American Journal of Epidemiology

Vol. 193, No. 4
https://doi.org/10.1093/aje/kwad228
Advance Access publication:
November 17, 2023

Original Contribution

Associations of Anti–COVID-19 Measures and Lifestyle Changes During the COVID-19 Pandemic With Sleep Patterns in the Netherlands: A Longitudinal Study

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Initially submitted March 10, 2023; accepted for publication November 14, 2023.

Although there is scientific evidence for an increased prevalence of sleep disorders during the coronavirus disease 2019 (COVID-19) pandemic, there is still limited information on how lifestyle factors might have affected sleep patterns. Therefore, we followed a large cohort of participants in the Netherlands ($n = 5{,}420$) for up to 1 year (September 2020–2021) via monthly Web-based questionnaires to identify lifestyle changes (physical activity, cigarette smoking, alcohol consumption, electronic device use, and social media use) driven by anti–COVID-19 measures and their potential associations with self-reported sleep (latency, duration, and quality). We used the Containment and Health Index (CHI) to assess the stringency of anti–COVID-19 measures and analyzed associations through multilevel ordinal response models. We found that more stringent anti–COVID-19 measures were associated with higher use of electronic devices (per interquartile-range increase in CHI, odds ratio (OR) = 1.47, 95% confidence interval (CI): 1.40, 1.53), less physical activity (OR = 0.94, 95% CI: 0.90, 0.98), lower frequency of alcohol consumption (OR = 0.63, 95% CI: 0.60, 0.66), and longer sleep duration (OR = 1.11, 95% CI: 1.05, 1.16). Lower alcohol consumption frequency and higher use of electronic devices and social media were associated with longer sleep latency. Lower physical activity levels and higher social media and electronic device use were related to poorer sleep quality and shorter sleep duration.

anti–COVID-19 measures; coronavirus disease 2019; COVID-19 pandemic; lifestyle changes; lockdown stringency; sleep patterns; well-being

Abbreviations: AMIGO, Occupational and Environmental Health Cohort Study; CHI, Containment and Health Index; CI, confidence interval; COVID-19, coronavirus disease 2019; IQR, interquartile range; OR, odds ratio; PIAMA, Prevention and Incidence of Asthma and Mite Allergy; VGO, Livestock Farming and Neighboring Residents' Health.

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2, emerged at the end of 2019 in Wuhan, China (1), and on March 11, 2020, was declared a pandemic by the World Health Organization (2). During the 3 years that the global health emergency lasted, different containment and preventive measures were implemented worldwide to restrict behaviors that increased the risk of infection. While these measures were undoubtedly important in controlling the spread of the virus, they also disrupted the normal rhythm of life and caused physical and psychosocial health effects (3, 4).

Along with high rates of anxiety and depression (4, 5), there was an increase in sleep problems during the pandemic, with an estimated prevalence of 38% in the general population (5, 6). The impact of the pandemic on sleep capability and well-being is likely to have reflected the sum of its direct and indirect effects. Direct effects refer to acute COVID-19 infection and/or its chronic repercussions, which can include anxiety, depression, fatigue, and sleep disturbances (7–9). Indirect effects result from changes in living conditions due to the pandemic and arise from the rigor of policy measures implemented to control the spread of the virus. These effects stem primarily from educational disruption, financial insecurity, social isolation, lack of physical exercise, constant exposure to threatening information, and substantial lifestyle changes (10–13).

Sleep is vital for optimal physiological and neurological functioning (14, 15), as well as for proper hormone secretion and immune response (14). Furthermore, sleep disorders have been reported to increase morbidity and mortality (16). Changes in sleep patterns are relevant consequences of any contingency (5, 6), and understanding and preventing conditions that promote sleep problems is vital for the population's well-being and health during pandemic crises. In the IMPACT Study, we followed 3 diverse cohorts of adults in the Netherlands to investigate the effect of anti–COVID-19 measures on lifestyle changes and sleep patterns.

METHODS

Study design and study population

Participants were recruited from 3 ongoing cohort studies based in the Netherlands: the Occupational and Environmental Health Cohort Study (AMIGO), the Prevention and Incidence of Asthma and Mite Allergy (PIAMA) Study, and the Livestock Farming and Neighboring Residents' Health (VGO) Project, whose designs have been described in detail elsewhere (17–20). Briefly, AMIGO is a population-based cohort study of 14,829 adults aged ≥30 years recruited between 2011 and 2012 (17); the VGO cohort was formed in 2012 and comprises 8,971 adults aged ≥18 years living in rural areas (19, 20); and PIAMA is a birth cohort study of 3,963 young adults born between 1996 and 1997 (18).

All cohort members who had a valid e-mail (AMIGO, PIAMA) or postal (VGO) address available ($n = 24{,}636$; 88.7%) received an invitation letter to participate in the IMPACT Study, and 5,420 (22%) agreed to participate. Recruitment was carried out independently for each cohort, resulting in different starting dates and follow-up periods. Participants were followed for up to 1 year from September 2020 to August 2021 (AMIGO) and from December 2020 to August (PIAMA) or September (VGO) 2021.

Participants were asked to complete a baseline questionnaire including items on sociodemographic variables (age, sex, occupational status). Afterward, they received monthly questionnaires that included, among other items, questions on sleep patterns and lifestyle determinants (for the exact questionnaires, see Web Appendices 1 and 2, available at https://doi.org/10.1093/aje/kwad228). All questionnaires were provided and answered using a mobile application.

Lifestyle determinants

We investigated 5 lifestyle determinants, all analyzed as categorical variables: physical activity (5 levels ranging from less than 15 minutes/day to more than 2 hours/day), current cigarette smoking (yes or no), alcohol consumption frequency (6 levels ranging from no alcohol consumption to 6–7 days/week), electronic device use (5 levels ranging from less than 1 hour/day to 10 or more hours/day), and social media use (3 levels ranging from no social media use to more than 1 hour/day).

Sleep-related variables

Sleep patterns were analyzed through 3 ordinal categorical variables in relation to the last 4 weeks: sleep latency or amount of time needed to fall asleep (from 15 minutes or less to more than 30 minutes), sleep duration (from 5 hours or less to more than 8 hours of sleep per night), and sleep quality (from poor to excellent quality).

