29] or a positive association with monounsaturated [30] or polyunsaturated [31] fatty acids. Still, the latter findings are subject to controversy, as no association between polyunsaturated fatty acids and sleep quality was found in a cross-sectional study[19], and a randomized controlled trial failed to find any effect of a carbohydrate (55% of total calories) or a high fat (60% of total calories) diet on sleep quality as assessed by the PSQI.[19] Conversely, our findings are in agreement with a previous study assessing the association between sleep duration and diet[32] and with other studies reporting no association between sleep quality and long-chain omega-3 fatty acids.[19] Possible explanations include a low sample size leading to a low statistical power or that our database missed the nutrients that have been reported to be associated with sleep quality. Indeed, a recent review reported that zinc, vitamin B6 and polyphenols were associated with sleep quality,[6] and another review suggested that low serum levels of vitamin D were associated with poorer sleep quality.[33]

Participants reporting poor sleep quality had lower scores of the Mediterranean diet as defined by Vormund, but not as defined by Trichopoulou. Those findings confirm positive associations between the Mediterranean diet and sleep quality as reported previously,[8,16-17] Interestingly, the Vormund score differs from the original Mediterranean score by giving a positive effect to dairy products, and it has been suggested that milk intake improves sleep quality [9,34-35]. Still, no association was found between dairy products and sleep quality in our study, suggesting that dairy products alone might not be associated with sleep quality, or that only specific dairy products such as cheese (**Figure 1**) are associated with sleep quality. Further studies are needed to replicate our findings.

Sleep and adherence to dietary guidelines

Participants reporting poor sleep quality had a lower likelihood to comply with the meat recommendations and, to a lesser degree, a lower likelihood of complying with the fruits and the fish guidelines. Those findings are in agreement with the literature, as a higher consumption of fruits and vegetables,[11,36] fish,[34,37-38] and a lower consumption of meat (a source of saturated fat[29]) have been associated with a better sleep quality. Overall, our results indicate that a healthy diet favours sleep quality.

Sleep and food items

The food items with the strongest negative association with poor sleep quality were carrots, cheese, green salad, pasta, salmon, fruit tart, white fish, tomatoes, and olive oil. Those findings are in agreement with the literature, as a higher consumption of dairy products,[9,34,35] fruits and vegetables,[11,36,37] and fatty fish[34,37,38] is associated with a better sleep quality. Conversely, foods positively associated with poor sleep quality were rusks, sugar, lemonade, soda, syrups, milk in coffee, cake and dried pastries, mineral water, margarine, and low-fat products. Those findings are partly in agreement with the literature, where increased consumption of caffeinated beverages was associated with poor sleep quality[36]; for instance, milk in coffee might be a proxy of increased coffee consumption, although no association between coffee and sleep quality was found. Similarly, as cake and dried pastries are energy-dense foods, our findings are in agreement with a study reporting a positive association between higher energy-dense foods and poor sleep quality.[39] Finally, the association between sugary foods and poor sleep intake is in agreement with a study reporting that high sugar intake was associated with lighter, less restorative sleep.[40]

Implications for clinical practice

Our results suggest that consumption of healthy foods such as fruits, vegetables, fatty fish and dairy products favourably influences sleep quality, while the consumption of sugary foods decreases sleep quality. Hence, patients with poor sleep quality should be encouraged to adopt a Mediterranean type of diet, including dairy products, as a component of their treatment. Further, besides a favourable effect on sleep quality, the Mediterranean diet is also beneficial against type 2 diabetes[41] and cardiovascular disease.[42]

Strengths and limitations

This study's principal advantages rest on its sample size, which is considerably greater than those identified in previous studies. Additionally, we were able to conduct three interviews, with the same sleep and dietary intake questionnaires. The extensive panel of dietary markers examined is another significant strength.

There are some limitations to this study. First, many participants didn't complete the sleep questionnaire; therefore, a selection bias could be present. Still, the results were similar after weighting for exclusion. Secondly, sleep quality and dietary intake were assessed using self-reported questionnaires that could show different results from reality. Another limitation was the absence of information regarding the last meal consumed prior to the examined sleep period, which is likely to have the greatest impact on sleep quality.[43] Fourthly, our study was cross-sectional, and no causal effect of diet on sleep can be inferred; similarly, the issue of reverse causation (i.e., sleep quality affecting subsequent dietary intake) cannot be excluded[44]. Still, our results replicate those of previous studies, where no consistent association was found between dietary intake and sleep quality.[36,45]

Conclusions

No consistent associations were found between a large panel of nutritional markers and sleep quality. Components of the Mediterranean diet such as dairy, fruits and vegetables might be beneficial, while consumption of sugary foods or meat might favour poor sleep quality.

