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Increased sleep and daytime problems due to the COVID-19 pandemic. Results from a multinational harmonized questionnaire study

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Abstract

Objectives - Sleep is important for human health and well-being. No previous study has assessed whether the COVID-19 pandemic impacts sleep and daytime function across the globe.

Methods - This large-scale international survey used a harmonized questionnaire. Fourteen countries participated during the period May to August 2020. Sleep and daytime problems (e.g., poor sleep quality, sleep onset and maintenance problems, nightmares, hypnotic use, fatigue, excessive sleepiness) occurring "before" and "during" the pandemic were investigated. In total, 25,484 people participated and 22,151 (86.9%) responded to the key parameters and were included. Effects of COVID-19 infection, confinement, and financial suffering were considered. In the fully adjusted logistic regression models, results (weighted and stratified by country) were adjusted for gender, age, marital status, educational level, ethnicity, presence of sleep problems before COVID-19, and severity of the COVID-19 pandemic in each country at the time of the survey.

Results - The responders were mostly women (64%) with mean age 41.8 years (median 39 years, range 18-95). In total, 3.0% reported having had COVID-19, 42.2% reported having been in confinement, and 55.9% had suffered financially. All sleep and daytime problems worsened during the pandemic by about 10% or more. Also improvements in sleep and daytime function were reported. For example, sleep quality worsened in about 20% of subjects and improved in about 5%. COVID-19 was particularly associated with poor sleep quality, early morning awakening and daytime sleepiness. Confinement was associated with poor sleep quality, problems falling asleep, and with decreased use of hypnotics. Financial suffering was associated with all sleep and daytime problems, including nightmares and fatigue even in the fully adjusted logistic regression models.

Conclusions – Sleep problems, fatigue, and excessive sleepiness increased significantly throughout the world during the first phase of the COVID-19 pandemic. Problems were associated with confinement and especially with financial suffering.

Summary Box

What is already known about this subject?

- Poor sleep is associated with a multitude of health problems including mental health, diabetes, obesity, cardiovascular diseases, cancer, dementia, increased accident risk, and mortality.
- In Spring 2020, the global COVID-19 pandemic changed sleep-wake habits.
- Various sleep problems have been reported from different countries.
- Little is known about the the effects of COVID-19 infections versus other effects related to the COVID-19 pandemic.

What are the new findings?

- Sleep and daytime problems worsened during the pandemic by about 10% or more in all countries, but in some cases sleep and daytime function improved. For example, sleep quality worsened in about 20% of subjects and improved in about 5%.
- COVID-19 infection was particularly associated with poor sleep quality, early morning awakening and daytime sleepiness.
- Confinement was associated with poor sleep quality, problems falling asleep, and with decreased use of hypnotics.
- Financial suffering was associated with all sleep and daytime problems, including nightmares and fatigue even in the fully adjusted logistic regression models.

How might it impact on clinical practice in the foreseeable future?

Asking questions about sleep and daytime alertness should become part of routine clinical practice as poor sleep may also increase risk of becoming infected by SARS-CoV-2-virus. COVID-19 illness may cause fatigue and sleepiness, but confinement and especially financial suffering are important factors independently of an infection. In the future we will see, whether post-covid fatigue and sleepiness will persist in some people. We will also see if the incidence of some other neurological disorders will increase in the future after having been infected by different variants of the SARS-CoV-2-virus.

Introduction

The COVID-19 pandemic is the deadliest since the 1918 Spanish flu. The disease exhibits a far higher fatality rate than the seasonal flu, while also causing both acute and lingering symptoms for many of those afflicted. As of February 2021, there have been more than 114 million confirmed cases and more than 2.5 million deaths attributed to COVID-19 worldwide. Peoples' lives have been affected in many ways.

Sleep is vital for cognitive, emotional, and somatic functioning and vice versa. Poor sleep is associated with a multitude of health problems, such as anxiety, depression, suicidal ideation, obesity, cardiovascular diseases, cancer, dementia, increased accident risk, and mortality.[1] Also, sleep problems may increase sick leave and work disability.[2] Of note, sleep may exhibit a bidirectional relationship with an infectious disease like COVID-19. Poor sleep may compromise in vivo antibody responses to novel antigens,[3] thus increasing the risk of becoming infected by SARS-CoV-2-virus.[4] On the other hand the COVID-19 pandemic may have stressful personal consequences, both practical and emotional, that impair sleep.

Apart from the well-established symptoms of breathing difficulties, fever, loss of smell and taste, COVID-19 has been linked to a range of cognitive and psychiatric symptoms including increased anxiety and depression,[5] panic attacks, irrational fears, post-traumatic stress, fatigue, and sleep

disturbances, [6, 7]and other behavioral factors like “panic buying” may also be associated with anxiety and poor sleep.[8] Social isolation, home confinement and loneliness have been associated with increased morbidity [5, 6, 9-11] and even with increased mortality.[9]

Reduced physical activity and daylight exposure, and a lack of social Zeitgebers due to no longer having a fixed work schedule, as well as increased worry may have negatively impacted sleep. [12, 13]Nevertheless, lockdown may have had some positive sleep effect. Extrinsically imposed schedules, such as the early morning rush to work, have been replaced by flexible work hours at home. Therefore, sleep duration may have increased and daytime sleepiness decreased for some people, [14, 15]although sleep quality arising from worries and uncertainties may have remained poor.[14]

The International Covid Sleep Study (ICOSS) was initiated in March 2020 to improve global understanding of these important relationships.[7] It includes 14 participating countries across four continents (Asia, Europe, North America, South America). We hypothesised that various sleep–wake problems would increase during, compared with before, the pandemic. Also, we hypothesised that infection with SARS-CoV-2-virus infection would be associated with sleep problems, which in turn would strongly correlate with social confinement, familial, work-related, and other psychosocial factors.[7]

The main focus of the present study was on the impact of the first wave of the COVID-19 pandemic on sleep and daytime problems. The role of COVID-19, confinement, and financial problems due to the pandemic on these sleep and daytime problems was investigated. Also, we examine country-specific differences in the rates of these sleep and daytime problems.

Methods

Survey

The research protocol and the final standardized survey questionnaire was published previously[7]. The study complies with the Declaration of Helsinki. All countries obtained ethical approval or exemptions in keeping with national research governance and regulations. As we aimed to investigate possible changes in the frequency and presentation of various sleep and daytime problems in relation to COVID-19 and confinement, the survey enquired about symptoms and experiences both “before” and “during” the pandemic. After gathering data on important sociodemographic variables (age, gender, marital status, etc), the survey incorporated multiple questions on sleep problems using the validated Basic Nordic Sleep Questionnaire[16]. Scale responses for many of these items such as difficulty falling asleep, problems staying asleep, fatigue, daytime sleepiness, and nightmares were 1 “never or less frequently than once per month”, 2 “less than once per week”, 3 “on 1-2 days per week”, 4 “on 3-5 days per week” and 5 “daily or almost daily”. Sleep quality was assessed by the question “How well have you been sleeping”, with response

alternatives “well”, “rather well”, “neither well nor badly”, “rather badly” and “badly”.[7] In addition, dates and country of response were recorded. This allowed us to relate the timing of responses to the patterning of pandemic exposure and confinement in each country in accordance with centralised WHO records[17].

The survey questionnaire[7] was translated into different languages and administered in 14 countries/areas (Austria, Brazil, Canada, China/ Hong Kong, China/ Jinlin, Finland, France, Italy, Japan, Norway, Poland, Sweden, The UK, USA) between May and August 2020. To be included in the survey, a minimum of 400 responders with complete answers from any given country had to be available. The most commonly used online platforms for administration of the survey were RedCap and Qualtrics. Potential participants were solicited in each country for example by informing about the survey in the University web pages, national newspapers or television, Facebook or Twitter. All responders were anonymous volunteers and aged 18 years or older.

Participants

A total of 25,484 participants completed the survey. Of these, 3,333 subjects did not complete the survey in full. After excluding them, 22,151 participants (86.9%) provided complete data and were included in the analysis.

Patient and Public Involvement

No patient involved.

Data reduction and analyses

All survey items and variables names were identical across countries to facilitate merging of data into a single file. This data integration and all statistical computations were conducted using STATA 15.1 (StataCorp, College Station, USA). There was no requirement for data imputation for missing data and no replacement of subjects. Multivariate analyses and statistical analyses were conducted by weighting of data by the number of inhabitants in the country/area of interest and by the number of responders in that country. Different countries were used as strata. Observations were used as sampling unit and non-parametric statistics were applied with proportions and 95% confidence intervals calculated. Logistic regression analyses and other comparative analyses were utilised using appropriate weighting for the merged data. We specifically analysed effects of COVID-19 infection (self-reported), confinement for at least two weeks, and suffering from financial losses because of COVID-19.

Results

Table 1 presents the demographics of the total study population. The median age of the responders was 39 years (range 18-95 y; mean 41.8). In total, 3.0% (n=739) reported having had COVID-19, 42.2% reported having been restricted to their home (in confinement) during the pandemic, and 55.9% reported having suffered financially due to the pandemic (Table 1). Table 1 also presents information on the number of participants from each country.

Sleep and daytime problems before and during COVID-19

Occurrence of sleep and daytime problems for all participants from the 14 countries is summarised in Figure 1 and Table 2. The data clearly show that all sleep and daytime problems increased during relative to before the COVID-19 pandemic. In fact, the prevalence of most of the problems (poor sleep quality, sleep onset problems, sleep maintenance problems, fatigue, excessive sleepiness, and falling asleep during daytime) increased by about 10% or more. The smallest percentage increase was in hypnotic use, but even such use increased dramatically from 7.8% to 12.2% during the pandemic (Figure 1, Table 2).

Worsening and improvement of sleep and daytime problems

Table 2 provides data on the percentage of participants who reported having *improved*, *unchanged* or *worsened* sleep and daytime problems over the time course of the pandemic. Whereas, the majority of participants reported that their sleep and daytime problems were unchanged from before to during the pandemic, sleep quality worsened in about 20% and improved in about 5% of participants. Results also differed depending on the variable of interest. For example, 6.9% reported an increase in hypnotic use and a 20.8% worsening of sleep quality during the pandemic (Table 2).

Factors associated with the occurrence of sleep and daytime problems

Table 3 presents prevalence data on sleep and daytime problems during the pandemic, segmented by three variables of interest i.e. infection with COVID-19, reports of being in confinement, and suffering financially due to the pandemic. Crude (unadjusted) percentages showed that infection with COVID-19 was significantly associated with poor sleep quality, early morning awakening, nightmares, hypnotic use, fatigue, and excessive sleepiness. In a multiple logistic regression model all sleep and daytime problems were significantly associated with COVID-19 after adjustment for gender, age, marital status, and educational level. However, in the fully adjusted model, with adjustment also for ethnicity, presence of the problem before the pandemic, confinement, financial suffering, and the severity of the COVID-19 pandemic in each country at the time of the survey, only poor sleep quality, early morning awakening, and sleepiness remained significant (Table 3).

Confinement during the pandemic was associated with all the reported sleep and daytime problems in crude as well as in two of the adjusted analyses. However, in the fully adjusted model,

confinement was only positively associated with poor sleep quality and sleep onset problems, whereas a negative association with hypnotic use appeared (Table 3).

Financial suffering during the pandemic was associated with all sleep and daytime problems, both in crude and in all adjusted logistic regression analyses (Table 3). The highest odds ratio was seen for hypnotic use, which more than doubled during the pandemic in the fully adjusted model.

Country-specific differences

Supplement tables 1 and 2 present detailed data on sleep and daytime problems reported for each of the 14 countries. Problems increased in all countries during versus before the pandemic, but to differing degrees, and non-significantly for some countries. For instance, poor sleep quality increased in prevalence especially in Canada (nearly 4 times increase) and the UK (3 times higher). Fatigue significantly increased in prevalence in many countries but not in China (Jinlin and Hong Kong), France, Italy, and Japan. The increase in prevalence of fatigue was particularly pronounced in Sweden and the UK with more than 2.5-fold increase (Supplement Table 2).

Discussion

To our knowledge this international collaborative study is the first to compare the occurrence of sleep and daytime problems during the pandemic in different countries and continents using harmonized data.[7]

The results of the ICOSS-project show that sleep problems increased in prevalence in all countries. More than 20% of participants reported a worsening of sleep quality. Other sleep-related issues, such as problems with sleep onset and maintenance, nightmares, and hypnotic use all increased significantly during the pandemic compared with the situation before. Interestingly, there were some participants who reported improvements in sleep during the pandemic. During the pandemic, people in many countries had at least some constraints. Many were forced or recommended to stay at home and many have been working at home. The resulting worktime flexibility may have helped some to improve their sleep during the pandemic. The prevalence of fatigue and excessive sleepiness increased by about 10% during the pandemic, but a minority of participants reported improved daytime function (e.g. less fatigue and daytime sleepiness).