COVID-19 containment measures

To study the impact of the anti–COVID-19 measures on both lifestyle and sleep, we used the Containment and Health Index (CHI) from the Oxford COVID-19 Government Response Tracker (21). The CHI is an additive unweighted index that ranges from 0 to 100, with higher values indicating the implementation of more stringent measures. Data from the Oxford COVID-19 Government Response Tracker were provided in a time-series format where we observed little day-to-day variation within months, so we took the monthly average of daily CHI values for the calendar month to which each questionnaire referred (see Web Figure 1 and Web Table 1).

Confounders and variable selection

Covariates included in the multivariable-adjusted models were selected using directed acyclic graphs (see Web Figures 2–4). A distinction was made between clear potential confounders (set A) and confounders that could also be mediators (set B) to assess the possibility of under- or overadjustment (see Web Table 2). The variables considered were age, sex, occupational status (self-employed, employed, retired, student, or other), any chronic health condition (yes or no), mental illness (yes or no), COVID-19 infection (yes/possibly or no), perception of general and physical health (Likert-type scales with 5 levels), levels of stress, fatigue, anxiety, happiness, concern, and loneliness (Likert-type scales with 5 or 4 levels), and adaptability and positive development (Likert-type scales with 4 levels of agreement). We included mean hours of sunlight per month, data obtained from the Royal Netherlands Meteorological Institute (22), to account for a potential seasonal effect.

For all sleep outcomes, covariate adjustment sets A and B were entered into the model separately. A forward stepwise procedure was performed, and variables that changed association estimates by more than 10% were retained in the final models.

Statistical analysis

All statistical analyses were performed using R software (version 4.0.2) and RStudio (version 1.4.1717) (R Foundation for Statistical Computing, Vienna, Austria). Correlations between all lifestyle determinants and potential confounders were calculated using Spearman's rank correlation coefficient and Cramer's V from the χ^2 test.

To investigate the relationship between lifestyle determinants and the stringency of anti–COVID-19 policy measures, we fitted a model for each lifestyle determinant as the outcome variable and CHI as the explanatory variable for each cohort separately. To investigate the associations of anti–COVID-19 measures and lifestyle factors with sleep during the pandemic, each sleep variable was used as an outcome variable, and lifestyle determinants and CHI were both used as covariates. In our primary analysis, we analyzed each cohort separately. Cumulative link mixed models were fitted considering the presence of multilevel data (individual level) and the ordinal nature of the outcomes. A secondary analysis was performed on a data set comprising all 3 cohorts to obtain overall estimates, using cohort as a fixed effect given the large sample size of the study (23). Since there is currently no package within R that allows modeling of autocorrelation structures for mixed ordinal regression using frequentist statistics, we also fitted the overall models using a Bayesian multilevel approach with weakly informative cumulative prior distributions and an autoregressive term of order 1 (AR1).

Since CHI followed a seasonal pattern, the models adjusted for mean number of hours of sunlight per month to assess changes in association estimates as a sensitivity analysis. Additionally, due to loss to follow-up and missing data in our variables (at most, 24.5%), final models were fitted using an imputed data set with the "last observation carried forward" method. This method was chosen since the variables exhibited a rather stable pattern over time within participants and we mainly observed a nonmonotonic pattern of missing data. Lastly, all final models were checked for violations of the underlying statistical assumptions, including the proportional odds assumption.

Ethics approval

The Medical Research Ethics Committee of University Medical Centre Utrecht assessed the project plan and concluded that official approval of a Medical Research Ethics Committee was not required under the Dutch Human Subjects Medical Research Act, since no invasive human research procedures were performed. All participants gave written informed consent prior to enrollment, within the Declaration of Helsinki framework.

RESULTS

Of a total of 5,420 IMPACT participants, 3,383 were from AMIGO (62.4%), 1,184 from VGO (21.8%), and 853 from PIAMA (15.7%). The overall response rate was 22%. Response rates were highest for PIAMA (44.6%) and lowest for VGO (14.1%) (see Web Tables 3–6). A total of 4,495 (82.9%) participants completed the baseline questionnaire before the follow-up period (see Web Figure 5). Almost all participants completed at least 1 follow-up questionnaire (n = 5,011; 92.5%), with a median number of observations per participant of 9 (interquartile range (IQR), 7–11). Compared with the source population, IMPACT participants were more likely to have a high socioeconomic status (see Web Tables 3–6).

The baseline characteristics of the participants are shown in Table 1. The average age of the total study population was 55 years; the PIAMA cohort comprised young adults (average age = 24.6 (IQR, 24.4–24.9) years), while the AMIGO and VGO cohorts mostly consisted of older adults (average ages were 61.0 (IQR, 54.4–68.3) and 60.3 (IQR, 53.3–69.0) years, respectively). The evaluated lifestyle determinants and covariates exhibited little to no correlation with each other (Web Tables 7–11). The highest positive correlation was observed between the use of electronic devices and the use of social media (Pearson's $\rho = 0.25$; $P < 0.001$), and the highest negative correlations were observed between age and use of social media ($\rho = -0.37$; $P < 0.001$) and between physical activity and use of electronic devices ($\rho = -0.21$; $P < 0.001$).

Lifestyle changes during the pandemic

During the study period, the CHI value reached a maximum of 71.2 (February 2021) and a minimum of 45.4 (July 2021) (see Web Figure 1). Participants from AMIGO and VGO reported higher physical activity levels and consumed alcohol more frequently than PIAMA participants (Web Table 12 and Web Figures 6 and 7). Few participants were smokers: Overall, 534 (9.9%) reported smoking on at least 1 questionnaire (Web Table 13 and Web Figure 8). Use of electronic devices and social media was higher among PIAMA participants than among VGO and AMIGO participants (Web Figures 9 and 10).