Abbreviations

ANOVA, analysis of variance

BP, blood pressure

BMI, body mass index

DBP, diastolic blood pressure

CI, confidence interval

FFQ, food frequency questionnaire

OR, odds ratio

PSQI, Pittsburgh Sleep Quality Index

SBP, systolic blood pressure

TEI, total energy intake

WHO, World Health Organization

CREDIT author statement

Joana Lopes Oliveira: investigation, formal analysis, writing – original draft, visualization. **Pedro Marques-Vidal**: conceptualization, data curation, validation, writing – review & editing, supervision.

Funding

The CoLaus|PsyCoLaus study was supported by unrestricted research grants from GlaxoSmithKline, the Faculty of Biology and Medicine of Lausanne, the Swiss National Science Foundation (grants 3200B0–105993, 3200B0-118308, 33CSCO-122661, 33CS30-139468, 33CS30-148401, 33CS30_177535 and 3247730_204523) and the Swiss Personalized Health Network (project: Swiss Ageing Citizen Reference). The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Data availability statement

The data of CoLaus|PsyCoLaus study used in this article cannot be fully shared as they contain potentially sensitive personal information on participants. According to the Ethics Committee for Research of the Canton of Vaud, sharing these data would be a violation of the Swiss legislation with respect to privacy protection. However, coded individual-level data that do not allow researchers to identify participants are available upon request to researchers who meet the criteria for data sharing of the CoLaus|PsyCoLaus Datacenter (CHUV, Lausanne, Switzerland). Any researcher affiliated to a public or private research institution who complies with the CoLaus|PsyCoLaus standards can submit a research application to research.colaus@chuv.ch or research.psycolaus@chuv.ch. Proposals requiring baseline data only, will be evaluated by the baseline (local) Scientific Committee (SC) of the CoLaus and PsyCoLaus studies. Proposals requiring follow-up data will be evaluated by the follow-up (multicentric) SC of the CoLaus|PsyCoLaus cohort study. Detailed instructions for gaining access to the CoLaus|PsyCoLaus data used in this study are available at www.colaus-psycolaus.ch/professionals/how-to-collaborate/.

Conflict of interest

The authors report no conflict of interest.

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Figure legends

Figure 1: volcano plot showing Spearman correlation coefficients on the X-axis and $-\log_{10}$(p-value) in the Y-axis between sleep quality as defined by the Pittsburgh Sleep Quality Index and daily consumption of the 97 items composing the food frequency questionnaire for the first (circles), second (triangles) and third (squares) follow-ups of the CoLaus|PsyCoLaus study, Lausanne, Switzerland. Negative correlations indicate a beneficial effect on sleep quality, while positive correlations indicate a deleterious effect. The horizontal lines indicate the p-values of 0.05 (long dashes) and 0.01 (short dashes).

Tables

Table 1: Characteristics of participants according to sleep quality, stratified by study period, CoLaus|PsyCoLaus study, Lausanne, Switzerland.

	2009-2012			2014-2017			2018-2021		
	PSQI≤5	**PSQI>5**	**P-value**	**PSQI≤5**	**PSQI>5**	**P-value**	**PSQI≤5**	**PSQI>5**	**P-value**
Sample size	**2525**	**1332**		**1557**	**793**		**1126**	**491**	
Women (%)	1251 (49.5)	794 (59.6)	<0.001	777 (49.3)	456 (57.5)	<0.001	534 (47.4)	309 (62.9)	<0.001
Age (years)	56.7 ± 10.3	58.2 ± 10.5	<0.001	60.1 ± 9.2	61.9 ± 9.8	<0.001	63.3 ± 8.9	63.9 ± 9.3	0.254
Education (%)			<0.001			0.205			0.408
Low	1196 (47.4)	717 (53.8)		693 (44.0)	374 (47.2)		487 (43.3)	230 (46.8)	
Middle	706 (28.0)	347 (26.1)		453 (28.7)	227 (28.6)		344 (30.6)	141 (28.7)	
High	623 (24.7)	268 (20.1)		431 (27.3)	192 (24.2)		295 (26.2)	120 (24.4)	
Living alone (%)	974 (38.6)	626 (47.0)	<0.001	376 (28.2)	259 (39.4)	<0.001	291 (30.8)	165 (40.7)	<0.001
Smoking (%)			0. 880			0.726			0.881
Never	1045 (41.4)	558 (41.9)		672 (42.6)	328 (41.4)		484 (43.0)	205 (41.8)	
Former	951 (37.7)	504 (37.8)		630 (40.0)	317 (40.0)		447 (39.7)	201 (40.9)	
Current	529 (21.0)	270 (20.3)		275 (17.4)	148 (18.7)		195 (17.3)	85 (17.3)	
BMI (kg/m^2)	25.9 ± 4.3	26.1 ± 4.6	0.165	25.9 ± 4.4	26.2 ± 4.4	0.253	26.0 ± 4.3	26.0 ± 4.7	0.908
BMI categories			0.446			0.532			0.079
Normal	1150 (45.5)	591 (44.4)		715 (45.3)	343 (43.3)		495 (44.0)	235 (47.9)	
Overweight	993 (39.3)	519 (39.0)		624 (39.6)	319 (40.2)		440 (39.1)	163 (33.2)	
Obese	382 (15.1)	222 (16.7)		238 (15.1)	131 (16.5)		191 (17.0)	93 (18.9)	
Diet (%)	733 (29.0)	468 (35.1)	<0.001	349 (22.1)	180 (22.7)	0.754	309 (27.4)	143 (29.1)	0.488
Hypertension (%)	955 (37.8)	594 (44.6)	<0.001	623 (40.0)	343 (43.3)	0.080	518 (46)	238 (48.5)	0.360
Diabetes (%)	232 (9.2)	134 (10.1)	0.380	100 (6.3)	73 (9.2)	0.011	82 (7.3)	34 (6.9)	0.798
Sleep medicines (%)	45 (1.8)	235 (17.7)	<0.001	33 (2.1)	145 (12.3)	<0.001	20 (1.8)	85 (17.3)	<0.001