The COVID-19 pandemic has changed people's lives dramatically. Gatherings of more than a few individuals have been severely limited across public places, at the same time as schools and universities have been closed. Many have had to undergo quarantine or have had to live in isolation, in many cases for extended periods of time. In line with our findings of an increase in several sleep related problems, other studies have been published in different countries on how people's sleep-

wake rhythm has changed during the pandemic.[6, 18, 19] For instance, an Italian study found that more than 50% of the 6,519 participants reported poor sleep quality, with risk factors including female gender, knowing a person who died from COVID-19, changing sleeping habits, and a high stress level.[19] Another reason why the lockdown affected sleep in such drastic ways, apart from isolation, may have been the increasing use of cell phones, laptops, and watching TV during lockdown. There have been studies demonstrating that increased screen exposure exacerbates sleep disturbances during lockdown.[15, 20] Dutta et al. observed that social jet lag and sleep debt were significantly less during than before lockdown in India.[20]

Anxiety and other psychological effects of confinement were reported previously.[6, 21] In our survey, confinement was associated especially with problems of falling asleep and poor sleep quality. Interestingly, confinement was negatively associated with hypnotic use which may be related to the findings that some participants were sleeping well during confinement. Use of hypnotics varied by country. This may reflect different country specific attitudes towards use of hypnotics. The effects of confinement are closely related to effects of loneliness, which is related to COVID-19 and to increased mental and physical morbidity.[22, 23]

The prevalence of nightmares increased significantly in most countries. This increase may be related to increased levels of stress, anxiety, depression, PTSD (Post traumatic Stress Disorder)[18] or even suicidal ideation[24] during the lockdown caused by the pandemic. Furthermore, nightmares and acting out in sleep are associated with REM sleep behaviour disorder, which in turn is a known risk factor of alpha-synucleinopathies.[25]

In our survey the COVID-19 infection was associated with poor sleep quality, problems of waking up too early in the morning, and daytime sleepiness. The worsening effect of infection on sleepiness may be biological. In a meta-analysis of ten studies, 53% of patients with COVID-19 had olfactory dysfunction and 44% had gustatory dysfunction.[26] Some dysfunction may be long-lasting.[27] The olfactory bulbs are in contact with the midbrain including the sleep-wake regulating orexin cell groups.[28] By retrograde axonal transport this pathway allows viruses to directly reach the brain and possibly alter brain functions, including sleep and wake regulation.[28] Our study demonstrates the association between COVID-19, fatigue, and sleepiness. This needs to be investigated in more detail in the future. We cannot make strong inferences at the moment because of the cross-sectional nature of our survey. We asked about the symptoms “before” and “during”. So, we know about the change related to COVID-19, but we cannot say much about the consequences of a possible COVID-19. There is increasing evidence of long-lasting symptoms of ”Long-Covid”-syndrome, that may be more prevalent in patients who complain of poor sleep quality.[4] Some of the main complaints among such patients are fatigue, sleepiness, anxiety, and orthostatic intolerance – resembling symptoms of myalgic encephalopathy/chronic fatigue syndrome.[29]

We found more sleep and daytime problems in countries where the pandemic was escalating at the time of the survey than in countries where the situation was stable. As suggested by the cumulative number of Sars-2-Cov confirmed deaths, during spring, the situation was bad in Italy, Spain, and France; while during the survey the worst situations were in Brazil, the US, and Sweden. Use of hypnotics increased especially in Brazil and the US. Complaints of fatigue, daytime sleepiness, and falling asleep at daytime increased clearly in the UK and US. Sleep problems increased somewhat less in other countries except in China/Jinlin, France, and Italy, where no significant increase was observed for some of the complaints. Interestingly, the pandemic started in the Wuhan area in China, and in Europe the pandemic started in the spring 2020 especially in areas with many tourists, such as Austria, Italy, France and Spain. In June and July 2020, new cases continued to rise sharply in Brazil and in the US as the first wave leveled off in China, Japan and in most European countries.

There are several possible confounders for differences in occurrence of sleep problems including ethnic, cultural, and meteorological differences. The ethnic, social, and financial differences were included in the logistic regression models, but we have not included effects of seasons. The survey was conducted in May-August 2020, when we had late spring-early summer in the Northern hemisphere and late fall-early winter in the Southern hemisphere (Brazil). The days were very long in the North (Finland, Norway, Sweden, and Canada). We cannot make strong inferences, but the situation and occurrences of sleep problems varied between Finland, Norway, and Sweden. The differences were most probably due more to political, social, and psychological differences between these countries. In Finland and Norway, strict restrictions were used while there were very few restrictions in Sweden.

The strongest factor associated with all types of sleep and daytime problems was the presence of financial suffering related to COVID-19. The effects of financial suffering may probably be explained by stress and other psychological effects. All these effects influence sleep, autonomic nervous system, and immunity. Higher educational level is known to associate with better financial situation. Recent studies have shown also that occurrence of COVID-19 is associated with lower educational level, unemployment, and low income.[30]

Strengths

Our survey has multiple strengths. It is based on a harmonized questionnaire with validated questions that were translated into different languages. Prior to our effort, the occurrence of sleep problems has been studied in many countries, but the questions have not been identical, making

comparisons between countries difficult. In the first phase of our ICOSS-collaboration, we collected data from fourteen participated countries using a standardized protocol and a harmonized questionnaire. This allows us to make inferences about worldwide effects of COVID-19, confinement, and financial status in different countries.

Limitations

Our study has several limitations. Recall bias is possible as we asked participants to report on their sleep and daytime problems both "before" and "during" the COVID-19 pandemic. The experience of the spring 2020 has probably been memorable for most people. Even though we tried to be clear in the instructions, some people may have compared "before" with "now", rather than "during". We know the epidemiological situation in each country at the moment of responding. As we have discussed, and as our results show, the increase in most sleep problems was greatest in countries where the incidence of new cases was increasing at the time of survey (e.g. Brazil, the UK, the US) compared with countries where the situation was more stable? at the time of the survey (China/ Jinlin, France and Italy). As the situation had been much worse in the latter countries than in for example Norway and Finland, it is possible that subjects were thinking of the situation at the time of the response date rather than during the pandemic and confinement as a whole.

Some participants with sleep and wake problems may have exaggerated their symptoms during COVID-19. As the survey was done online, people without access to internet, and possibly a greater proportion of elderly people, would have been unable to participate. This limits generalization of our results. However, given the observed consistency across countries, we are confident that our results reflect the situation before and during the pandemic. Furthermore, we had young and old responders from both genders and from different ethnic backgrounds, suggesting that our results are representative for a large proportion of citizens in the participating countries.

The frame of sampling and also sample sizes varied by country and relative to the population of the country. There were also ethnic differences. For these reasons we have used weighting, but even then, one must be cautious in making strong inferences. The most striking differences were found between the US and other countries. The responders in the USA were younger and most responders were men, while in other countries most responders were women.

What needs to be studied?

Many unanswered questions remain. More detailed understanding of the nature of sleep and daytime function during the pandemic is needed. What are the effects of anxiety and depression on sleep and daytime problems? How can we explain the increase of nightmares during the pandemic? The increase of fatigue and daytime sleepiness needs to be studied in more depth.

CONCLUSIONS

Sleep problems, fatigue, and daytime sleepiness increased significantly throughout the world during the first phase of the COVID pandemic. As sleep and health share a bi-directional relationship, such problems were significantly associated with COVID-19 infection, but also with confinement and especially with financial suffering. On a global level, the social and psychological effects seem to play a more important role than the biological effects of the COVID-19 as a disease on these sleep and daytime problems.

Sharing information and data: Interested readers should contact members of the core group in order to participate in future studies as part of the ICOSS collaboration.

Contributions of Authors: Members of the core group (BB, FC, CAE, BH, CMM, MP, TP) contributed in all phases of the study (conception and design, data collection, data analysis and interpretation, drafting the article, critical revision of the article, final approval of the version to be published). Yves Dauvilliers and Ilona Merikanto contributed in the design of the survey, data collection, data analysis and interpretation, critical revision of the article and final approval of the version to be published. Christian Benedict, Courtney J Bolstad, Jonathan Cedernaes, Ngan Yin Chan, Luigi de Gennaro, Fang Han, Yuichi Inoue, Kentaro Matsui, Damien Leger, Ana Suely Cunha, Sergio Mota-Rolim, Michael R Nadorff, Guiseppe Plazzi, Jules Schneider, Mariusz Sieminski and Yun Kwok Wing contributed in data collection, critical revision of the article and final approval of the version to be published. No external editors were used.

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Table 1. Characteristics of the study population.

	% (N= 25,454)
Gender (n=24,353)	
Male	33.9 (8,257)
Female	66.0 (16,081)
Other	0.1 (15)
Age (n= 24,218)	
<25 years	14.9 (3,613)
25-34 years	25.4 (6,160)
35-44 years	18.7 (4,525)
45-54 years	16.6 (4,018)
55-64 years	13.4 (3,253)
65+ years	10.9 (2,649)
Marital status (n=24,264)	
Single	36.3 (8,814)
Cohabiting	56.0 (13,578)
Divorced/separated	6.1 (1,467)
Widowed	1.7 (405)
Education (n=24,069)	
Below University	73.2 (17,619)
College/University	26.8 (6,450)
Ethnicity (n=23,935)	
Caucasian/white	44.2 (10,588)
Asian	40.2 (9,632)
Other	15.5 (3,715)
COVID-19 infection (n=24,497)	
No	79.5 (19,464)
Yes	3.0 (739)
Do not know	17.5 (4,294)
Confinement (n= 23,072)	
No	57.8 (13,339)
Two weeks or less	8.6 (1,987)
3-4 weeks	5.1 (1,187)
5-6 weeks	4.0 (926)
7-8 weeks	5.4 (1,240)
More than 8 weeks	19.0 (4,393)
Financial suffering (n=24,324)	
Not at all	44.1 (10,718)
A little	28.4 (6,907)
Somewhat	15.1 (3,662)
Much	8.4 (2,037)
Very much/severely	4.1 (1,000)
Country (n=25,484)	
Austria	3.3 (722)
Brazil	8.2 (1,821)
Canada	9.4 (2,080)
China/Jinlin	4.8 (1,071)
China/Hongkong	8.1 (1,790)
Finland	3.9 (869)
France	4.9 (1,089)
Italy	6.5 (1,439)
Japan	30.5 (6,744)
Norway	4.8 (1,060)
Poland	2.0 (433)
Sweden	3.3 (733)
United Kingdom	5.7 (1,257)
USA	4.7 (1,043)

Table 2. Sleep and daytime problems among all participants in the ICOSS study (n=25.484).

All countries	Before pandemic (CI)	During pandemic (CI)	Improved	Unchanged	Worsened
Poor sleep quality[1]	12.5% (11.8-13.2%)	28.2% (27.1-29.3%)*	5.2%	74.0%	20.8%
Sleep onset problems[2]	14.8% (13.9-15.7%)	27.9% (26.9-29.1%)*	4.4%	77.8%	17.8%
Sleep maintenance problems[3]	17.1% (16.2-18.1%)	27.9% (26.8-29.1%)*	4.2%	80.6%	15.2%
Early morning awakening[4]	13.6% (12.7-14.5%)	21.7% (20.6-22.7%)*	5.0%	81.8%	13.2%
Nightmares[5]	8.5% (7.7-9.4%)	15.0% (14.0-16.0%)*	2.9%	87.6%	9.5%
Hypnotic use[6]	7.8% (7.1-8.6%)	12.2% (11.2-13.2%)*	2.4%	90.7%	6.9%
Fatigue[7]	20.7% (19.8-21.7%)	29.9% (28.8-31.0%)*	8.0%	74.9%	17.1%
Excessive sleepiness[8]	18.5% (17.6-19.5%)	27.7% (26.6-28.9%)*	6.9%	76.9%	16.2%

[1] Proportion reporting sleep quality "rather badly" or "badly". [2] Proportion reporting sleep onset problems 3+ days/week. [3] Proportion reporting sleep maintenance problems 3+ day/week. [4] Proportion reporting early morning awakening (EMA) problems 3+ days/week. Proportion reporting nightmares 3+ nights/week. [6]Hypnotic use 3+ days/week. [7]Proportion reporting fatigue 3+ days/week. [8]Proportion reporting excessive daytime sleepiness 3+ day/week. CI: 95% confidence interval. *Statistically significant difference from *before* pandemic (P<0.0001).

