Association of Chronotype and Shiftwork with COVID-19 Infection

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Chronotype, Shiftwork and COVID-19

Abstract

Objective: This study assesses whether chronotype is related to COVID-19 infection and whether there is an interaction with shift work.

Methods: Cross-sectional survey of 19,821 U.S. adults

Results: COVID-19 infection occurred in 40% of participants, 32.6% morning and 17.2% evening chronotypes. After adjusting for demographic and socioeconomic factors, shift work, sleep duration and comorbidities, morning chronotype was associated with a higher (aOR: 1.15, 95% CI 1.10-1.21) and evening chronotype with a lower (aOR: 0.82, 95% CI: 0.78-0.87) prevalence of COVID-19 infection in comparison to an intermediate chronotype. Working exclusively night shifts was not associated with higher prevalence of COVID-19. Morning chronotype and working some evening shifts was associated with the highest prevalence of previous COVID-19 infection (aOR: 1.87, 95% CI: 1.28-2.74).

Conclusion: Morning chronotype and working a mixture of shifts increase risk of COVID-19 infection.

Key Words: COVID-19, Shift work, chronotype, diurnal preference

Learning Outcomes

- Describe the association between chronotype and prevalence of COVID-19
  infection

- Summarize the combined effect of chronotype and shift work on the prevalence
  of COVID-19 infection

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Introduction

A number of underlying medical conditions such as cardiovascular disease, diabetes, and obesity increase the risk for COVID-19 infection and severity.[1,2] Sleep conditions also are important risk factors associated with increased prevalence and worse outcomes for COVID-19 disease; emerging evidence demonstrates that obstructive sleep apnea[3–6] and more recently, insomnia and reduced sleep duration are linked to an increase in prevalence and worse COVID-19 disease outcomes.[7] Circadian rhythmicity is important in the regulation of immune system and inflammatory processes.[8,9] Chronotype is a trait that strongly reflects circadian timing as well as social and homeostatic factors.[10] Recently, evening chronotype has been associated with greater risk of poor health with increased rates of obesity, cardiovascular disease, and diabetes.[11,12] However, there have been few studies of whether a specific diurnal preference or chronotype is associated with a greater risk for COVID-19 disease. In a single center study in France, social jet lag as a marker of evening chronotype was associated with a higher rate of COVID-19.[13] In contrast, the COVID-19 Outbreak Public Evaluation (COPE) Initiative reported that morning in comparison to evening chronotype was associated with a higher rate of COVID infection;[7] while in a study using UK Biobank participants, no association was observed between a specific chronotype and COVID-19.[14] Thus, the impact of chronotype on COVID-19 has not been determined.

During the height of the COVID-19 pandemic, sleep patterns changed. As a result of lockdowns and social restrictions, stress, meal timing, anxiety and depression, social isolation, and the migration to remote working, both increases and decreases in sleep duration as well as changes in sleep timing occurred.[15–17] The presence of these factors may allow the development of circadian misalignment which increases risk of cardiovascular and metabolic disorders, and importantly infections. Circadian misalignment is a characteristic of shift workers who have been shown to have an

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increased risk of developing respiratory infections.[18,19] It has been suggested that shift workers are at greater risk for COVID-19.[20–22] This has been confirmed by several studies observing that night shift work is associated with higher rates of COVID-19 infection and hospitalization.[23–27]

Investigations examining whether the adverse effect of shift work on health is modified by chronotype suggest that shift workers with evening chronotype may have greater risk for diabetes and obesity.[12] However, there have been no assessments of whether risk of infection and in particular COVID-19 is similarly affected.

In this study, we examined whether both morning and evening chronotypes were more likely to have had a COVID-19 infection in comparison to those who were intermediate chronotypes. Additionally, we examined whether there is a synergistic association between chronotype and shift work, with COVID-19 infection. To accomplish this, we used data from the first four 2022 waves of COPE Initiative (http://www.thecopeinitiative.org/), a program focused on accumulating data on public attitudes, behaviors and beliefs related to the COVID-19 pandemic from large scale, demographically representative samples.

Methods

Study Design and Participants

From March 10, 2022 to August 18, 2022, the COPE Initiative administered four successive waves of public health surveillance surveys. Dates of administration were: Wave 1 (March 10-30, 2022), Wave 2 (April 4-May 1, 2022), Wave 3 (May 4-June 2, 2022) and Wave 4 (July 28-August 18, 2022). Using demographic quota sampling to approximate population estimates for age, sex, race, and ethnicity based on the 2020 U.S. census, each wave consisted of more than 5000 unique participants recruited by Qualtrics,

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LLC (Provo, Utah, and Seattle, Washington, U.S.). The Monash University Human Research Ethics Committee (Study #24036) approved the study.