BMI, body mass index; PSQI, Pittsburgh sleep quality index. Results are expressed as number of participants (percentage) for categorical variables and as average±standard deviation for continuous variables Between-group comparisons performed using chi-square for categorical variables and student's t-test for continuous variables.

Table 2: Bivariate associations between sleep quality and dietary intake, stratified by study period, CoLaus|PsyCoLaus study, Lausanne, Switzerland.

	2009-2012			2014-2017			2018-2021		
	PSQI≤5	PSQI>5	P-value	PSQI≤5	PSQI>5	P-value	PSQI≤5	PSQI>5	P-value
Sample size	**2525**	**1332**		**1557**	**793**		**1126**	**491**	
Nutrients (as % of TEI)									
Total protein	15.5 ± 3.2	15.5 ± 3.4	0.574	15.9 ± 3.4	15.7 ± 3.1	0.159	15.8 ± 3.3	15.7 ± 2.9	0.436
Vegetal protein	4.7 ± 1.2	4.6 ± 1.2	0.417	4.6 ± 1.1	4.5 ± 1.2	0.499	4.5 ± 1.1	4.6 ± 1.2	0.323
Animal protein	10.9 ± 3.6	10.8 ± 3.8	0.809	11.3 ± 3.7	11.2 ± 3.5	0.290	11.3 ± 3.7	11.1 ± 3.3	0.325
Total carbohydrates	46.4 ± 8.6	46.4 ± 9.2	0.958	44.7 ± 8.7	44.4 ± 9.1	0.425	43.5 ± 8.8	43.4 ± 8.8	0.829
Monosaccharides	23.4 ± 8.2	23.6 ± 8.3	0.412	22.8 ± 7.9	22.3 ± 7.9	0.155	22.2 ± 8.2	22.0 ± 7.6	0.733
Polysaccharides	22.9 ± 7.6	22.7 ± 7.9	0.368	21.8 ± 7.3	22.0 ± 7.8	0.590	21.3 ± 7.1	21.3 ± 7.4	0.875
Total fat	33.9 ± 6.5	33.8 ± 7.0	0.490	35.4 ± 6.8	35.5 ± 7.1	0.808	36.5 ± 6.9	36.3 ± 6.7	0.662
Saturated fat	12.6 ± 3.2	12.4 ± 3.3	0.160	12.9 ± 3.2	12.9 ± 3.3	0.542	13.4 ± 3.3	13.1 ± 3.1	0.156
Monounsaturated fat	13.6 ± 3.5	13.6 ± 3.8	0.964	14.6 ± 3.9	14.6 ± 4.0	0.871	15.1 ± 4.0	15.2 ± 4.0	0.744
Polyunsaturated fat	4.7 ± 1.5	4.8 ± 1.5	0.560	4.8 ± 1.4	4.9 ± 1.4	0.407	4.8 ± 1.3	4.9 ± 1.4	0.471
Dietary scores									
Mediterranean [a]	4.0 ± 1.5	3.9 ± 1.5	0.060	4.1 ± 1.5	3.9 ± 1.5	0.006	3.9 ± 1.5	4.0 ± 1.5	0.887
Mediterranean [b]	4.7 ± 1.9	4.6 ± 2.0	0.019	4.7 ± 2.0	4.5 ± 1.9	0.026	4.5 ± 2.0	4.6 ± 1.9	0.347
AHEI	31.9 ± 9.9	32.3 ± 10.3	0.278	32.2 ± 9.9	31.9 ± 9.9	0.465	31.6 ± 10	32.4 ± 9.8	0.146
Dietary guidelines									
Fruits ≥ 2/day	1038 (41.1)	549 (41.2)	0.949	705 (45.0)	305 (39.0)	0.005	444 (39.9)	204 (42.2)	0.391
Vegetables ≥3/day	174 (6.9)	91 (6.8)	0.945	128 (8.2)	55 (7.0)	0.340	75 (6.7)	26 (5.4)	0.300
Meat ≤ 5/week	1564 (61.9)	789 (59.2)	0.101	905 (57.7)	446 (57.0)	0.765	690 (62.2)	285 (59.3)	0.274
Fish all ≥ 1/week	1689 (66.9)	882 (66.2)	0.672	1119 (71.4)	560 (71.3)	0.989	779 (69.8)	335 (68.8)	0.685
Fish not fried ≥ 1/week	1014 (40.2)	536 (40.2)	0.961	765 (48.7)	337 (42.9)	0.008	209 (18.7)	86 (17.6)	0.616
Dairy ≥ 3/day	188 (7.5)	116 (8.7)	0.166	110 (7.0)	67 (8.6)	0.169	66 (6.0)	38 (7.9)	0.147
At least 3 guidelines [c]	586 (23.2)	306 (23.0)	0.869	393 (25.2)	177 (22.8)	0.212	260 (23.7)	107 (22.6)	0.621
At least 3 guidelines [d]	435 (17.2)	218 (16.4)	0.498	304 (19.5)	128 (16.5)	0.083	435 (39.7)	183 (38.6)	0.697