Table 3. Prevalence (%) of sleep and daytime problems depending of COVID-19 infection, confinement and financial problems due to the pandemic. All countries are included in the analyses.

	Poor sleep quality[1]	SO problems[2]	SM problems[3]	EMA problems[4]	Nightmares[5]	Hypnotic use[6]	Fatigue[7]	Excessive sleepiness[8]
COVID-19 infection								
Yes % (CI)	34.3 (29.2-39.9)	31.2 (26.2-36.7)	32.9 (27.6-38.6)	32.8 (27.6-38.5)	27.8 (22.8-33.5)	28.5 (23.4-34.3)	36.0 (30.7-41.6)	40.8 (35.2-46.6)
No % (CI)	27.8 (26.7-28.9)	27.7 (26.6-28.8)	27.5 (26.4-28.7)	20.8 (19.7-21.8)	14.0 (13.0-15.0)	10.9 (10.0-11.9)	29.4 (28.3-30.6)	26.7 (25.6-27.8)
OR adjusted.1[9]	**1.62 (1.26-2.07)**	**1.35 (1.04-1.75)**	**1.42 (1.09-1.84)**	**1.93 (1.48-2.50)**	**2.05 (1.53-2.75)**	**2.68 (2.00-3.60)**	**1.43 (1.11-1.83)**	**1.92 (1.49-2.46)**
OR adjusted.2[10]	**1.71 (1.31-2.22)**	1.27 (0.94-1.72)	1.25 (0.89-1.77)	**1.64 (1.20-2.47)**	**1.59 (1.09-2.33)**	**1.83 (1.15-2.91)**	**1.35 (1.01-1.79)**	**1.72 (1.29-2.30)**
OR fully adjusted[11]	**1.55 (1.18-2.03)**	1.11 (0.82-1.52)	1.12 (0.79-1.59)	**1.48 (1.07-2.04)**	1.19 (0.80-1.76)	1.44 (0.88-2.35)	1.20 (0.89-1.61)	**1.51 (1.13-2.02)**
Confinement								
Yes % (CI)	30.3 (28.8-31.8)	31.9 (30.4-33.4)	29.6 (28.1-31.2)	23.2 (21.8-24.7)	17.4 (16.1-18.8)	13.5 (12.3-14.9)	32.6 (31.0-34.2)	30.8 (29.3-32.4)
No % (CI)	24.4 (22.9-25.8)	20.4 (18.9-21.9)	24.7 (23.1-26.2)	18.8 (17.3-20.3)	10.8 (9.4-12.3)	10.0 (8.7-11.5)	24.8 (23.2-26.4)	22.0 (20.5-23.7)
OR adjusted.1[9]	**1.37 (1.22-1.53)**	**1.67 (1.47-1.88)**	**1.42 (1.25-1.60)**	**1.38 (1.20-1.59)**	**1.56 (1.30-1.88)**	**1.42 (1.16-1.74)**	**1.36 (1.20-1.53)**	**1.46 (1.29-1.65)**
OR adjusted.2[10]	**1.37 (1.22-1.54)**	**1.35 (1.11-1.63)**	**1.30 (1.11-1.53)**	**1.30 (1.12-1.53)**	**1.60 (1.30-1.96)**	**1.30 (1.01-1.68)**	**1.35 (1.18-1.53)**	**1.24 (1.06-1.45)**
OR fully adjusted[11]	**1.19 (1.02-1.37)**	**1.28 (1.09-1.50)**	1.15 (0.97-1.36)	0.95 (0.80-1.13)	1.09 (0.84-1.43)	**0.70 (0.53-0-92)**	1.02 (0.87-1.18)	1.07 (0.91-1.25)
Suffered financially								
Yes % (CI)	33.7 (30.6-36.9)	34.3 (31.1-37.7)	33.6 (30.4-37.0)	31.1 (28.0-34.5)	25.0 (21.9-28.4)	22.3 (19.2-25.7)	37.8 (34.5-41.2)	36.2 (32.9-39.6)
No % (CI)	27.3 (26.2-28.4)	26.7 (25.6-27.9)	26.8 (25.7-28.0)	19.9 (18.8-21.0)	13.0 (12.1-14.1)	10.3 (9.4-11.3)	28.4 (27.2-29.6)	26.2 (25.0-27.4)
OR adjusted.1[9]	**1.44 (1.23-1.69)**	**1.46 (1.24-1.73)**	**1.47 (1.25-1.73)**	**1.87 (1.57-2.23)**	**2.06 (1.68-2.53)**	**2.29 (1.84-2.86)**	**1.57 (1.34-1.84)**	**1.61 (1.37-1.90)**
OR adjusted.2[10]	**1.45 (1.22-1.72)**	**1.40 (1.15-1.70)**	**1.36 (1.10-1.67)**	**1.72 (1.41-2.09)**	**1.68 (1.31-2.16)**	**2.10 (1.56-2.83)**	**1.47 (1.23-1.77)**	**1.56 (1.29-1.89)**
OR fully adjusted 2[11]	**1.38 (1.16-1.64)**	**1.36 (1.12-1.66)**	**1.32 (1.07-1.64)**	**1.67 (1.36-2.05)**	**1.67 (1.29-2.16)**	**2.03 (1.50-2.75)**	**1.44 (1.20-1.73)**	**1.50 (1.23-1.82)**

[1] Proportion reporting sleep quality "rather badly" or "badly". [2] Proportion reporting sleep onset (SO) problems 3+ days/week. [3] Proportion reporting sleep maintenance (SM) problems 3+ day/week. [4] Proportion reporting early morning awakening (EMA) problems 3+ days/week. [5] Proportion reporting nightmares 3+ nights/week. [6] Hypnotic use 3+ days/week. [7] Proportion reporting fatigue 3+ days/week. [8] Proportion reporting excessive daytime sleepiness 3+ day/week. CI: 95% confidence interval. OR: odds ratios. [9]OR with adjustment for gender, age, marital status (single, cohabiting, divorced/separated, widowed) and education (below University, University). [10]OR adjusted in addition for ethnicity (Asian, Caucasian/European, Other) and also for the presence of the problem before COVID. [11]Fully adjusted model: OR adjusted in addition for the other factors (presence of COVID-19, financial suffering and confinement) and also the severity of the COVID-19 epidemic in each country at the moment of the survey as measured by cumulative number of cases per 100 000 at the median time of the survey in each country. Results are weighted and stratified by countries.

Figure text:

Figure 1A and B. Prevalence of all sleep problems before and during pandemic.

Text below the figure:
There was a statistically significant difference in the prevalence before and during pandemic for all sleep problems (P<0.0001). Error bars represents standard deviation.

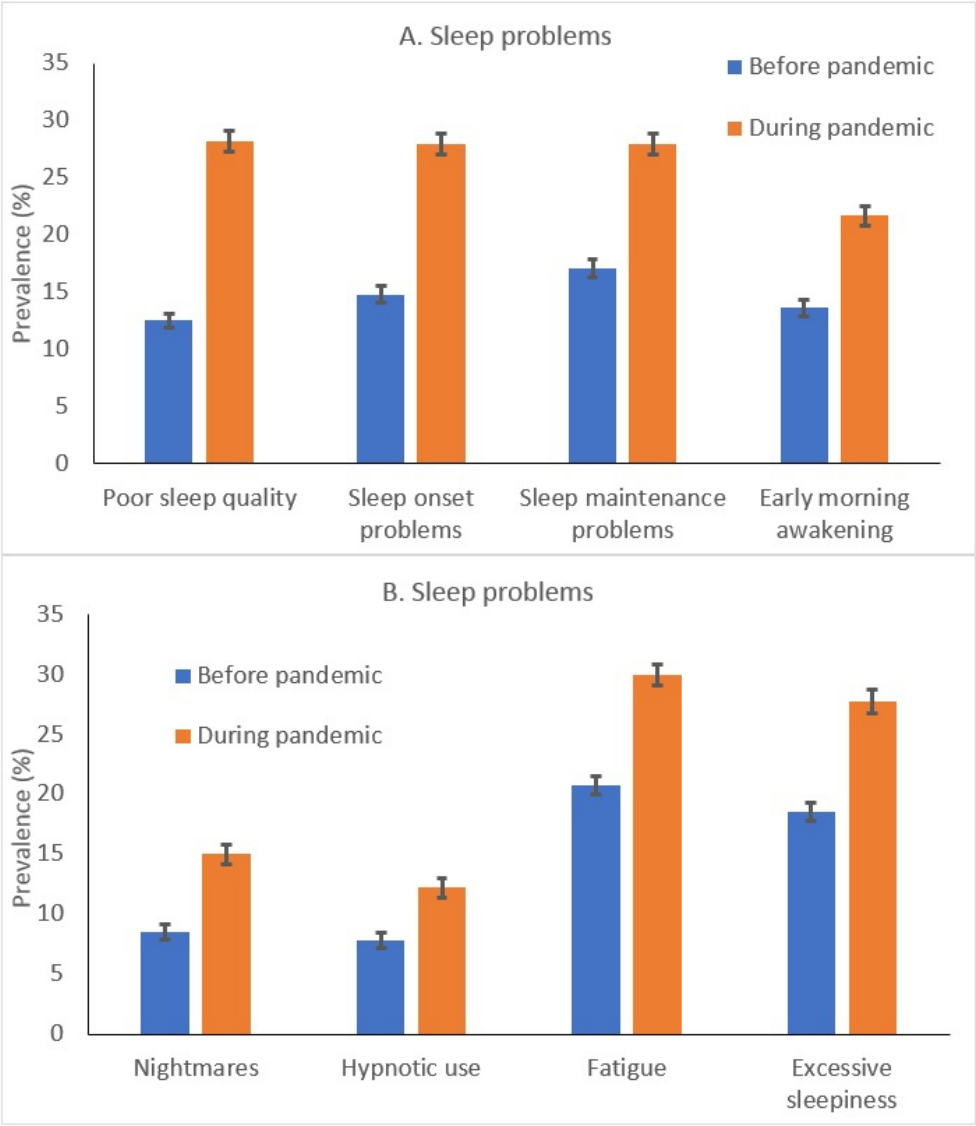

Figure 1A and B. Prevalence of all sleep problems before and during pandemic.

189x217mm (96 x 96 DPI)

Supplement 1. Sleep problems.