Estimates of the associations between CHI and lifestyle determinants are reported in Table 2 and Web Figure 11. Odds ratios (ORs) for the association with CHI were positive for the use of electronic devices in all 3 cohorts but larger in PIAMA (per IQR increase in CHI, OR = 2.34, 95% confidence interval (CI): 1.95, 2.85) than in VGO (OR = 1.35, 95% CI: 1.20, 1.50) and AMIGO (OR = 1.41, 95% CI: 1.33, 1.48). Furthermore, a higher CHI value was associated with a lower frequency of alcohol consumption in all 3 cohorts (Table 2). Higher CHI values were associated with increased odds of exercising more hours per day only in PIAMA (Table 2). CHI was positively associated with social media use only in AMIGO (Table 2). Chi was negatively associated with the odds of being a smoker in all cohorts (Table 2); however, cohort-specific associations were not always statistically significant due to limited statistical power, considering the low proportion of smokers in the sample.

Associations of CHI and lifestyle determinants with sleep latency

Fully adjusted ORs for the association between lifestyle determinants and sleep latency are reported in Table 3 and Figure 1. For the PIAMA cohort only, a higher CHI value was associated with shorter sleep latency (per IQR increase, OR = 0.82, 95% CI: 0.71, 0.95). Overall, a higher frequency of alcohol consumption was associated with shorter sleep latency compared with no alcohol consumption, and more pronounced associations were observed for more frequent consumption. Using social media for more than 1 hour per

Table 1. Baseline Characteristics of the Study Population and Its 3 Individual Cohorts, IMPACT Study, the Netherlands, September 2020–2021

Characteristic	IMPACT Cohort						Total (*n* = 5,420)	
	PIAMA (*n* = 853)		AMIGO (*n* = 3,383)		VGO (*n* = 1,184)			
	No.	%	No.	%	No.	%	No.	%
Age, years								
Mean[a]	24.6 (0.3)		61.0 (8.9)		60.3 (11.1)		55.1 (15.8)	
Median[b]	24.6 (24.4–24.9)		61.8 (54.4–68.3)		61.2 (53.3–69.0)		59.0 (48.5–67.3)	
Range	24.0–25.3		39.9–76.8		27.4–79.2		24.0–79.2	
Missing data	81		282		164		527	
Sex								
Male	273	35.5	1,463	47.2	504	49.6	2,240	45.8
Female	496	64.5	1,638	52.8	513	50.4	2,647	54.2
Missing data	84		282		167		533	
Occupation								
Self-employed	25	3.3	286	9.5	108	10.7	419	8.8
Employed	348	45.3	1,450	48.1	483	48.0	2,281	47.6
Retired	0	0.0	945	31.4	332	33.0	1,277	26.7
Student	365	47.5	2	0.1	1	0.1	368	7.7
Other	31	4.0	330	11.0	82	8.2	443	9.3
Missing data	84		370		178		632	
Health-care worker								
No	650	77.1	2,541	85.8	978	82.7	4,169	83.6
Yes	193	22.9	422	14.2	204	17.3	819	16.4
Missing data	10		420		2		432	
Chronic health condition								
No	370	49.1	1,006	33.6	397	39.9	1,773	37.4
Yes	260	34.5	1,767	59.0	542	54.4	2,569	54.2
Yes + mental illness	124	16.4	221	7.4	57	5.7	402	8.5
Missing data	99		389		188		676	

Abbreviations: AMIGO, Occupational and Environmental Health Cohort Study; PIAMA, Prevention and Incidence of Asthma and Mite Allergy; VGO, Livestock Farming and Neighboring Residents' Health.
[a] Values are presented as mean (standard deviation).
[b] Values are presented as median (interquartile range).

day was associated with longer sleep latency. Finally, the use of electronic devices for 4–6 hours per day was associated with longer sleep latency; however, the same association was not found with the use of electronic devices for 7 or more hours per day.

Associations of CHI and lifestyle determinants with sleep duration

Adjusted estimates of the association between lifestyle determinants and sleep duration are presented in Table 4 and Figure 2. Overall, we observed longer sleep duration with higher CHI values: Per IQR increase in CHI, the OR for having a longer sleep duration was 1.11 (95% CI: 1.05, 1.16). However, for PIAMA participants, we observed the opposite: A higher CHI value was associated with shorter sleep duration (OR = 0.85, 95% CI: 0.75, 0.96). Additionally, exercising for less than 30 minutes per day and being a smoker were associated with shorter sleep duration, and the use of electronic devices also exhibited a negative association.

Associations of CHI and lifestyle determinants with sleep quality

Fully adjusted ORs for associations of lifestyle determinants with sleep quality are reported in Table 5 and Figure 3. Although CHI was not associated with sleep quality in any of the analyses, physical activity and social media use showed negative associations. Overall, engaging in less than 30 minutes of exercise per day and spending more than 1

Table 2. Estimated Odds Ratios for Associations Between Containment and Health Index Values and Lifestyle Determinants in the 3 Individual Cohorts and in Overall Analyses, IMPACT Study, the Netherlands, September 2020–2021[a]

Lifestyle Determinant and IMPACT Cohort	Odds Ratio	95% Credible Interval	No. of Participants	No. of Observations
Physical activity				
PIAMA	1.19	1.02, 1.40	727	5,816
AMIGO	0.96	0.91, 1.01	3,142	34,810
VGO	1.02	0.91, 1.15	1,097	8,224
Overall	0.94	0.90, 0.98	5,009	51,470
Current cigarette smoking				
PIAMA	0.49	0.15, 1.33	769	6,493
AMIGO	0.91	0.49, 1.62	3,141	34,801
VGO	0.27	0.11, 0.56	1,097	8,142
Overall	0.43	0.14, 0.84	5,007	51,453
Alcohol consumption				
PIAMA	0.60	0.50, 0.69	769	6,493
AMIGO	0.68	0.64, 0.71	3,143	34,823
VGO	0.56	0.50, 0.63	1,096	8,190
Overall	0.63	0.60, 0.66	5,008	51,465
Electronic devices				
PIAMA	2.34	1.95, 2.85	769	6,493
AMIGO	1.41	1.33, 1.48	3,136	34,749
VGO	1.35	1.20, 1.50	1,092	8,092
Overall	1.47	1.40, 1.53	4,997	51,354
Social media				
PIAMA	1.06	0.77, 1.46	769	6,493
AMIGO	1.08	1.01, 1.16	3,139	34,780
VGO	0.98	0.85, 1.12	1,095	8,082
Overall	1.06	1.00, 1.14	5,003	51,414

Abbreviations: AMIGO, Occupational and Environmental Health Cohort Study; CHI, Containment and Health Index; IQR, interquartile range; PIAMA, Prevention and Incidence of Asthma and Mite Allergy; VGO, Livestock Farming and Neighboring Residents' Health.