Survey Items

Participants self-reported demographic, anthropometric, and socioeconomic information including age, race, ethnicity, sex, height and weight, education level, employment status and household income. In addition, they reported information on several current and past medical conditions by answering the question: "Have you ever been diagnosed with any of the following conditions: high blood pressure, cardiovascular disease (e.g., heart attack, stroke, angina), gastrointestinal disorder (e.g., acid reflux, ulcers, indigestion), cancer, chronic kidney disease, liver disease, sickle cell disease, chronic obstructive pulmonary disease or asthma?" Possible responses to each condition were "Never", "Yes I have in the past, but don't have it now", "Yes I have, but I do not regularly take medications or receive treatment", and "Yes I have, and I am regularly taking medications or receiving treatment".

Each survey contained identical items related to COVID-19 infection status and the number of COVID-19 vaccinations participants had obtained. Ascertainment of past COVID-19 infection was obtained using responses from the following questions related to COVID-19 testing:

1. "Have you ever tested positive?"
2. "Despite never testing positive, are you confident that you have had COVID-19?"
3. "Despite never testing positive, have you received a clinical diagnosis of COVID-19?"
4. "Have you experienced a problem with decreased sense of smell or taste at any point since January 2020?"

Chronotype was ascertained by asking participants the following question from the Horne & Östberg Morningness-Eveningness questionnaire:"[28] "One hears about 'morning' and 'evening' types of people. Which one of these types do you consider yourself to be?" Possible responses were "Definitely a 'morning' type", "Rather more of a 'morning' than an 'evening' type", "Rather more of an 'evening' than a 'morning' type", "Definitely an 'evening' type".[29] Morningness was defined as definitely a "morning" type and eveningness conversely was defined as definitely an "evening" type. Rather more of an "evening" and rather more of a "morning" were classified as neither morning nor evening type (intermediate).

Sleep duration was assessed using a question from the Pittsburgh Sleep Quality Index .[30] Responses were rounded to the nearest hour; those <3 hours or >12 hours were excluded as improbable estimates (N=987) as was done in a previous analysis of this cohort.[7]

For participants who endorsed self-employment, full or part-time employment, the following question was asked to determine the presence of shift work: "Currently, what type of shifts do you work? (Select all that apply)" Possible responses were:

1. "Day shift occurs any time between 6am and 7pm"
2. "Evening shift occurs any time between 3pm and midnight"
3. "Night shift is any shift in which the majority of the work hours occur between 10pm and 8am"

From these responses, 5 work shift categories were constructed: retired/not working, day shift only, day and/or some evening shifts, day and/or evening shifts and some night shifts, and night shift only. In addition, participants who were employed were asked to provide the percentage of their paid work hours that were completed remotely.

Statistical Analyses

Summary data for continuous or ordinal variables are reported as their respective means and standard deviations (SD) and for categorical variables as their percentages. Consistent with previous analyses, we defined a positive history of COVID-19 infection as an affirmative response to having tested positive for COVID-19, new loss of taste or smell or a clinical diagnosis of COVID-19. Number of COVID-19 vaccinations was utilized as an ordinal variable and also dichotomized as boosted (>2 vaccinations) or not boosted (≤2 vaccinations). Comorbid medical conditions were defined as currently having the condition whether treated or untreated. The effect of comorbid medical conditions was evaluated by summing the number of conditions reported by the participant (minimum value 0, maximum value 9). Body mass index (BMI) was calculated using self-reported height and weight as kg/m^2. Socioeconomic covariates were dichotomized as follows: employment (retired vs. not retired), education (high school or less vs. some college or higher) and income in U.S. Dollars to approximate 200% of the 2022 U.S. Poverty Level for a family of 4 (<$50,000 vs ≥$50,000).[31]

Comparisons of continuous or ordinal variables stratified by COVID-19 infection status were performed using Student's unpaired t-test. Bivariate comparisons of categorical variables stratified by COVID-19 infection were completed using χ^2.