	Poor sleep quality[1]	SO problems[2]	SM problems[3]	EMA problems[4]	Nightmares[5]
Austria					
Before (CI)	15.8% (13.5-18.3%)	8.5% (6.8-10.5%)	20.7% (18.1-23.5%)	8.2% (6.5-10.2%)	1.1% (0.6-2.1%)
During (CI)	28.5% (25.6-31.6%)	18.2% (15.8-20.9%)	30.1% (27.2-33.3%)	17.2% (14.8-19.8%)	5.1% (3.8-6.7%)
Brazil					
Before (CI)	14.3% (12.8-16.0%)	19.4% (17.7-21.3%)	14.4% (12.9-16.1%)	12.7% (11.3-14.3%)	4.9% (4.0-6.0%)
During (CI)	32.6% (30.5-34.8%)	43.5% (41.3-45.8%)	31.4% (29.3-33.5%)	22.1% (20.2-24.0%)	15.6% (14.0-17.3%)
Canada					
Before (CI)	11.7% (10.5-13.1%)	17.8% (16.3-19.4%)	24.9% (23.2-26.8%)	17.0% (15.5-18.6%)	5.5% (4.6-6.5%)
During (CI)	44.8% (42.7-46.8%)	32.7% (30.7-34.7%)	38.9% (36.9-41.0%)	29.4% (27.5-31.4%)	11.4% (10.1-12.8%)
China/Jinlin					
Before (CI)	10.7% (9.0-12.7%)	6.3% (5.0-7.9%)	4.0% (3.0-5.4%)	6.5% (5.2-8.2%)	1.1% (0.6-2.0%)
During (CI)	18.0% (15.8-20.4%)	9.6% (8.0-11.5%)	6.8% (5.5-8.5%)	7.6% (6.1-9.3%)	2.3% (1.6-3.4%)
China/Hongkong					
Before (CI)	11.7% (10.0-13.6%)	6.9% (5.6-8.5%)	5.6% (4.5-7.1%)	4.8% (3.8-6.2%)	2.4% (1.7-3.4%)
During (CI)	21.5% (19.2-23.8%)	11.4% (9.8-13.3%)	9.8% (8.2-11.5%)	8.7% (7.3-10.4%)	4.0% (3.0-5.2%)
Finland					
Before (CI)	18.0% (15.5-20.8%)	14.2% (11.9-16.8%)	19.1% (16.5-22.0%)	8.2% (6.5-10.4%)	2.2% (1.4-3.5%)
During (CI)	24.6% (21.7-27.7%)	19.8% (17.1-22.7%)	25.2% (22.2-28.3%)	13.7% (11.5-16.3%)	5.7% (4.3-7.6%)
France					
Before (CI)	11.7% (9.8-14.0%)	16.3% (13.8-19.2%)	25.6% (22.6-28.9%)	16.9% (14.3-19.7%)	6.3% (4.8-8.3%)
During (CI)	33.7% (30.5-37.1%)	26.2% (23.0-29.7%)	29.8% (26.5-33.3%)	21.9% (18.9-25.1%)	8.6% (6.7-11.0%)
Italy					
Before (CI)	10.6% (9.2-12.3%)	18.2% (16.4-20.2%)	16.4% (14.7-18.3%)	10.8% (9.4-12.5%)	7.3% (6.2-8.7%)
During (CI)	21.5% (19.5-23.6%)	22.7% (20.6-24.8%)	19.8% (17.9-21.9%)	15.1% (13.4-17.0%)	10.4% (9.0-12.1%)
Japan					
Before (CI)	16.8% (15.9-17.7%)	10.4% (9.7-11.1%)	18.8% (17.9-19.8%)	8.9% (8.3-9.6%)	3.6% (3.2-4.1%)
During (CI)	22.4% (21.4-23.4%)	15.4% (14.6-16.3%)	23.2% (22.2-24.2%)	12.9% (12.2-13.7%)	5.3% (4.8-5.9%)
Norway					
Before (CI)	22.2% (19.5-25.1%)	21.6% (18.9-24.6%)	33.5% (30.3-36.8%)	15.1% (12.8-17.7%)	3.0% (2.0-4.5%)
During (CI)	30.6% (27.5-33.8%)	29.8% (26.7-33.1%)	39.7% (36.3-43.2%)	21.4% (18.6-24.4%)	5.4% (4.0-7.2%)
Poland					
Before (CI)	11.0% (8.3-14.6%)	13.9% (10.8-17.8%)	9.0% (6.5-12.3%)	9.5% (6.9-12.9%)	1.3% (0.5-3.1%)
During (CI)	29.9% (25.5-34.7%)	28.4% (24.0-33.1%)	20.3% (16.5-24.6%)	24.5% (20.4-29.1%)	5.0% (3.2-7.7%)

Sweden					
Before (CI)	16.0% (13.3-19.1%)	13.8% (11.3-16.7%)	[6]	12.0% (9.6-14.8%)	1.0% (0.4-2.2%)
During (CI)	30.7% (27.2-34.5%)	24.6% (21.4-28.2%)	[6]	21.4% (18.3-24.8%)	6.2% (4.5-8.4%)
United Kingdom					
Before (CI)	16.6% (14.5-18.8%)	14.1% (12.1-16.2%)	21.7% (19.4-24.2%)	12.2% (10.4-14.2%)	1.6% (1.0-2.5%)
During (CI)	52.7% (49.7-55.6%)	37.3% (34.4-40.2%)	44.5% (41.6-47.5%)	33.0% (30.2-35.8%)	12.8% (10.9-14.9%)
USA					
Before (CI)	9.2% (7.6-11.2%)	13.5% (11.6-15.8%)	17.4% (15.2-19.9%)	17.4% (15.2-19.9%)	16.8% (14.6-19.2%)
During (CI)	23.5% (21.0-26.2%)	23.9% (21.4-26.6%)	27.6% (25.0-30.5%)	25.1% (22.5-27.9%)	23.6% (21.1-26.3%)

[1] Proportion reporting sleep quality "rather badly" or "badly". [2] Proportion reporting sleep onset (SO) problems 3+ days/week. [3] Proportion reporting sleep maintenance (SM) problems 3+ day/week. [4] Proportion reporting early morning awakening (EMA) problems 3+ days/week. [5] Proportion reporting nightmares 3+ nights/week. CI: 95% confidence interval. [6] Missing data.

Supplement 2. Daytime problems and hypnotic use.

	Fatigue[1]	Excessive sleepiness[2]	Falling asleep during daytime[3]	Hypnotic use[4]
Austria				
Before (CI)	20.8% (18.2-23.6%)	18.4% (16.0-21.2%)	21.6% (19.0-24.4%)	2.4% (1.6-3.7%)
During (CI)	28.2% (25.3-31.3%)	26.5% (23.6-29.5%)	30.5% (27.8-33.7%)	3.7% (2.6-5.1%)
Brazil				
Before (CI)	27.8% (25.8-29.9%)	24.4% (22.5-26.4%)	26.0% (24.0-28.0%)	7.1% (6.0-8.3%)
During (CI)	37.4% (35.2-39.6%)	35.2% (33.1-37.4%)	32.2% (30.2-34.4%)	9.9% (8.6-11.4%)
Canada				
Before (CI)	17.9% (16.4-19.6%)	12.4% (11.1-13.8%)	10.9% (9.7-12.3%)	6.6% (5.7-7.8%)
During (CI)	28.5% (26.6-30.5%)	20.3% (18.6-22.0%)	20.2% (18.5-22.0%)	8.7% (7.5-9.9%)
China/Jinlin				
Before (CI)	10.3% (8.6-12.2%)	9.7% (8.1-11.6%)	15.1% (13.1-17.4%)	1.2% (0.7-2.1%)
During (CI)	12.8% (10.9-14.9%)	11.7% (9.9-13.7%)	15.5% (13.5-17.8%)	1.4% (0.8-1.0%)
China/Hongkong				
Before (CI)	23.1% (20.8-25.5%)	18.9% (16.8-21-1%)	10.5% (8.9-12.3%)	3.2% (2.4-4.4%)
During (CI)	27.8% (25.4-30.4%)	24.4% (22.1-26.9%)	16.0% (14.0-18.1%)	4.3% (3.3-5.6%)
Finland				
Before (CI)	20.6% (18.0-23.6%)	22.8% (20.0-25.8%)	12.9% (10.7-15.4%)	10.1% (8.2-12.4%)
During (CI)	27.6% (24.6-30.8%)	28.4% (25.3-31.6%)	19.8% (17.2-22.7%)	10.4% (8.4-12.7%)
France				
Before (CI)	14.7% (12.3-17.4%)	7.4% (5.7-9.5%)	12.1% (9.9-14.6%)	4.0% (2.8-5.7%)
During (CI)	19.7% (16.9-22.9%)	8.6% (6.7-10.9%)	17.3% (14.6-20.4%)	4.1% (2.9-5.9%)
Italy				
Before (CI)	19.6% (17.7-21.6%)	17.1% (15.4-19.1%)	13.4% (11.8-15.1%)	3.1% (2.4-4.1%)
During (CI)	21.9% (20.7-22.7%)	19.9% (18.0-22.0%)	15.8% (14.1-17.7%)	4.8% (3.8-6.0%)
Japan				
Before (CI)	19.9% (19.0-20.9%)	15.0% (14.2-15.9%)	10.3% (9.6-11.0%)	4.6% (4.2-5.2%)
During (CI)	21.7% (20.7-22.7%)	18.1% (17.2-19.0%)	13.4% (12.6-14.2%)	5.2% (4.7-5.8%)
Norway				
Before (CI)	26.1% (23.1-29.2%)	23.5% (20.7-26.5%)	21.5% (18.8-24.5%)	8.2% (6.5-10.3%)
During (CI)	34.2% (31.0-37.6%)	31.4% (28.2-34.7%)	29.9% (26.9-33.2%)	11.6% (9.5-14.1%)
Poland				

Before (CI)	26.8% (22.6-31.5%)	21.8% (18.0-26.3%)	18.6% (15.0-22.9%)	6.1% (4.1-9.0%)
During (CI)	42.5% (37.6-47.8%)	37.1% (32.4-42.1%)	31.9% (27.4-36.8%)	9.8% (7.2-13.2%)
Sweden				
Before (CI)	12.0% (9.6-14.8%)	30.7% (27.2-34.5%)	13.9% (11.4-16.9%)	5.5% (4.0-7.6%)
During (CI)	32.7% (29.1-36.5%)	37.5% (33.8-41.4%)	32.6% (29.0-36.4%)	7.0% (5.2-9.3%)
United Kingdom				
Before (CI)	18.8% (16.6-21.2%)	16.6% (14.6-18.9%)	9.7% (8.1-11.6%)	1.8% (1.2-2.7%)
During (CI)	46.9% (43.9-49.9%)	38.1% (35.2-41.0%)	26.0% (23.4-28.7%)	3.4% (2.4-4.6%)
USA				
Before (CI)	18.4% (16.2-20.9%)	18.7% (16.4-21.2%)	21.7% (19.2-24.3%)	13.1% (11.2-15.3%)
During (CI)	28.6% (26.0-31.5%)	29.8% (27.1-32.7%)	36.5% (33.7-39.5%)	22.5% (20.0-25.1%)

[1] Proportion reporting fatigue 3+ days/week. [2] Proportion reporting excessive daytime sleepiness 3+ day/week.
[3] Proportion reporting moderate or high chance of falling asleep daytime without intending to.
[4] Hypnotic use 3+ days/week. CI, confidence interval.

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Sleep and daytime problems during the COVID-19 pandemic. Effects of coronavirus infection, confinement, and financial suffering. A multinational survey using a harmonised questionnaire

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Abstract

Objectives - Sleep is important for human health and well-being. No previous study has assessed whether the COVID-19 pandemic impacts sleep and daytime function across the globe.

Methods - This large-scale international survey used a harmonized questionnaire. Fourteen countries participated during the period May to August 2020. Sleep and daytime problems (poor sleep quality, sleep onset and maintenance problems, nightmares, hypnotic use, fatigue, excessive sleepiness) occurring "before" and "during" the pandemic were investigated. In total, 25,484 people participated and 22,151 (86.9%) responded to the key parameters and were included. Effects of COVID-19, confinement, and financial suffering were considered. In the fully adjusted logistic regression models, results (weighted and stratified by country) were adjusted for gender, age, marital status, educational level, ethnicity, presence of sleep problems before COVID-19, and severity of the COVID-19 pandemic in each country at the time of the survey.

Results - The responders were mostly women (64%) with mean age 41.8 (SD 15.9) years (median 39, range 18-95). Altogether, 3.0% reported having had COVID-19, 42.2% reported having been in confinement, and 55.9% had suffered financially. All sleep and daytime problems worsened during the pandemic by about 10% or more. Also, some participants reported improvements in sleep and daytime function. For example, sleep quality worsened in about 20% of subjects and improved in about 5%. COVID-19 was particularly associated with poor sleep quality, early morning awakening and daytime sleepiness. Confinement was associated with poor sleep quality, problems falling asleep, and with decreased use of hypnotics. Financial suffering was associated with all sleep and daytime problems, including nightmares and fatigue even in the fully adjusted logistic regression models.

Conclusions – Sleep problems, fatigue, and excessive sleepiness increased significantly throughout the world during the first phase of the COVID-19 pandemic. Problems were associated with confinement and especially with financial suffering.

Strengths and limitations of this study

- This was a large, multinational internet-based survey on sleep problems, fatigue and sleepiness realized in 14 different countries.
- Harmonized questionnaires were used allowing comparability of results.
- This study gives associations, but one must be cautious in making inferences on causality because there has been no follow-up.
- The results are based on self-report without clinical assessments or sleep recordings.
- A recall bias is possible as concerns any "before" the pandemic and "during" the pandemic comparisons.

Introduction

The COVID-19 pandemic is the deadliest since the 1918 Spanish flu. The disease exhibits a far higher fatality rate than the seasonal flu, while also causing both acute and lingering symptoms for many of those afflicted. As of 10 September 2021, there have been more than 223 million confirmed cases and more than 4.6 million deaths attributed to COVID-19 worldwide.[1] Peoples' lives have been affected in many ways.

Sleep is vital for cognitive, emotional, and somatic functioning and vice versa. Poor sleep is associated with a multitude of health problems, such as anxiety, depression, suicidal ideation, obesity, cardiovascular diseases, cancer, dementia, increased accident risk, and mortality.[2] Also, sleep problems may increase sick leave and work disability.[3] Of note, sleep may exhibit a bidirectional relationship with an infectious disease like COVID-19. Poor sleep may compromise in vivo antibody responses to novel antigens,[4] thus increasing the risk of becoming infected by SARS-CoV-2-virus.[5] On the other hand the COVID-19 pandemic may have stressful personal consequences, both practical and emotional, that impair sleep.