[a] Association estimates were calculated using a Bayesian framework. The odds ratio represents the odds of each lifestyle determinant being rated in category j or above ($Y \geq j$) at a 1-IQR increase in CHI (IQR = 11.5) relative to no increase. For example, for a 1-IQR increase in CHI, the odds of exercising more hours per week were 1.19 times higher than without an increase in CHI.

hour per day on social media were associated with a decrease in the odds of having a better-rated sleep quality.

Sensitivity analyses

As can be seen in Figures 1–3, the Bayesian models, which allowed control for autocorrelation structures, produced slightly stronger association estimates with reduced precision compared with the cumulative link mixed models. Inconsistencies in the directions of associations based on the cumulative link mixed model analyses were observed between the PIAMA cohort relative to the overall analyses, which were largely driven by the AMIGO cohort due to differences in sample sizes. Higher CHI was associated with shorter sleep latencies and shorter sleep durations in PIAMA, in contrast to longer sleep duration and no observed association with sleep latency in the overall analyses (Figures 1 and 2). Finally, neither repeating the analyses with an imputed data set nor adjusting for average hours of sunlight per month produced notable changes in the association estimates (Web Tables 14–31).

DISCUSSION

In this large prospective cohort study, we observed that more stringent policy measures during the pandemic may have been related to lifestyle changes. Specifically, we observed associations between the rigor of anti–COVID-19

Table 3. Estimated Odds Ratios for Associations Between Lifestyle Determinants and Sleep Latency[a] in the IMPACT Study, the Netherlands, September 2020–2021[b]

Lifestyle Determinant	Odds Ratio	95% Credible Interval	No. of Observations	% of Observations
CHI value	1.04	0.96, 1.11	44,554	100
Physical activity				
<15.0 minutes/day	1.11	0.89, 1.38	4,508	10.1
15.0–29.9 minutes/day	0.92	0.80, 1.06	12,298	27.6
30.0–59.9 minutes/day	1.00	Referent	15,672	35.2
1.0–2.0 hours/day	1.10	0.94, 1.29	9,215	20.7
>2.0 hours/day	1.01	0.76, 1.35	2,861	6.4
Current cigarette smoking				
No	1.00	Referent	41,394	92.9
Yes	1.28	0.81, 2.03	3,160	7.1
Alcohol consumption				
None	1.00	Referent	10,280	23.2
<1 day/week	0.95	0.77, 1.18	8,218	18.4
1 day/week	0.62	0.47, 0.80	6,064	13.6
2–3 days/week	0.65	0.50, 0.85	11,144	25.0
4–5 days/week	0.55	0.39, 0.75	4,377	9.8
6–7 days/week	0.33	0.21, 0.50	4,471	10.0
Electronic device use				
<1 hour/day	0.93	0.72, 1.18	4,170	9.4
1–3 hours/day	1.00	Referent	18,477	41.5
4–6 hours/day	1.31	1.10, 1.55	11,041	24.8
7–9 hours/day	1.16	0.93, 1.46	7,425	16.7
≥10 hours/day	1.37	0.99, 1.91	3,441	7.7
Social media use				
No use	0.98	0.80, 1.20	13,582	30.5
≤1 hour/day	1.00	Referent	20,874	46.9
>1 hour/day	1.57	1.31, 1.90	10,098	22.7

Abbreviations: CHI, Containment and Health Index; IQR, interquartile range.

[a] Sleep latency categories: ≤15 minutes (reference category), 16–30 minutes, and >30 minutes.

[b] Association estimates correspond to the Bayesian models from the overall analysis, adjusted for chronic condition, mental illness, fatigue level, and stress level. The odds ratio represents the odds of each response variable being rated in category j or above ($Y \geq j$) at a 1-IQR increase in CHI relative to no increase, or in each category relative to the reference category.

measures and physical activity, alcohol consumption, and electronic device use. In addition, participants reported slightly longer sleep duration during the months with more stringent anti–COVID-19 measures.

Our study participants reported higher levels of sedentary behavior during the pandemic, with higher electronic device use and lower physical activity levels during the months with more stringent measures. Despite the wide range of analytical methods encountered in the literature, our findings are consistent with those published previously indicating increases of 2–3 hours of screen time per day as compared with prepandemic levels (24–30). In our study, participants in the young adult cohort (average age = 25 years) spent, on average, 8 hours per day using electronic devices in the months with the highest lockdown stringency, 3 hours more than during months with the lowest stringency. In contrast, most older adults (average age = 60 years) had 1–3 hours of daily electronic device use, with an increase of up to 3 more hours per day in months with more stringent measures.

Most of the current scientific evidence seems to indicate an overall decrease in alcohol consumption levels during the pandemic (31–33). However, there are also reports of an increase in alcohol abuse behaviors, and people with a known alcohol use disorder were at high risk of increasing their alcohol use levels (26, 33–35). Our study found that an increase in containment levels was associated with a lower