Multivariable modelling using logistic regression was utilized to determine whether circadian preference and shift work categories were associated with COVID-19 infection. In an initial analysis including all participants with complete data, an initial baseline model was constructed only entering chronotype as a categorical variable with morningness and eveningness compared to the referent of neither morningness nor eveningness. We then developed increasingly complex models by sequentially including demographic factors, comorbidities and vaccination status, socioeconomic factors, shift

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work category, and sleep duration. In a subsequent model, to separately determine the joint effects of diurnal preference and shift work on the prevalence of COVID-19 infection, analysis was limited only to participants who were full-time, part-time, or self-employed. Models sequentially included demographic factors, comorbidities and vaccination status, socioeconomic factors, and sleep duration as well as 2-way interactions between diurnal preference and shift work categories. In addition, we performed sensitivity analyses with stricter (i.e., using COVID-19 infection as a positive test only) and broader (i.e., our original definition plus presumed positive, but not tested as an indicator of a past COVID-19 infection) definitions.

All analyses were conducted using IBM SPSS version 28 (Armonk, NY). A $p<0.05$ was considered statistically significant.

Results

Table 1 shows the bivariate associations between COVID-19 infection status, diurnal preference, and co-morbid medical, demographic, and social characteristics of the cohort. Of the 19821 participants, 7932 (40.0%) had at least one COVID-19 infection. Morning and evening diurnal preferences were observed in 31.9% and 19.4% of participants respectively. Among COVID-19 positive in comparison to COVID-19 negative participants, there was a higher percentage of morning types (32.6 vs 31.4%) and a lower percentage of evening types (17.2 vs. 20.9%, $p \leq 0.001$). Participants who were retired or unemployed were less likely to have had a COVID-19 infection (12.5 vs. 30.8%, $p \leq 0.001$). COVID-19 positive in comparison to COVID-19 negative participants were younger (40.2 ± 15.8 vs. 50.4 ± 18.0 y, $p \leq 0.001$), had a slightly shorter self-reported sleep duration (6.8 ± 1.6 vs. 6.9 ± 1.7 h, $p \leq 0.001$), had a slightly larger percent of time working remotely (36 ± 34 vs. 32 ± 38%, $p \leq 0.001$), were slightly more overweight (BMI: 28.7 vs. 28.3 kg/m^2, $p<0.001$) had more comorbidities (1.7 ± 2.4 vs. 0.8 ± 1.2, $p \leq 0.001$), and were less

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likely to have received a COVID-19 booster vaccination (27.6 vs. 46.4%, p≤0.001). COVID-19 positive participants also were more likely to be Hispanic, not retired and have an income more than $50,000 per year.

Table 2 displays the logistic regression models for the association between having had a COVID-19 infection and either a morning or evening diurnal preference in comparison to a reference group without a definite preference. In models including demographics, comorbidities, vaccination status, and socioeconomic factors, morning preference was related to a 20% greater likelihood of COVID-19 infection. In contrast, evening preference was 20% less likely to be linked to a COVID-19 infection. These associations were not materially affected by the type of work shift, percent time working remotely or after adjustment for sleep duration.

In Table 3 are the bivariate associations between COVID-19 infection and diurnal preference, and co-morbid medical, demographic, and social characteristics of the cohort limited only to members who were employed. In comparison to the entire cohort, participants were slightly younger, more likely to be male, and had a higher income. Participants who worked a mixture of shift types had a higher prevalence rate of infection in comparison to those who worked only day shifts or only night shifts (p<0.001).

Table 4 shows the fully adjusted logistic regression model which adjusted for percent remote work and sleep duration documenting the association between COVID-19 infection and diurnal preference, work shift category and the interactions between diurnal preference and work shift category. In comparison to neither definite morning nor evening preference, there was a 18% greater likelihood of infection in those with morning preference and a 16% lower likelihood in those with an evening preference. Both were comparable to the aORs observed for the overall cohort. In comparison to working only a day shift, a greater risk of COVID-19 infection was observed in those working a

mixture of day and evening shifts (aOR: 1.25, 95% CI: 1.10-1.41); working a mixture of day, evening, and night shifts approached significance (aOR: 1.18, 95% CI: 0.97-1.44). Working only night shifts was not associated with a higher prevalence of COVID-19 infection. The overall interaction between diurnal preference and work shift category was significant (Wald χ^2=13.864, p=0.031). Individual interaction terms indicated that there was a higher likelihood of infection in participants who had a morning preference and working a combination of day and evening shifts (aOR: 1.87, 95% CI: 1.28-2.74); the association with those with a morning preference and working a mixture of day, evening, and night shifts approached significance (aOR: 1.72, 95% CI:0.98-3.02).

Sensitivity analyses indicated that our findings were similar using slightly stricter or more liberal definitions of COVID-19. However, a definition that required a positive test only lost statistical significance.