Apart from the well-established symptoms of breathing difficulties, fever, loss of smell and taste, COVID-19 has been linked to a range of cognitive and psychiatric symptoms including increased anxiety and depression,[6] panic attacks, irrational fears, post-traumatic stress, fatigue, and sleep disturbances, [7, 8]and other behavioral factors like "panic buying" may also be associated with anxiety and poor sleep.[9] Social isolation, home confinement and loneliness have been associated with increased morbidity [6, 7, 10-12] and even with increased mortality.[10]

Reduced physical activity and daylight exposure, and a lack of social Zeitgebers due to no longer having a fixed work schedule, as well as increased worry may have negatively impacted sleep. [13, 14]Nevertheless, lockdown may have had some positive sleep effect. Extrinsically imposed schedules, such as the early morning rush to work, have been replaced by flexible work hours at home. Therefore, sleep duration may have increased and daytime sleepiness decreased for some people, [15, 16]although sleep quality arising from worries and uncertainties may have remained poor.[15]

The International Covid Sleep Study (ICOSS; https://www2.helsinki.fi/en/projects/icoss) was initiated in March 2020 to improve global understanding of these important relationships.[8] It includes 14 participating countries across four continents (Asia, Europe, North America, South America). We hypothesised that various sleep–wake problems would increase during, compared with before, the pandemic. Also, we hypothesised that infection with SARS-CoV-2-virus would be associated with

sleep problems, which in turn would strongly correlate with social confinement, familial, work-related, and other psychosocial factors.[8]

Objectives

The focus of the present study was on the impact of the first wave of the COVID-19 pandemic on sleep and daytime problems. The sleep problems of interest in this study were poor sleep quality, problems of falling asleep (sleep onset problems), problems of maintaining sleep, early morning awakenings, nightmares and use of hypnotics. The sleep-related daytimes problems of interest were fatigue and excessive daytime sleepiness. The role of COVID-19, confinement, and financial problems due to the pandemic on these sleep and daytime problems was investigated. Also, we examined country-specific differences in the rates of these sleep and daytime problems.

Methods

Survey

The research protocol and the final standardized survey questionnaire was published previously[8]. As we aimed to investigate possible changes in the frequency and presentation of various sleep and daytime problems in relation to COVID-19 and confinement, the survey enquired about symptoms and experiences both "before" and "during" the pandemic. After gathering data on important sociodemographic variables (age, gender, marital status, etc), the survey incorporated multiple questions on sleep problems using the validated Basic Nordic Sleep Questionnaire[17]. Scale responses for many of these items such as difficulty falling asleep, problems staying asleep, fatigue, daytime sleepiness, and nightmares were 1 "never or less frequently than once per month", 2 "less than once per week", 3 "on 1-2 days per week", 4 "on 3-5 days per week" and 5 "daily or almost daily". Sleep quality was assessed by the question "How well have you been sleeping", with response alternatives "well", "rather well", "neither well nor badly", "rather badly" and "badly".[8] As we wanted to concentrate on clinically meaningful problems, we used mainly a cut-point of 4 (a problem was occurring at least on 3 days/nights per week). The individual cut-points for different questions are given in the results.

Occurrence of COVID-19 was asked as: "Have you had COVID-19?" The response alternatives were: 0) "No", 1) "Yes" and 2) "I do not know". Only those responding "yes" were defined as having had COVID-19. The participants were also asked "Have you been tested positive for corona virus (laboratory test for COVID-19)?": 0) "No", 1) "Yes", 2) "I do not know".

Confinement was asked as*:* "During the COVID-19 pandemic, have you been restricted to stay at home/ protected/ in quarantine?" Response alternatives were: 0) "No"; 1) "Two weeks or less"; 2) "3 to 4 weeks"; 3) "5 to 6 weeks"; 4) "7 to 8 weeks"; 5) "More than 8 weeks". The reason for confinement was asked as: "What were your reasons for being restricted to stay at home/ protected/

in quarantine?": 0) "I have not been restricted to stay at home"; 1) "There was a 'lockdown' across society"; 2) "I had symptoms or someone in the household had symptoms"; 3) "Partly because of lockdown, and partly because of symptoms"; 4) "Due to work regulations"; 5) "Due to travelling abroad". In this study confinement was dichotomized to 0) "no confinement" and 1) "had been in confinement" for any reason. Financial suffering was based on a single question: "Has your financial status (economy) suffered from the pandemic?". The response alternatives were: 0) "Not at all"; 1) "A little"; 2) "Somewhat"; 3) "Much"; 4) "Very much/ Severely". We used much or very much/severely to define "financial suffering" in this study.

In addition, dates and country of response were recorded. This allowed us to relate the timing of responses to the patterning of pandemic exposure and confinement in each country in accordance with centralised WHO records.[1]

The survey questionnaire[8] was translated into different languages and administered in 14 countries/areas (Austria, Brazil, Canada, China/ Hong Kong, China/ Jilin, Finland, France, Italy, Japan, Norway, Poland, Sweden, The UK, USA) between May and August 2020. To be included in the survey, a minimum of 400 responders with complete answers from any given country had to be available. The most used online platforms for administration of the survey were RedCap and Qualtrics. Potential participants were solicited in each country for example by informing about the survey in the University web pages, national newspapers or television, Facebook or Twitter. All responders were anonymous volunteers and aged 18 years or older.

Participants

In order to be able to adjust results in each country by gender, age (5 groups), history of COVID-19 and history of confinement (5 periods) and other factors (e.g. financial effects, circadian type etc.) we decided in advance, before starting the survey in each country, that the target is at least 400 responders (target = 2 x 2 x 2 x 2 x 5 x 5) in each participating country. All participating centres agreed on that. The figure was considered realistic, but also large enough to allow tabulations by gender, different age-groups, marital status, educational levels, and ethnicity. It was not an absolute level, but we used that so that all participating countries would understand why their data might not have been used if there were very few responders. The survey was started in Germany later than in the other participating countries. Therefore, Germany did not have enough responders when we merged the data in the fall 2020, and their data were not included in this study.

A total of 25,484 subjects gave their informed consent in the beginning of the survey and participated. Of them, 3,333 subjects did not complete the survey in full. After excluding them, 22,151 participants (86.9%) provided complete data and were included in the analyses.

Patient and Public Involvement

No patient or public involvement.

Data reduction and analyses

All survey items and variables names were identical across countries to facilitate merging of data into a single file. This data integration and all statistical computations were conducted using STATA 15.1 (StataCorp, College Station, USA). There was no requirement for data imputation for missing data and no replacement of subjects. Shapiro-Wilk test was used for testing of normality. Means and standard deviation were given in the descriptive results if the distributions were normal. It the distributions were not normal, we have also given medians, percentiles, and range. For occurrences and rates we have given the 95% confidence limits. Multivariate analyses and statistical analyses were conducted by weighting of data by the number of inhabitants in the country/area of interest and by the number of responders in that country. Different countries were used as strata. Observations were used as sampling unit and non-parametric statistics were applied with proportions and 95% confidence intervals calculated. Logistic regression analyses and other comparative analyses were utilised using appropriate weighting for the merged data. We specifically analysed effects of COVID-19 infection (self-reported), confinement for at least two weeks, and suffering from financial losses because of COVID-19.

Ethics approval, consent, and reporting

The anonymous online survey made re-identification of the respondents impossible. All countries obtained approval from their Internal Reviews Board before starting the survey. The ethical diary numbers are: Canada REB#20-5540, China (Hong Kong) CREC2020.277, France 2218275, Germany EA1/161/20, Italy 0000836, Japan 194, UK R70002/RE001 and USA IRB-20-257. Due to the anonymous nature of survey collection, the Regional Ethical Board did not require an ethical evaluation or approval, and formal ethical committee permissions were exempted in the rest of the participating countries: Austria, Brazil, China (Jilin), Finland, Norway, Poland and Sweden in keeping with the national research governance and regulations. Informed consent was obtained, and the procedures followed all principles that are stated by the Declaration of Helsinki.

Results

Table 1 presents the demographics of the total study population. The age distribution is shown in table 1. It was skewed to the left (Shapiro-Wilk W 0,955; P<0,0001). Ten percent were aged 18 to 22 years, and 10 percent were aged 65 to 95 years. The median age of the responders was 39 years (range 18-95 y; mean 41.8; SD 15.9). In total, 3.0% (n=739) reported having had COVID-19. 404 of them (54.7%) had been tested positive and 50 (6.8%) did not know if they had been tested positive or not. Altogether 42.2% reported having been restricted to their home (in confinement) during the

pandemic, and 55.9% reported having suffered financially due to the pandemic (Table 1). Table 1 also presents information on the number of participants from each country.

Sleep and daytime problems before and during COVID-19

Occurrence of sleep and daytime problems for all participants from the 14 countries is summarised in Figure 1 and Table 2. The data clearly show that all sleep and daytime problems increased during relative to before the COVID-19 pandemic. In fact, the prevalence of most of the problems (poor sleep quality, sleep onset problems, sleep maintenance problems, fatigue, excessive sleepiness, and falling asleep during daytime) increased by about 10% or more. The smallest percentage increase was in hypnotic use, but even such use increased dramatically from 7.8% to 12.2% during the pandemic (Figure 1, Table 2).

Worsening and improvement of sleep and daytime problems

Table 2 provides data on the percentage of participants who reported having *improved*, *unchanged* or *worsened* sleep and daytime problems over the time course of the pandemic. Whereas most participants reported that their sleep and daytime problems were unchanged from before to during the pandemic, sleep quality worsened in about 20% and improved in about 5% of participants. Results also differed depending on the variable of interest. For example, 6.9% reported an increase in hypnotic use and a 20.8% worsening of sleep quality during the pandemic (Table 2).

Factors associated with the occurrence of sleep and daytime problems

Table 3 presents prevalence data on sleep and daytime problems during the pandemic, segmented by three variables of interest, i.e., COVID-19, reports of being in confinement, and suffering financially due to the pandemic. Crude (unadjusted) percentages showed that having had COVID-19 was significantly associated with poor sleep quality, early morning awakening, nightmares, hypnotic use, fatigue, and excessive sleepiness. In a multiple logistic regression model all sleep and daytime problems were significantly associated with COVID-19 after adjustment for gender, age, marital status, and educational level. However, in the fully adjusted model, with adjustment also for ethnicity, presence of the problem before the pandemic, confinement, financial suffering, and the severity of the COVID-19 pandemic in each country at the time of the survey, only poor sleep quality, early morning awakening, and sleepiness remained significant (Table 3).

Confinement during the pandemic was associated with all the reported sleep and daytime problems in crude as well as in two of the adjusted analyses. However, in the fully adjusted model, confinement was only positively associated with poor sleep quality and sleep onset problems, whereas a negative association with hypnotic use appeared (Table 3).

Financial suffering during the pandemic was associated with all sleep and daytime problems, both in crude and in all adjusted logistic regression analyses (Table 3). The highest odds ratio was seen for hypnotic use, which more than doubled during the pandemic in the fully adjusted model.

Country-specific differences

Supplement tables 1 and 2 present detailed data on sleep and daytime problems reported for each of the 14 countries. Problems increased in all countries during versus before the pandemic, but to differing degrees, and non-significantly for some countries. For instance, poor sleep quality increased in prevalence especially in Canada (nearly 4 times increase) and the UK (3 times higher). Fatigue significantly increased in prevalence in many countries but not in China (Jilin and Hong Kong), France, Italy, and Japan. The increase in prevalence of fatigue was particularly pronounced in Sweden and the UK with more than 2.5-fold increase (Supplement Table 2).

Discussion

Many papers, including meta-analyses, have been published on sleep and sleep disorders related to the pandemic.[6, 18, 19] However, to our knowledge this international collaborative study is the first to compare the occurrence of sleep and daytime problems during the pandemic in different countries and continents using harmonized data.[8]

The results of the ICOSS-project show that sleep problems increased in prevalence in all countries. More than 20% of participants reported a worsening of sleep quality. Other sleep-related issues, such as problems with sleep onset and maintenance, nightmares, and hypnotic use all increased significantly during the pandemic compared with the situation before.