[a], according to Trichopoulo et al.; [b], according to Vormund et al.; [c], using all types of fish; [d], excluding fried fish. AHEI, alternative healthy eating index; PSQI, Pittsburgh sleep quality index; TEI, total energy intake. Results are expressed as number of participants (percentage) for categorical variables and as average±standard deviation for continuous variables Between-group comparisons performed using chi-square for categorical variables and student's t-test for continuous variables.

Table 3: Multivariable analysis of the associations between sleep quality and dietary intake, stratified by study period, CoLaus|PsyCoLaus study, Lausanne, Switzerland.

	2009-2012			2014-2017			2018-2021		
	PSQI≤5	**PSQI>5**	**P-value**	**PSQI≤5**	**PSQI>5**	**P-value**	**PSQI≤5**	**PSQI>5**	**P-value**
Sample size	**2525**	**1332**		**1557**	**793**		**1126**	**491**	
Nutrients (as % of TEI)									
Total protein	15.5 ± 0.1	15.5 ± 0.1	0.814	15.8 ± 0.1	15.7 ± 0.1	0.329	15.8 ± 0.1	15.7 ± 0.2	0.713
Vegetal protein	4.66 ± 0.02	4.63 ± 0.03	0.481	4.57 ± 0.03	4.49 ± 0.05	0.159	4.53 ± 0.04	4.49 ± 0.06	0.597
Animal protein	10.9 ± 0.1	10.9 ± 0.1	0.988	11.3 ± 0.1	11.2 ± 0.1	0.664	11.3 ± 0.1	11.2 ± 0.2	0.881
Total carbohydrates	46.4 ± 0.2	46.4 ± 0.2	0.758	45.0 ± 0.2	44.4 ± 0.3	0.205	43.8 ± 0.3	43.1 ± 0.5	0.169
Monosaccharides	23.5 ± 0.2	23.4 ± 0.2	0.720	22.9 ± 0.2	22.1 ± 0.3	0.033	22.4 ± 0.3	21.4 ± 0.4	0.046
Polysaccharides	22.8 ± 0.2	22.8 ± 0.2	0.959	21.9 ± 0.2	22.2 ± 0.3	0.461	21.3 ± 0.2	21.5 ± 0.4	0.612
Total fat	33.9 ± 0.1	33.8 ± 0.2	0.579	35.3 ± 0.2	35.4 ± 0.3	0.716	36.5 ± 0.2	36.2 ± 0.3	0.601
Saturated fat	12.6 ± 0.1	12.4 ± 0.1	0.231	12.8 ± 0.1	12.9 ± 0.1	0.394	13.3 ± 0.1	13.2 ± 0.2	0.741
Monounsaturated fat	13.6 ± 0.1	13.6 ± 0.1	0.835	14.5 ± 0.1	14.6 ± 0.2	0.844	15.1 ± 0.1	15.1 ± 0.2	0.870
Polyunsaturated fat	4.72 ± 0.03	4.74 ± 0.04	0.702	4.81 ± 0.04	4.88 ± 0.06	0.311	4.85 ± 0.04	4.84 ± 0.07	0.870
Dietary patterns									
Mediterranean [a]	4.00 ± 0.03	3.95 ± 0.04	0.400	4.12 ± 0.04	3.95 ± 0.06	0.028	4.01 ± 0.05	4.02 ± 0.08	0.927
Mediterranean [b]	4.72 ± 0.04	4.62 ± 0.05	0.136	4.86 ± 0.06	4.53 ± 0.09	0.002	4.60 ± 0.07	4.70 ± 0.11	0.436
AHEI	31.9 ± 0.2	32.2 ± 0.3	0.350	32.5 ± 0.3	32.0 ± 0.4	0.318	32.1 ± 0.3	32.2 ± 0.5	0.887
Dietary guidelines									
Fruits ≥ 2/day	1 (ref.)	0.92 (0.79-1.06)	0.252	1 (ref.)	0.71 (0.57-0.87)	0.001	1 (ref.)	0.95 (0.74-1.23)	0.715