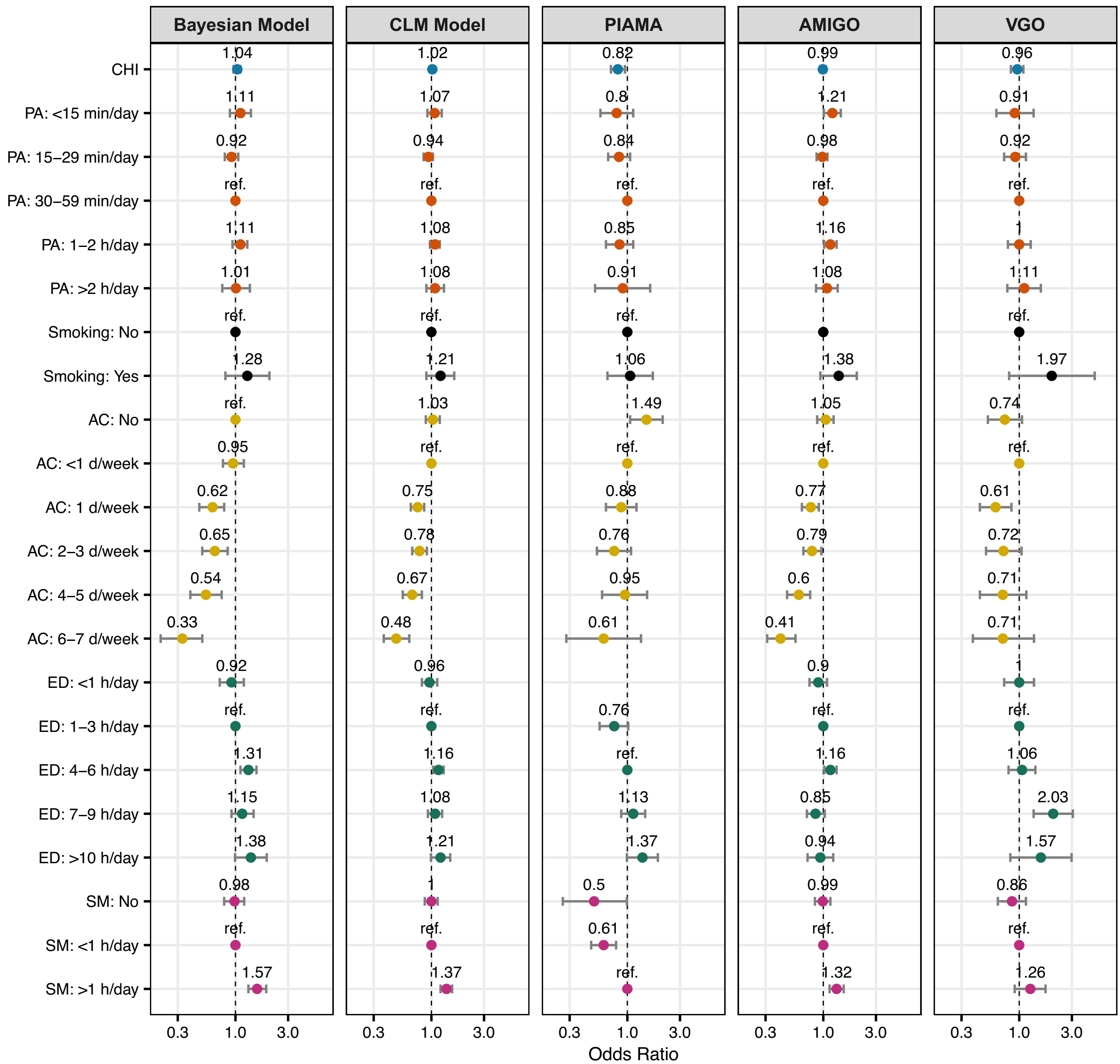

Figure 1. Adjusted odds ratios (circles) and 95% confidence intervals (bars) for associations between lifestyle determinants and sleep latency in overall analyses (Bayesian model and cumulative link mixed (CLM) model) and individual cohort analyses (Prevention and Incidence of Asthma and Mite Allergy (PIAMA) Study, Occupational and Environmental Health Cohort Study (AMIGO), and Livestock Farming and Neighboring Residents' Health (VGO) Project), IMPACT Study, the Netherlands, September 2020–2021. AC, alcohol consumption; CHI, Containment and Health Index; d, days; ED, electronic devices; h, hours; min, minutes; PA, physical activity; ref., referent; SM, social media.

frequency of alcohol consumption. This finding could be explained by reduced accessibility of alcoholic beverages as a result of the closure of bars and restaurants, as well as a decline in social drinking during the pandemic's peaks.

It has been observed that young adults were more likely to engage in unhealthy lifestyle behaviors than older adults during the pandemic (26, 31). In line with this, we found stronger positive associations between anti–COVID-19 measures and electronic device use in our young adult cohort. However, this finding could also be partly attributed to the shift to online activities during the pandemic (e.g., home-schooling/studying and home office use), given that this population was mainly studying or working. In addition, despite the observed positive association between anti–COVID-19 measures and self-reported physical activity in the young adult population during periods of higher

Table 4. Estimated Odds Ratios for Associations Between Lifestyle Determinants and Sleep Duration[a] in the IMPACT Study, the Netherlands, September 2020–2021[b]

Lifestyle Determinant	Odds Ratio	95% Credible Interval	No. of Observations	% of Observations
CHI value	1.11	1.05, 1.16	44,490	100
Physical activity				
<15.0 minutes/day	0.84	0.71, 0.98	4,473	10.1
15.0–29.9 minutes/day	0.80	0.72, 0.88	12,291	27.6
30.0–59.9 minutes/day	1.00	Referent	15,629	35.1
1.0–2.0 hours/day	1.06	0.95, 1.17	9,249	20.9
>2.0 hours/day	1.06	0.88, 1.27	2,848	6.4
Current cigarette smoking				
No	1.00	Referent	41,243	92.7
Yes	0.54	0.41, 0.73	3,247	7.3
Alcohol consumption				
None	1.00	Referent	10,162	22.8
<1 day/week	0.91	0.79, 1.06	8,210	18.5
1 day/week	0.97	0.80, 1.16	6,144	13.8
2–3 days/week	1.00	0.82, 1.21	11,122	25.0
4–5 days/week	1.28	1.03, 1.60	4,317	9.7
6–7 days/week	1.31	0.99, 1.73	4,535	10.2
Electronic device use				
<1 hour/day	1.30	1.11, 1.52	4,184	9.4
1–3 hours/day	1.00	Referent	18,539	41.7
4–6 hours/day	0.89	0.80, 0.99	10,989	24.7
7–9 hours/day	0.72	0.61, 0.83	7,392	16.6
≥10 hours/day	0.69	0.56, 0.84	3,386	7.6
Social media use				
No use	0.98	0.85, 1.13	13,525	30.4
≤1 hour/day	1.00	Referent	20,907	47.0
>1 hour/day	1.01	0.90, 1.15	10,058	22.6

Abbreviations: CHI, Containment and Health Index; COVID-19, coronavirus disease 2019; IQR, interquartile range.