Interestingly, there were some participants who reported improvements in sleep during the pandemic. This was reflected also in use of hypnotics. While around six percent used more hypnotics than before the pandemic, around two percent decreased their hypnotics use. During the pandemic, people in many countries had at least some constraints. Many were forced or recommended to stay at home, and many have been working at home. The resulting worktime flexibility may have helped some people to improve their sleep during the pandemic. This is seen also in decrease of social jetlag during the pandemic.[20] The prevalence of fatigue and excessive sleepiness increased by about 10% during the pandemic, but a minority of participants reported improved daytime function (e.g. less fatigue and daytime sleepiness).

The COVID-19 pandemic has changed people's lives dramatically. Gatherings of more than a few individuals have been severely limited across public places, at the same time as schools and universities have been closed. Many have had to undergo quarantine or have had to live in isolation, in many cases for extended periods of time. In line with our findings of an increase in several sleep

related problems, other studies have been published in different countries on how people's sleep-wake rhythm has changed during the pandemic.[7, 21, 22] For instance, an Italian study found that more than 50% of the 6,519 participants reported poor sleep quality, with risk factors including female gender, knowing a person who died from COVID-19, changing sleeping habits, and a high stress level.[22] Another reason why the lockdown affected sleep in such drastic ways, apart from isolation, may have been the increasing use of cell phones, laptops, and watching TV during lockdown. There have been studies demonstrating that increased screen exposure exacerbates sleep disturbances during lockdown.[16, 23] Dutta et al. observed that social jet lag and sleep debt were significantly less during than before lockdown in India.[23] Also some other studies have shown that sleep may, in fact, be better during the pandemic, in line with our results.[16, 20, 24]

Anxiety and other psychological effects of confinement were reported previously.[7, 25] In our survey, confinement was associated especially with problems of falling asleep and poor sleep quality. Interestingly, confinement was negatively associated with hypnotic use which may be related to the findings that some participants were sleeping well during confinement. Use of hypnotics varied by country. This may reflect different country specific attitudes towards use of hypnotics. The effects of confinement are closely related to effects of loneliness, which is related to COVID-19 and to increased mental and physical morbidity.[26, 27]

The prevalence of nightmares increased significantly in most countries. This increase may be related to increased levels of stress, anxiety, depression, PTSD (Post traumatic Stress Disorder)[21] or even suicidal ideation[28] during the lockdown caused by the pandemic. Furthermore, nightmares and acting out in sleep are associated with REM sleep behaviour disorder, which in turn is a known risk factor of alpha-synucleinopathies.[29]

In our survey, COVID-19 was associated with poor sleep quality, problems of waking up too early in the morning, and daytime sleepiness. The worsening effect of infection on sleepiness may be biological. In a meta-analysis of ten studies, 53% of patients with COVID-19 had olfactory dysfunction and 44% had gustatory dysfunction.[30] Some dysfunction may be long-lasting.[31] The olfactory bulbs are in contact with the midbrain including the sleep-wake regulating orexin cell groups.[32] By retrograde axonal transport this pathway allows viruses to directly reach the brain and possibly alter brain functions, including sleep and wake regulation.[32] Our study demonstrates the association between COVID-19, fatigue, and sleepiness. This needs to be investigated in more detail in the future. We cannot make strong inferences now because of the cross-sectional nature of our survey. We asked about the symptoms "before" and "during". So, we know about the change related to COVID-19, but we cannot say much about the consequences of a possible COVID-19. There is increasing evidence of long-lasting symptoms of "Post-Covid syndrome" or "Long-Covid"-syndrome, that may be more prevalent in patients who complain of poor sleep quality.[5] In addition to

respiratory and cardiovascular symptoms, some common complaints among such patients are fatigue, poor sleep quality, post-exertional malaise, cognitive disorders and symptoms of orthostatic intolerance – resembling symptoms of myalgic encephalopathy/chronic fatigue syndrome.[33-36]

We found more sleep and daytime problems in countries where the pandemic was escalating at the time of the survey than in countries where the situation was stable. As suggested by the cumulative number of COVID-19 confirmed deaths, during spring, the situation was bad in Italy, Spain, and France; while during the survey the worst situations were in Brazil, the US, and Sweden. Use of hypnotics increased especially in Brazil and the US. Complaints of fatigue, daytime sleepiness, and falling asleep at daytime increased clearly in the UK and US. Sleep problems increased somewhat less in other countries except in China/Jilin, France, and Italy, where no significant increase was observed for some of the complaints. Interestingly, the pandemic started in the Wuhan area in China, and in Europe the pandemic started in the spring 2020 especially in areas with many tourists, such as Austria, Italy, France, and Spain. In June and July 2020, new cases continued to rise sharply in Brazil and in the US as the first wave levelled off in China, Japan and in most European countries.

There are several possible confounders for differences in occurrence of sleep problems including ethnic, cultural, and meteorological differences. The ethnic, social, and financial differences were included in the logistic regression models. Furthermore, profession and working status during the pandemic may have an effect. We included educational level in the models. However, professions and working status were not included in this study. Also, we have not included effects of seasons. The survey was conducted in May-August 2020, when we had late spring-early summer in the Northern hemisphere and late fall-early winter in the Southern hemisphere (Brazil). The days were very long in the North (Finland, Norway, Sweden, and Canada). We cannot make strong inferences, but the situation and occurrences of sleep problems varied between Finland, Norway, and Sweden. The differences were most probably due more to political, social, and psychological differences between these countries. In Finland and Norway, strict restrictions were used while there were very few restrictions in Sweden.

The strongest factor associated with all types of sleep and daytime problems was the presence of financial suffering related to COVID-19. The effects of financial suffering may probably be explained by stress and other psychological effects. All these effects influence sleep, autonomic nervous system, and immunity. Higher educational level is known to associate with better financial situation. Recent studies have shown also that occurrence of COVID-19 is associated with lower educational level, unemployment, and low income.[37]

Strengths

Our survey has multiple strengths. It is based on a harmonized questionnaire with validated questions that were translated into different languages. Prior to our effort, the occurrence of sleep

problems has been studied in many countries, but the questions have not been identical, making comparisons between countries difficult. In the first phase of our ICOSS-collaboration, we collected data from fourteen participated countries using a standardized protocol and a harmonized questionnaire. This allows us to make inferences about worldwide effects of COVID-19, confinement, and financial status in different countries.

Limitations

Our study has several limitations. Recall bias is possible as we asked participants to report on their sleep and daytime problems both "before" and "during" the COVID-19 pandemic. The experience of the spring 2020 has probably been memorable for most people but it is possible that some people did not remember how they were sleeping before spring 2020. Even though we tried to be clear in the instructions, some people may have compared "before" with "now", rather than "during". We know the epidemiological situation in each country now of responding. As we have discussed, and as our results show, the increase in most sleep problems was greatest in countries where the incidence of new cases was increasing at the time of survey (e.g. Brazil, the UK, the USA) compared with countries where the situation was more stable at the time of the survey (China/ Jilin, France and Italy). As the situation had been much worse in the latter countries than in for example Norway and Finland, it is possible that subjects were thinking of the situation at the time of the response date rather than during the pandemic and confinement.

Some participants with sleep and wake problems may have exaggerated their symptoms during COVID-19. As the survey was done online, people without access to internet, and possibly a greater proportion of elderly people, would have been unable to participate. This limits generalization of our results. However, given the observed consistency across countries, we are confident that our results reflect the situation before and during the pandemic. Furthermore, we had young and old responders from both genders and from different ethnic backgrounds, suggesting that our results are representative for a large proportion of citizens in the participating countries.

One important limitation of our study is, that the information on having had COVID-19 was based on subjective reports. Mild diseases may have occurred without reporting them. Also, many subjects did not know whether they had been tested positive or not. Therefore, we included on the category of COVID-19 only those, who knew that they have had the disease. The study was conducted around the time of the first wave and access to formal testing was limited in spring and summer 2020.

Another limitation is that financial suffering was based on a single question. As this was an anonymous survey, we could not use any objective data. There are important socioeconomic differences between different countries. There are limitations to using a single item to appraise such an important variable. However, there were two reasons that led the study group to decide on this item. First, it was impractical to ask a series of more detailed questions in the context of the survey.

Second, and related to the first, we felt it would be very challenging to equate income levels across 14 countries to construct a reliable index of financial hardship. By asking people if they experienced suffering to financial status, we felt we had a reasonable proxy of changes in personal financial circumstances.

The frame of sampling and also sample sizes varied by country and relative to the population of the country. There were also ethnic differences. For these reasons we have used weighting, but even then, one must be cautious in making strong inferences. The most striking differences were found between the USA and other countries. The responders in the USA were younger and most responders were men, while in other countries most responders were women.

What needs to be studied?

Many unanswered questions remain. We have listed our main hypotheses in an earlier publication.[8] More detailed understanding of the nature of sleep and daytime function during the pandemic is needed. What are the effects of anxiety and depression on sleep and daytime problems? How can we explain the increase of nightmares during the pandemic? The increase of fatigue and daytime sleepiness needs to be studied in more depth. Effects of circadian types[38] and the relationship between sleep apnoea and COVID-19 must be studied further as well as effects of different factors on symptoms of restless legs and symptoms of REM-sleep behaviour disorder. We would need more subjects having had COVID-19 in order to have better information on the effects of the viral infection and effects of the pandemic situation with restrictions and limitation to “normal” life. Finally, effects of socioeconomic factors should be studied in more depth in the future.

Clinical implications

This was an anonymous survey. Therefore, we cannot make any direct inferences on causality. Some of the clinical implications are that also social, economic, and psychological factors are important when we treat people during the pandemic. Our results implicate that sleep and daytime problems may be caused by a coronavirus infection, but also by some other traumatic factors that are related to the pandemic, such as confinement and financial suffering.

CONCLUSIONS

Sleep problems, fatigue, and daytime sleepiness increased significantly throughout the world during the first phase of the COVID pandemic. As sleep and health share a bi-directional relationship, such problems were significantly associated with COVID-19, but also with confinement and especially with financial suffering. On a global level, the social and psychological effects seem to play a more important role than the biological effects of the COVID-19 as a disease on these sleep and daytime problems.

Data Availability Statement: The data are available upon reasonable request to the corresponding author.

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Table 1. Characteristics of the study population.

	% (N= 25,454)
Gender (n=24,353)	
Male	33.9 (8,257)
Female	66.0 (16,081)
Other	0.1 (15)
Age (n= 24,218)	
<25 years	14.9 (3,613)
25-34 years	25.4 (6,160)
35-44 years	18.7 (4,525)
45-54 years	16.6 (4,018)
55-64 years	13.4 (3,253)
65+ years	10.9 (2,649)
Marital status (n=24,264)	
Single	36.3 (8,814)
Cohabiting	56.0 (13,578)
Divorced/separated	6.1 (1,467)
Widowed	1.7 (405)
Education (n=24,069)	
Below University	73.2 (17,619)
College/University	26.8 (6,450)
Ethnicity (n=23,935)	
Caucasian/white	44.2 (10,588)
Asian	40.2 (9,632)
Other	15.5 (3,715)
COVID-19 (n=24,497)	
No	79.5 (19,464)
Yes	3.0 (739)
Do not know	17.5 (4,294)
Confinement (n= 23,072)	
No	57.8 (13,339)
Two weeks or less	8.6 (1,987)
3-4 weeks	5.1 (1,187)
5-6 weeks	4.0 (926)
7-8 weeks	5.4 (1,240)
More than 8 weeks	19.0 (4,393)
Financial suffering (n=24,324)	
Not at all	44.1 (10,718)
A little	28.4 (6,907)
Somewhat	15.1 (3,662)
Much	8.4 (2,037)
Very much/severely	4.1 (1,000)
Country (n=25,484)	
Austria	3.3 (722)
Brazil	8.2 (1,821)
Canada	9.4 (2,080)
China/Jilin	4.8 (1,071)
China/Hongkong	8.1 (1,790)
Finland	3.9 (869)
France	4.9 (1,089)
Italy	6.5 (1,439)
Japan	30.5 (6,744)
Norway	4.8 (1,060)
Poland	2.0 (433)
Sweden	3.3 (733)
United Kingdom	5.7 (1,257)
USA	4.7 (1,043)

Table 2. Sleep and daytime problems among all participants in the ICOSS study (n=25,484).