Vegetables ≥3/day	1 (ref.)	0.94 (0.71-1.25)	0.687	1 (ref.)	0.77 (0.52-1.13)	0.175	1 (ref.)	0.68 (0.39-1.18)	0.170
Meat ≤ 5/week	1 (ref.)	0.82 (0.71-0.96)	0.010	1 (ref.)	1.01 (0.82-1.24)	0.908	1 (ref.)	0.75 (0.58-0.98)	0.032
Fish all ≥ 1/week	1 (ref.)	1.00 (0.86-1.16)	0.998	1 (ref.)	0.98 (0.78-1.22)	0.847	1 (ref.)	0.92 (0.70-1.21)	0.555
Fish not fried ≥ 1/week	1 (ref.)	1.02 (0.89-1.18)	0.748	1 (ref.)	0.74 (0.61-0.91)	0.004	1 (ref.)	0.94 (0.68-1.29)	0.687
Dairy ≥ 3/day	1 (ref.)	1.09 (0.84-1.41)	0.527	1 (ref.)	1.31 (0.91-1.89)	0.145	1 (ref.)	1.44 (0.89-2.34)	0.141
At least 3 guidelines [c]	1 (ref.)	0.90 (0.76-1.07)	0.222	1 (ref.)	0.85 (0.67-1.07)	0.166	1 (ref.)	0.77 (0.57-1.05)	0.103
At least 3 guidelines [d]	1 (ref.)	0.86 (0.71-1.04)	0.117	1 (ref.)	0.78 (0.60-1.01)	0.064	1 (ref.)	0.83 (0.64-1.08)	0.165

[a], according to Trichopoulo et al.; [b], according to Vormund et al.; [c], using all types of fish; [d], excluding fried fish. AHEI, alternative healthy eating index; PSQI, Pittsburgh sleep quality index; TEI, total energy intake. Multivariable analyses were conducted using

logistic regression for categorical outcomes, and results were expressed as odds ratio and (95% confidence interval). Multivariable analyses of continuous outcomes were conducted using ANOVA and results were expressed as multivariable-adjusted average±standard error. Multivariable analyses were adjusted on gender, age (continuous), education (high, middle, low), marital status (living with partner, living alone), smoking (never, former, current), presence of a diet (yes, no), BMI categories (normal, overweight, obese) and presence of sleep medicines (yes, no).

Table 4: correlations between sleep quality and daily amount consumed of each food group, stratified by study period, CoLaus|PsyCoLaus study, Lausanne, Switzerland.

Food group	2009-2012	p-value	2014-2017	p-value	2018-2021	p-value
Dairy	0.012	0.447	0.014	0.513	0.034	0.168
Meat	0.034	0.036	0.017	0.410	0.017	0.495
Processed meat	0.004	0.799	0.004	0.865	-0.009	0.715
Fish	0.007	0.661	-0.051	0.013	-0.004	0.877
Vegetables	0.010	0.542	-0.061	0.003	0.009	0.723
Fruit	-0.012	0.476	-0.059	0.004	-0.015	0.559
Alcohol	-0.011	0.482	-0.004	0.833	-0.033	0.188

Results are expressed as Spearman correlation coefficients between the PSQI score (as a continuous variable) and the daily amounts consumed for each food group.