[a] Sleep duration categories: ≤5.0 hours/night (reference category), 5.1–6.0 hours/night, 6.1–7.0 hours/night, 7.1–8.0 hours/night, and ≥8.1 hours/night.

[b] Association estimates correspond to the Bayesian models from the overall analysis, adjusted for occupation, a relative with COVID-19, interaction with people diagnosed with COVID-19, concern level, happiness level, stress level, and fidgeting level. The odds ratio represents the odds of each response variable being rated in category *j* or above ($Y \geq j$) at a 1-IQR increase in CHI relative to no increase, or in each category relative to the reference category.

containment levels, the older adult cohorts were characterized, in general, as being more physically active than the young adults during the entire study period. Apart from the differences in exercise levels and electronic device use, the associations between CHI and lifestyle were largely consistent across the 3 cohorts.

The scientific evidence indicates that increases in sleep duration and sleep latency occurred in parallel with a reduction in sleep quality throughout the COVID-19 pandemic (24, 36–41). This included increases in sleep duration due to later awakenings (24), longer times in bed but reduced sleep quality (37), and changes in the trajectories of sleep patterns in the adult population during 2020 compared with previous years (41). Accordingly, we observed a modest positive association between sleep duration and more stringent measures. We also observed that, due to lifestyle modifications, the pandemic may have contributed to longer times needed to fall asleep, as well as poorer sleep quality.

Higher electronic device use may have contributed to longer self-reported sleep latencies during the pandemic. Interestingly, we found that the correlation between social media use and electronic device use was low and that the

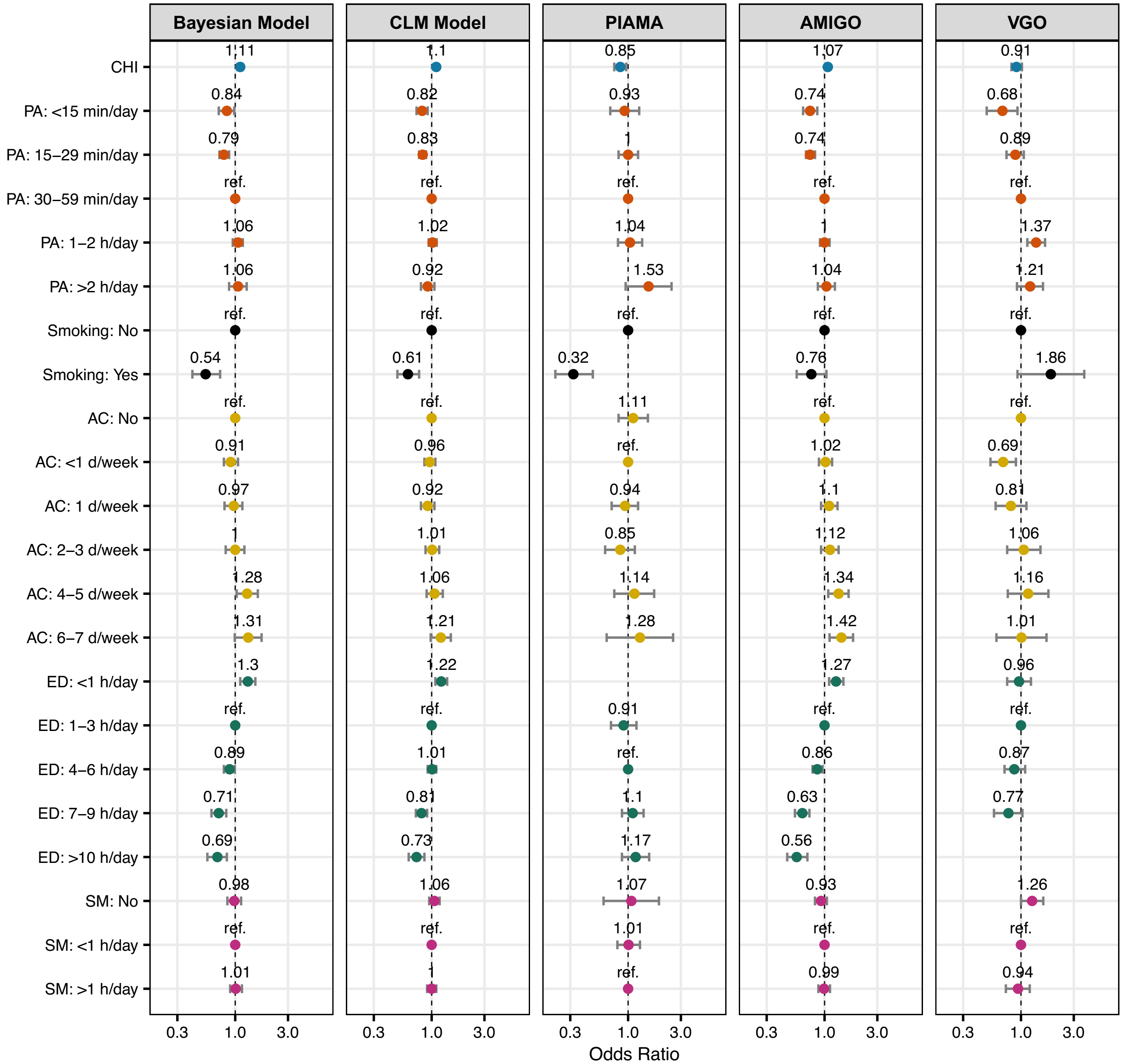

Figure 2. Adjusted odds ratios (circles) and 95% confidence intervals (bars) for associations between lifestyle determinants and sleep duration in overall analyses (Bayesian model and cumulative link mixed (CLM) model) and individual cohort analyses (Prevention and Incidence of Asthma and Mite Allergy (PIAMA) Study, Occupational and Environmental Health Cohort Study (AMIGO), and Livestock Farming and Neighboring Residents' Health (VGO) Project), IMPACT Study, the Netherlands, September 2020–2021. AC, alcohol consumption; CHI, Containment and Health Index; d, days; ED, electronic devices; h, hours; min, minutes; PA, physical activity; ref., referent; SM, social media.