All countries	Before pandemic (CI)	During pandemic (CI)	Improved	Unchanged	Worsened
Poor sleep quality[1]	12.5% (11.8-13.2%)	28.2% (27.1-29.3%)*	5.2%	74.0%	20.8%
Sleep onset problems[2]	14.8% (13.9-15.7%)	27.9% (26.9-29.1%)*	4.4%	77.8%	17.8%
Sleep maintenance problems[3]	17.1% (16.2-18.1%)	27.9% (26.8-29.1%)*	4.2%	80.6%	15.2%
Early morning awakening[4]	13.6% (12.7-14.5%)	21.7% (20.6-22.7%)*	5.0%	81.8%	13.2%
Nightmares[5]	8.5% (7.7-9.4%)	15.0% (14.0-16.0%)*	2.9%	87.6%	9.5%
Hypnotic use[6]	7.8% (7.1-8.6%)	12.2% (11.2-13.2%)*	2.4%	90.7%	6.9%
Fatigue[7]	20.7% (19.8-21.7%)	29.9% (28.8-31.0%)*	8.0%	74.9%	17.1%
Excessive sleepiness[8]	18.5% (17.6-19.5%)	27.7% (26.6-28.9%)*	6.9%	76.9%	16.2%

[1] Proportion reporting sleep quality "rather badly" or "badly". [2] Proportion reporting sleep onset problems 3+ days/week. [3] Proportion reporting sleep maintenance problems 3+ day/week. [4] Proportion reporting early morning awakening (EMA) problems 3+ days/week. Proportion reporting nightmares 3+ nights/week. [6]Hypnotic use 3+ days/week. [7]Proportion reporting fatigue 3+ days/week. [8]Proportion reporting excessive daytime sleepiness 3+ day/week. CI: 95% confidence interval. *Statistically significant difference from *before* pandemic (P<0.0001).

Table 3. Prevalence (%) of sleep and daytime problems depending of COVID-19, confinement and financial problems due to the pandemic. All countries are included in the analyses.

	Poor sleep quality[1]	SO problems[2]	SM problems[3]	EMA problems[4]	Nightmares[5]	Hypnotic use[6]	Fatigue[7]	Excessive sleepiness[8]
COVID-19								
Yes % (CI)	34.3 (29.2-39.9)	31.2 (26.2-36.7)	32.9 (27.6-38.6)	32.8 (27.6-38.5)	27.8 (22.8-33.5)	28.5 (23.4-34.3)	36.0 (30.7-41.6)	40.8 (35.2-46.6)
No % (CI)	27.8 (26.7-28.9)	27.7 (26.6-28.8)	27.5 (26.4-28.7)	20.8 (19.7-21.8)	14.0 (13.0-15.0)	10.9 (10.0-11.9)	29.4 (28.3-30.6)	26.7 (25.6-27.8)
OR adjusted.1[9]	**1.62 (1.26-2.07)**	**1.35 (1.04-1.75)**	**1.42 (1.09-1.84)**	**1.93 (1.48-2.50)**	**2.05 (1.53-2.75)**	**2.68 (2.00-3.60)**	**1.43 (1.11-1.83)**	**1.92 (1.49-2.46)**
OR adjusted.2[10]	**1.71 (1.31-2.22)**	1.27 (0.94-1.72)	1.25 (0.89-1.77)	**1.64 (1.20-2.47)**	**1.59 (1.09-2.33)**	**1.83 (1.15-2.91)**	**1.35 (1.01-1.79)**	**1.72 (1.29-2.30)**
OR fully adjusted[11]	**1.55 (1.18-2.03)**	1.11 (0.82-1.52)	1.12 (0.79-1.59)	**1.48 (1.07-2.04)**	1.19 (0.80-1.76)	1.44 (0.88-2.35)	1.20 (0.89-1.61)	**1.51 (1.13-2.02)**
Confinement								
Yes % (CI)	30.3 (28.8-31.8)	31.9 (30.4-33.4)	29.6 (28.1-31.2)	23.2 (21.8-24.7)	17.4 (16.1-18.8)	13.5 (12.3-14.9)	32.6 (31.0-34.2)	30.8 (29.3-32.4)
No % (CI)	24.4 (22.9-25.8)	20.4 (18.9-21.9)	24.7 (23.1-26.2)	18.8 (17.3-20.3)	10.8 (9.4-12.3)	10.0 (8.7-11.5)	24.8 (23.2-26.4)	22.0 (20.5-23.7)
OR adjusted.1[9]	**1.37 (1.22-1.53)**	**1.67 (1.47-1.88)**	**1.42 (1.25-1.60)**	**1.38 (1.20-1.59)**	**1.56 (1.30-1.88)**	**1.42 (1.16-1.74)**	**1.36 (1.20-1.53)**	**1.46 (1.29-1.65)**
OR adjusted.2[10]	**1.37 (1.22-1.54)**	**1.35 (1.11-1.63)**	**1.30 (1.11-1.53)**	**1.30 (1.12-1.53)**	**1.60 (1.30-1.96)**	**1.30 (1.01-1.68)**	**1.35 (1.18-1.53)**	**1.24 (1.06-1.45)**
OR fully adjusted[11]	**1.19 (1.02-1.37)**	**1.28 (1.09-1.50)**	1.15 (0.97-1.36)	0.95 (0.80-1.13)	1.09 (0.84-1.43)	**0.70 (0.53-0-92)**	1.02 (0.87-1.18)	1.07 (0.91-1.25)
Suffered financially								
Yes % (CI)	33.7 (30.6-36.9)	34.3 (31.1-37.7)	33.6 (30.4-37.0)	31.1 (28.0-34.5)	25.0 (21.9-28.4)	22.3 (19.2-25.7)	37.8 (34.5-41.2)	36.2 (32.9-39.6)
No % (CI)	27.3 (26.2-28.4)	26.7 (25.6-27.9)	26.8 (25.7-28.0)	19.9 (18.8-21.0)	13.0 (12.1-14.1)	10.3 (9.4-11.3)	28.4 (27.2-29.6)	26.2 (25.0-27.4)
OR adjusted.1[9]	**1.44 (1.23-1.69)**	**1.46 (1.24-1.73)**	**1.47 (1.25-1.73)**	**1.87 (1.57-2.23)**	**2.06 (1.68-2.53)**	**2.29 (1.84-2.86)**	**1.57 (1.34-1.84)**	**1.61 (1.37-1.90)**
OR adjusted.2[10]	**1.45 (1.22-1.72)**	**1.40 (1.15-1.70)**	**1.36 (1.10-1.67)**	**1.72 (1.41-2.09)**	**1.68 (1.31-2.16)**	**2.10 (1.56-2.83)**	**1.47 (1.23-1.77)**	**1.56 (1.29-1.89)**
OR fully adjusted 2[11]	**1.38 (1.16-1.64)**	**1.36 (1.12-1.66)**	**1.32 (1.07-1.64)**	**1.67 (1.36-2.05)**	**1.67 (1.29-2.16)**	**2.03 (1.50-2.75)**	**1.44 (1.20-1.73)**	**1.50 (1.23-1.82)**

[1] Proportion reporting sleep quality "rather badly" or "badly". [2] Proportion reporting sleep onset (SO) problems 3+ days/week. [3] Proportion reporting sleep maintenance (SM) problems 3+ day/week. [4] Proportion reporting early morning awakening (EMA) problems 3+ days/week. [5] Proportion reporting nightmares 3+ nights/week. [6] Hypnotic use 3+ days/week. [7] Proportion reporting fatigue 3+ days/week. [8] Proportion reporting excessive daytime sleepiness 3+ day/week. CI: 95% confidence interval. OR: odds ratios. [9]OR with adjustment for gender, age, marital status (single, cohabiting, divorced/separated, widowed) and education (below University, University). [10]OR adjusted in addition for ethnicity (Asian, Caucasian/European, Other) and also for the presence of the problem before COVID. [11]Fully adjusted model: OR adjusted in addition for the other factors (presence of COVID-19, financial suffering and confinement) and also the severity of the COVID-19 epidemic in each country at the moment of the survey as measured by cumulative number of cases per 100 000 at the median time of the survey in each country. Results are weighted and stratified by countries.

Figure text:

Figure 1A and B. Prevalence of all sleep problems before and during pandemic.

Text below the figure:
There was a statistically significant difference in the prevalence before and during pandemic for all sleep problems (P<0.0001). Error bars represents standard deviation.

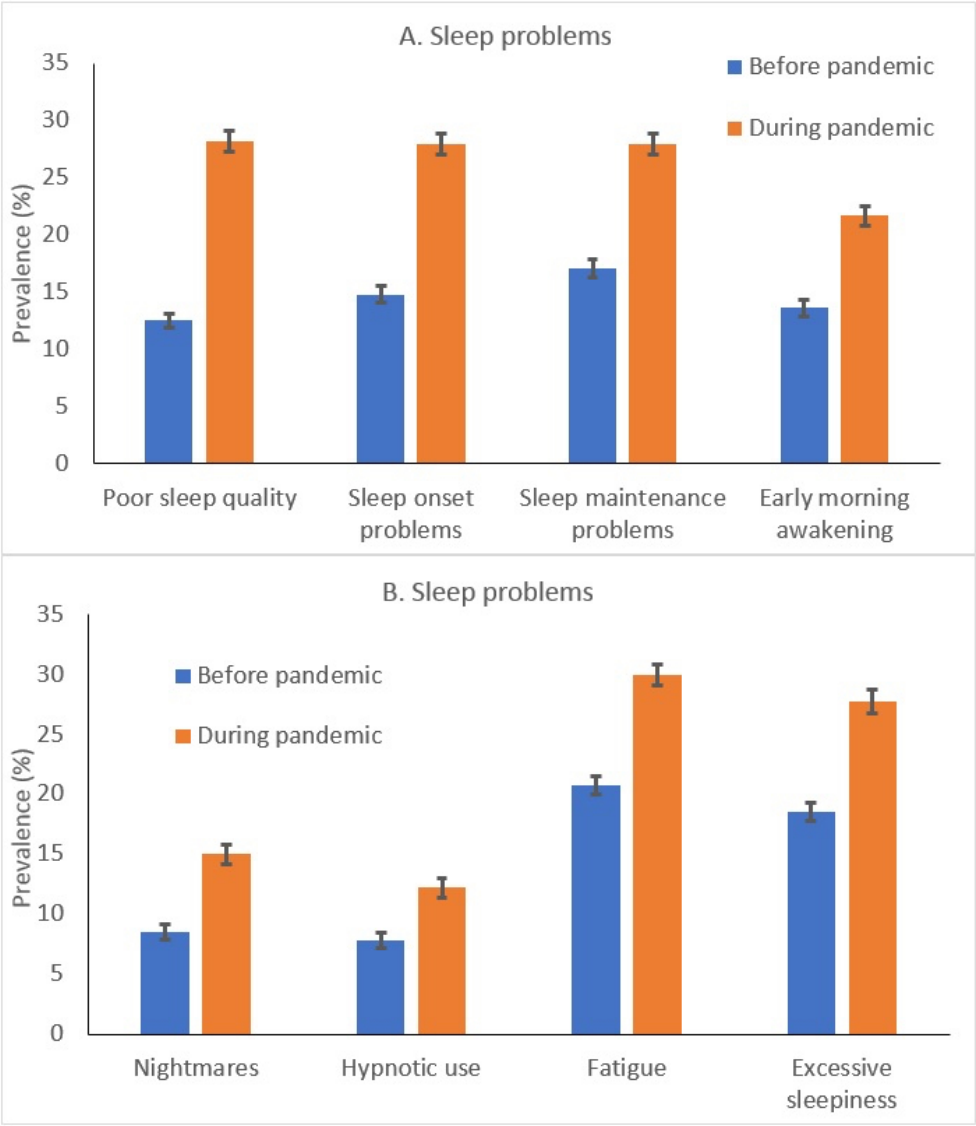

Figure 1A and B. Prevalence of all sleep problems before and during pandemic.

189x217mm (96 x 96 DPI)

Supplement 1. Sleep problems.

	Poor sleep quality[1]	SO problems[2]	SM problems[3]	EMA problems[4]	Nightmares[5]
Austria					
Before (CI)	15.8% (13.5-18.3%)	8.5% (6.8-10.5%)	20.7% (18.1-23.5%)	8.2% (6.5-10.2%)	1.1% (0.6-2.1%)
During (CI)	28.5% (25.6-31.6%)	18.2% (15.8-20.9%)	30.1% (27.2-33.3%)	17.2% (14.8-19.8%)	5.1% (3.8-6.7%)
Brazil					
Before (CI)	14.3% (12.8-16.0%)	19.4% (17.7-21.3%)	14.4% (12.9-16.1%)	12.7% (11.3-14.3%)	4.9% (4.0-6.0%)
During (CI)	32.6% (30.5-34.8%)	43.5% (41.3-45.8%)	31.4% (29.3-33.5%)	22.1% (20.2-24.0%)	15.6% (14.0-17.3%)
Canada					
Before (CI)	11.7% (10.5-13.1%)	17.8% (16.3-19.4%)	24.9% (23.2-26.8%)	17.0% (15.5-18.6%)	5.5% (4.6-6.5%)
During (CI)	44.8% (42.7-46.8%)	32.7% (30.7-34.7%)	38.9% (36.9-41.0%)	29.4% (27.5-31.4%)	11.4% (10.1-12.8%)
China/Jinlin					
Before (CI)	10.7% (9.0-12.7%)	6.3% (5.0-7.9%)	4.0% (3.0-5.4%)	6.5% (5.2-8.2%)	1.1% (0.6-2.0%)
During (CI)	18.0% (15.8-20.4%)	9.6% (8.0-11.5%)	6.8% (5.5-8.5%)	7.6% (6.1-9.3%)	2.3% (1.6-3.4%)
China/Hongkong					
Before (CI)	11.7% (10.0-13.6%)	6.9% (5.6-8.5%)	5.6% (4.5-7.1%)	4.8% (3.8-6.2%)	2.4% (1.7-3.4%)
During (CI)	21.5% (19.2-23.8%)	11.4% (9.8-13.3%)	9.8% (8.2-11.5%)	8.7% (7.3-10.4%)	4.0% (3.0-5.2%)
Finland					
Before (CI)	18.0% (15.5-20.8%)	14.2% (11.9-16.8%)	19.1% (16.5-22.0%)	8.2% (6.5-10.4%)	2.2% (1.4-3.5%)
During (CI)	24.6% (21.7-27.7%)	19.8% (17.1-22.7%)	25.2% (22.2-28.3%)	13.7% (11.5-16.3%)	5.7% (4.3-7.6%)
France					
Before (CI)	11.7% (9.8-14.0%)	16.3% (13.8-19.2%)	25.6% (22.6-28.9%)	16.9% (14.3-19.7%)	6.3% (4.8-8.3%)
During (CI)	33.7% (30.5-37.1%)	26.2% (23.0-29.7%)	29.8% (26.5-33.3%)	21.9% (18.9-25.1%)	8.6% (6.7-11.0%)
Italy					
Before (CI)	10.6% (9.2-12.3%)	18.2% (16.4-20.2%)	16.4% (14.7-18.3%)	10.8% (9.4-12.5%)	7.3% (6.2-8.7%)
During (CI)	21.5% (19.5-23.6%)	22.7% (20.6-24.8%)	19.8% (17.9-21.9%)	15.1% (13.4-17.0%)	10.4% (9.0-12.1%)
Japan					
Before (CI)	16.8% (15.9-17.7%)	10.4% (9.7-11.1%)	18.8% (17.9-19.8%)	8.9% (8.3-9.6%)	3.6% (3.2-4.1%)
During (CI)	22.4% (21.4-23.4%)	15.4% (14.6-16.3%)	23.2% (22.2-24.2%)	12.9% (12.2-13.7%)	5.3% (4.8-5.9%)
Norway					
Before (CI)	22.2% (19.5-25.1%)	21.6% (18.9-24.6%)	33.5% (30.3-36.8%)	15.1% (12.8-17.7%)	3.0% (2.0-4.5%)
During (CI)	30.6% (27.5-33.8%)	29.8% (26.7-33.1%)	39.7% (36.3-43.2%)	21.4% (18.6-24.4%)	5.4% (4.0-7.2%)
Poland					
Before (CI)	11.0% (8.3-14.6%)	13.9% (10.8-17.8%)	9.0% (6.5-12.3%)	9.5% (6.9-12.9%)	1.3% (0.5-3.1%)
During (CI)	29.9% (25.5-34.7%)	28.4% (24.0-33.1%)	20.3% (16.5-24.6%)	24.5% (20.4-29.1%)	5.0% (3.2-7.7%)

Sweden					
Before (CI)	16.0% (13.3-19.1%)	13.8% (11.3-16.7%)	[6]	12.0% (9.6-14.8%)	1.0% (0.4-2.2%)
During (CI)	30.7% (27.2-34.5%)	24.6% (21.4-28.2%)	[6]	21.4% (18.3-24.8%)	6.2% (4.5-8.4%)
United Kingdom					
Before (CI)	16.6% (14.5-18.8%)	14.1% (12.1-16.2%)	21.7% (19.4-24.2%)	12.2% (10.4-14.2%)	1.6% (1.0-2.5%)
During (CI)	52.7% (49.7-55.6%)	37.3% (34.4-40.2%)	44.5% (41.6-47.5%)	33.0% (30.2-35.8%)	12.8% (10.9-14.9%)
USA					
Before (CI)	9.2% (7.6-11.2%)	13.5% (11.6-15.8%)	17.4% (15.2-19.9%)	17.4% (15.2-19.9%)	16.8% (14.6-19.2%)
During (CI)	23.5% (21.0-26.2%)	23.9% (21.4-26.6%)	27.6% (25.0-30.5%)	25.1% (22.5-27.9%)	23.6% (21.1-26.3%)

[1] Proportion reporting sleep quality "rather badly" or "badly". [2] Proportion reporting sleep onset (SO) problems 3+ days/week. [3] Proportion reporting sleep maintenance (SM) problems 3+ day/week. [4] Proportion reporting early morning awakening (EMA) problems 3+ days/week. [5] Proportion reporting nightmares 3+ nights/week. CI: 95% confidence interval. [6] Missing data.

Supplement 2. Daytime problems and hypnotic use.

	Fatigue[1]	Excessive sleepiness[2]	Falling asleep during daytime[3]	Hypnotic use[4]
Austria				
Before (CI)	20.8% (18.2-23.6%)	18.4% (16.0-21.2%)	21.6% (19.0-24.4%)	2.4% (1.6-3.7%)
During (CI)	28.2% (25.3-31.3%)	26.5% (23.6-29.5%)	30.5% (27.8-33.7%)	3.7% (2.6-5.1%)
Brazil				
Before (CI)	27.8% (25.8-29.9%)	24.4% (22.5-26.4%)	26.0% (24.0-28.0%)	7.1% (6.0-8.3%)
During (CI)	37.4% (35.2-39.6%)	35.2% (33.1-37.4%)	32.2% (30.2-34.4%)	9.9% (8.6-11.4%)
Canada				
Before (CI)	17.9% (16.4-19.6%)	12.4% (11.1-13.8%)	10.9% (9.7-12.3%)	6.6% (5.7-7.8%)
During (CI)	28.5% (26.6-30.5%)	20.3% (18.6-22.0%)	20.2% (18.5-22.0%)	8.7% (7.5-9.9%)
China/Jinlin				
Before (CI)	10.3% (8.6-12.2%)	9.7% (8.1-11.6%)	15.1% (13.1-17.4%)	1.2% (0.7-2.1%)
During (CI)	12.8% (10.9-14.9%)	11.7% (9.9-13.7%)	15.5% (13.5-17.8%)	1.4% (0.8-1.0%)
China/Hongkong				
Before (CI)	23.1% (20.8-25.5%)	18.9% (16.8-21-1%)	10.5% (8.9-12.3%)	3.2% (2.4-4.4%)
During (CI)	27.8% (25.4-30.4%)	24.4% (22.1-26.9%)	16.0% (14.0-18.1%)	4.3% (3.3-5.6%)
Finland				
Before (CI)	20.6% (18.0-23.6%)	22.8% (20.0-25.8%)	12.9% (10.7-15.4%)	10.1% (8.2-12.4%)
During (CI)	27.6% (24.6-30.8%)	28.4% (25.3-31.6%)	19.8% (17.2-22.7%)	10.4% (8.4-12.7%)
France				
Before (CI)	14.7% (12.3-17.4%)	7.4% (5.7-9.5%)	12.1% (9.9-14.6%)	4.0% (2.8-5.7%)
During (CI)	19.7% (16.9-22.9%)	8.6% (6.7-10.9%)	17.3% (14.6-20.4%)	4.1% (2.9-5.9%)
Italy				
Before (CI)	19.6% (17.7-21.6%)	17.1% (15.4-19.1%)	13.4% (11.8-15.1%)	3.1% (2.4-4.1%)
During (CI)	21.9% (20.7-22.7%)	19.9% (18.0-22.0%)	15.8% (14.1-17.7%)	4.8% (3.8-6.0%)
Japan				
Before (CI)	19.9% (19.0-20.9%)	15.0% (14.2-15.9%)	10.3% (9.6-11.0%)	4.6% (4.2-5.2%)
During (CI)	21.7% (20.7-22.7%)	18.1% (17.2-19.0%)	13.4% (12.6-14.2%)	5.2% (4.7-5.8%)
Norway				
Before (CI)	26.1% (23.1-29.2%)	23.5% (20.7-26.5%)	21.5% (18.8-24.5%)	8.2% (6.5-10.3%)
During (CI)	34.2% (31.0-37.6%)	31.4% (28.2-34.7%)	29.9% (26.9-33.2%)	11.6% (9.5-14.1%)
Poland				

Before (CI)	26.8% (22.6-31.5%)	21.8% (18.0-26.3%)	18.6% (15.0-22.9%)	6.1% (4.1-9.0%)
During (CI)	42.5% (37.6-47.8%)	37.1% (32.4-42.1%)	31.9% (27.4-36.8%)	9.8% (7.2-13.2%)
Sweden				
Before (CI)	12.0% (9.6-14.8%)	30.7% (27.2-34.5%)	13.9% (11.4-16.9%)	5.5% (4.0-7.6%)
During (CI)	32.7% (29.1-36.5%)	37.5% (33.8-41.4%)	32.6% (29.0-36.4%)	7.0% (5.2-9.3%)
United Kingdom				
Before (CI)	18.8% (16.6-21.2%)	16.6% (14.6-18.9%)	9.7% (8.1-11.6%)	1.8% (1.2-2.7%)
During (CI)	46.9% (43.9-49.9%)	38.1% (35.2-41.0%)	26.0% (23.4-28.7%)	3.4% (2.4-4.6%)
USA				
Before (CI)	18.4% (16.2-20.9%)	18.7% (16.4-21.2%)	21.7% (19.2-24.3%)	13.1% (11.2-15.3%)
During (CI)	28.6% (26.0-31.5%)	29.8% (27.1-32.7%)	36.5% (33.7-39.5%)	22.5% (20.0-25.1%)

[1] Proportion reporting fatigue 3+ days/week. [2] Proportion reporting excessive daytime sleepiness 3+ day/week.
[3] Proportion reporting moderate or high chance of falling asleep daytime without intending to.
[4] Hypnotic use 3+ days/week. CI, confidence interval.

Partinen et al. BMJ Open ICOSS CHECKLIST… STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract - OK	Title and abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found - OK	Abstract; page # 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported - OK	Pages # 3 & 4
Objectives	3	State specific objectives, including any prespecified hypotheses - OK	Pages # 3 & 4
Methods			
Study design	4	Present key elements of study design early in the paper -OK	# 4, 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection -OK	# 5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up -OK	Not applicable
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed – OK	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable - OK	# 4, 5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group - OK	*# 4, 5*
Bias	9	Describe any efforts to address potential sources of bias -OK	# 4,5 & # 9-11
Study size	10	Explain how the study size was arrived at -OK	# 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why - OK	# 4 - 6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding – OK	# 4 - 6
		(*b*) Describe any methods used to examine subgroups and interactions -OK	# 5, 6
		(*c*) Explain how missing data were addressed -OK	# 4, 5
		(*d*) If applicable, explain how loss to follow-up was addressed - OK	Not applicable
		(*e*) Describe any sensitivity analyses - OK	Survey; Confidence limits given in tables

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed - OK	# 5 and Table 1
		(b) Give reasons for non-participation at each stage – OK; only complete responders included	# 4
		(c) Consider use of a flow diagram – OK, Survey, explained in the text	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders - OK	# 4, 5, Table 1
		(b) Indicate number of participants with missing data for each variable of interest – OK	# 4, 5
		(c) Summarise follow-up time (eg, average and total amount) – OK	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time - OK	Not applicable
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included - OK	In the tables
		(*b*) Report category boundaries when continuous variables were categorized - OK	Tables
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period - OK	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses - OK	Tables; odds ratios
Discussion			
Key results	18	Summarise key results with reference to study objectives - OK	# 6 - 8
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence - OK	# 8 - 10
Generalisability	21	Discuss the generalisability (external validity) of the study results - OK	# 10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based - OK	Title page & # 13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.