associations with sleep latency persisted despite mutual adjustment. This may indicate that exposure to social media could represent a fundamentally different exposure than exposure to electronic devices. Both social media and electronic device use involve exposure to bright screens, which has been linked to sleep problems due to impaired melatonin secretion, arousal, or sleep displacement (42, 43). However, the impact of social media on sleep could be more psychologically driven, as exposure to digital media could act as a stressor. Continuous exposure to worrying information on social media platforms during the pandemic led to psychological distress and the development of depression and anxiety (12, 44, 45). Given the widespread and intensive use of social media (also outside of the pandemic), especially in younger populations, clarifying the causal pathways of the relationships between use of social networks and sleep could

Table 5. Estimated Odds Ratios for Associations Between Lifestyle Determinants and Sleep Quality[a] in the IMPACT Study, the Netherlands, September 2020–2021[b]

Lifestyle Determinant	Odds Ratio	95% Credible Interval	No. of Observations	% of Observations
CHI value	1.00	0.96, 1.06	44,061	100
Physical activity				
<15.0 minutes/day	0.59	0.50, 0.68	4,435	10.1
15.0–29.9 minutes/day	0.80	0.73, 0.88	12,157	27.6
30.0–59.9 minutes/day	1.00	Referent	15,553	35.3
1.0–2.0 hours/day	1.03	0.92, 1.14	9,091	20.6
>2.0 hours/day	1.18	0.98, 1.41	2,825	6.4
Current cigarette smoking				
No	1.00	Referent	40,953	92.9
Yes	1.21	0.90, 1.60	3,108	7.1
Alcohol consumption				
None	1.00	Referent	10,063	22.8
<1 day/week	0.92	0.80, 1.06	8,171	18.5
1 day/week	0.95	0.80, 1.13	6,050	13.7
2–3 days/week	1.04	0.87, 1.26	11,040	25.1
4–5 days/week	1.03	0.83, 1.27	4,311	9.8
6–7 days/week	1.38	1.06, 1.78	4,426	10.1
Electronic device use				
<1 hour/day	0.98	0.83, 1.15	4,100	9.3
1–3 hours/day	1.00	Referent	18,261	41.4
4–6 hours/day	0.94	0.84, 1.06	10,909	24.8
7–9 hours/day	0.97	0.83, 1.13	7,366	16.7
≥10 hours/day	0.89	0.73, 1.10	3,425	7.8
Social media use				
No use	0.91	0.80, 1.05	13,352	30.3
≤1 hour/day	1.00	Referent	20,714	47.0
>1 hour/day	0.82	0.72, 0.92	9,995	22.7

Abbreviations: CHI, Containment and Health Index; COVID-19, coronavirus disease 2019; IQR, interquartile range.

[a] Sleep quality categories: poor/fair (reference category), not good/not bad, good, and excellent.

[b] Association estimates correspond to the Bayesian models from the overall analysis, adjusted for occupation, a relative with COVID-19, interaction with people diagnosed with COVID-19, concern level, happiness level, stress level, and fidgeting level. The odds ratio represents the odds of each response variable being rated in category j or above ($Y \geq j$) at a 1-IQR increase in CHI relative to no increase, or in each category relative to the reference category.

provide insights to improve the well-being of the population (46).

In our study, more stringent anti–COVID-19 measures were associated with a slight prolongation of sleep duration when we analyzed all cohorts together. However, for our young adult cohort (PIAMA), higher stringency was associated with lower sleep duration. This is contrary to what might be expected and contrasts with what has been reported previously (24, 40, 41) on the increase in sleep duration being more noticeable among young people due to the transition toward home environments like home schooling and home office use. Nevertheless, the negative associations of CHI with sleep duration in young adults could be partly explained by the increase in sedentary behaviors within this population, since low levels of physical activity and high electronic device use were associated with shorter sleep duration.

Researchers in several studies reported an increase in sleep duration during the pandemic, accompanied by a decrease in sleep quality (37, 39, 40), and we hypothesized that this could be partly explained by changes in exercise levels and social media use. It has long been known that regular

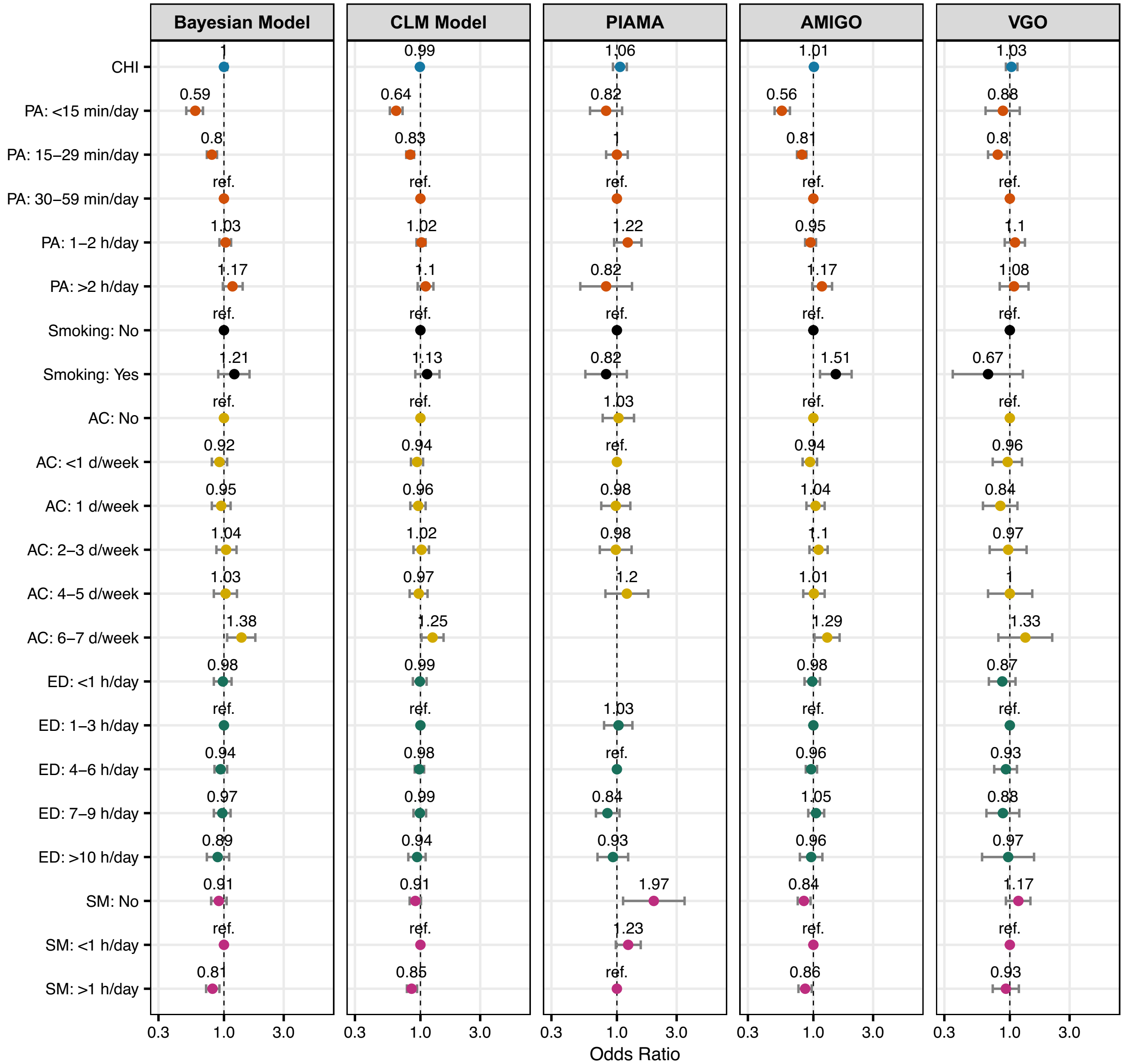

Figure 3. Adjusted odds ratios (circles) and 95% confidence intervals (bars) for associations between lifestyle determinants and sleep quality in overall analyses (Bayesian model and cumulative link mixed (CLM) model) and individual cohort analyses (Prevention and Incidence of Asthma and Mite Allergy (PIAMA) Study, Occupational and Environmental Health Cohort Study (AMIGO), and Livestock Farming and Neighboring Residents' Health (VGO) Project), IMPACT Study, the Netherlands, September 2020–2021. AC, alcohol consumption; CHI, Containment and Health Index; d, days; ED, electronic devices; h, hours; min, minutes; PA, physical activity; ref., referent; SM, social media.

exercise has positive effects on sleep (47–49), and we found that engaging in less than 30 minutes of exercise per day was related to both shorter sleep duration and poorer sleep quality. Poor sleep quality was also associated with social media use, possibly revealing a psychological pathway.

Since most of the current scientific evidence for the indirect effects of the COVID-19 pandemic is based on cross-sectional surveys, the main strength of our study relates to its longitudinal prospective design. To the best of our knowledge, the study described here is one of the largest adult cohort studies to have monitored lifestyle and well-being during the pandemic. We collected data from 3 large cohorts covering a wide range of adult ages and backgrounds (rural and urban), which allowed us to make direct comparisons between age groups and check the consistency of our findings across different populations.

Our study had several limitations, however, including a relatively low response rate (22%), which made it more prone to nonresponse bias. In addition, there were notable differences between enrolled participants and the source population in terms of socioeconomic background, which may limit the generalizability of these results. The rural (VGO) and young adult (PIAMA) populations were underrepresented in the overall analyses; thus, overall estimates were influenced primarily by the AMIGO cohort, consisting of older adults from mixed urban and rural settings. Lifestyle and sleep assessments were based on individual recall questions and not on objective measurement methods, so there was potential misclassification. Although the incorporation of the CHI as an objective indicator of the pandemic allowed us to assess associations between anti–COVID-19 measures and lifestyle, we were unable to distinguish between the severity of the pandemic itself and the rigor of the pandemic measures, since these are intricately interrelated (with more severe pandemic situations leading to more stringent pandemic measures) and both could have significantly influenced our findings. In addition, because CHI levels largely coincided with the seasons (highest CHI values during winter and fall with a decrease in spring and summer) and the data covered only a single seasonal cycle, the observed association estimates could have been biased by residual confounding.

This study advances our understanding of the impact of the COVID-19 pandemic on the lifestyle and well-being of the adult population by offering a plethora of descriptive data regarding the pandemic situation in the Netherlands. The pandemic has changed people's lifestyles, with potential repercussions for sleep patterns and well-being. It is not yet clear whether these changes will last, but given the role that sleep plays in the mental and physical well-being of the population, it is vitally important to study the factors that could have affected it in this pandemic and in any upcoming crisis.

ACKNOWLEDGMENTS

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This work was supported by internal funds from the Institute for Risk Assessment Sciences at Utrecht University and the EXPOSOME-NL Gravitation program (Dutch Research Council; project 024.004.017). The PIAMA Study has been funded by grants from the Netherlands Organization for Health Research and Development; the Netherlands Organization for Scientific Research; the Lung Foundation of the Netherlands; the Netherlands Ministry of Planning, Housing, and the Environment; the Netherlands Ministry of Health, Welfare, and Sport; and the National Institute for Public Health and the Environment. The VGO Project was funded by the Ministry of Health, Welfare and Sport and the Ministry of Economic Affairs of the Netherlands and supported by Lung Foundation Netherlands (grant 3.2.11.022). AMIGO was supported by the Netherlands Organization for Health Research within the program Electromagnetic Fields and Health Research (grants 85200001 and 85200002).

Researchers who are interested in accessing these data can send a request to Dr. Anke Huss (a.huss@uu.nl) or Dr. Ulrike Gehring (u.gehring@uu.nl).

We thank Stichting Informatie Voorziening Zorg (Houten, the Netherlands), a trusted third party, for assistance with enrolling participants from the VGO cohort and ensuring VGO participants' privacy.

Conflict of interest: none declared.

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