Discussion

In this study, morning and evening chronotypes were found to be differentially associated with COVID-19 infection; morning types were more likely and evening types were significantly less likely to be infected. Additionally, in comparison to working only day shifts, working a combination of different shift types, as opposed to day shifts only was associated with a higher prevalence of COVID-19 infection. This finding of higher infection rate was primarily observed in individuals with a morning chronotype who worked a combination of different shifts.

Morning chronotypes were more susceptible to COVID-19 infection than evening chronotypes; this finding is consistent with earlier preliminary results from the same cohort.[7] This observation stands in contrast to a large body of evidence demonstrating that the prevalence of cardiovascular disease risk factors and metabolic disorders is higher in evening chronotypes.[11,12] Furthermore, our results are distinct from the limited

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studies that also have assessed the association between chronotype and COVID-19. In a single center study, social jet lag as a marker of evening chronotype was found to be associated with a higher rate of COVID-19.[13] In contrast, no association between chronotype and COVID-19 infection was observed in two separate analyses of the UK Biobank[14,26] as well as in an analysis of long COVID from the Nurses' Health Study.[32] Additionally, to our knowledge, there have been no previous studies of an association between chronotype and infection risk from other pathogens.

Despite the paucity of clinical investigations related to chronotype and infection risk, there are mechanisms that could explain our finding of an association between morning chronotype and COVID-19 infection. A reduction in sleep duration has been linked to increased susceptibility to infection.[19] However, our observation remained robust after controlling for sleep duration in our modelling. Alternatively, various components of the immune system exhibit circadian rhythmicity.[33] Secretion of inflammatory cytokines, trafficking myeloid and lymphocyte subsets and maturation of leukocytes exhibit a circadian rhythm with the aggregate response favoring a proinflammatory response while asleep.[33] Some,[34,35] but not all[36,37] have found that time of day influences the antibody response to COVID-19 vaccination. Therefore, it is possible that immunity to COVID-19 is less robust in morning chronotypes resulting in greater susceptibility to infection.

In this study, the association between working night shift and COVID-19 infection was the same as working day shift. However, working a mixture of shifts, particularly ones that included evening shifts was associated with a higher likelihood of COVID-19 infection. These findings stand in contrast to some previous observations that have noted a positive association between rotating and consistent/permanent night shift work and COVID-19 infection.[24,25,27] However, not all studies have found a significant relationship among those who only worked consistent/permanent night shift.[23,26] Working night shifts

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and early morning shifts are associated with circadian misalignment as well as shorter sleep duration. Both may increase the propensity for COVID-19 infection as well as other respiratory contagions. However, night shift workers tend to have less interpersonal contact than day shift workers.[38] This may mitigate the adverse impact of circadian misalignment on increased risk of COVID-19 infection. Our results suggest that the impact of circadian misalignment and sleep loss, and consequent predisposition towards being infected with COVID-19 is greater among persons who irregularly perform shift work rather than in those who work permanent/consistent day or night shifts.

We observed a significant interaction between chronotype and shift work in which morning diurnal preference together with working a mixture of shifts was associated with the highest aOR of having had a COVID-19 infection. This implies that irregularity in sleep schedule was a major factor in susceptibility to COVID-19 infection in those with morning diurnal preference. Irregularity in sleep-wake patterns has been associated with higher levels of cardiovascular disease biomarkers[39] as well as a greater risk of cardiovascular disease.[40] Using UK Biobank data, sleep irregularity also has been demonstrated to increase risk of COVID-19 infection and its severity.[41] Potential explanatory mechanisms include the impact of sleep irregularity on reducing sleep duration as well as consequences of higher levels of circadian misalignment. Both of these factors can contribute to greater amounts of both acute and chronic inflammation resulting in higher risk of COVID-19 infection.

Our study should be interpreted in the context of several limitations. First, all of the data were self-reported including ascertainment of both diurnal preference (using a single self-report item) and COVID-19 infection. However, sensitivity analyses using different definitions of COVID-19 infection were qualitatively similar to the findings reported herein. In addition, broadly similar to a previous report, we found that morning chronotypes were more prevalent than evening chronotypes, suggesting that our

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ascertainment of chronotype was acceptable.[42] Second, our analyses were cross-sectional and causal inference cannot be assumed. Third, although we attempted to adjust for a number of factors known to increase risk of COVID-19 infection, residual confounding is possible.

In conclusion, morning diurnal preference is associated with an increase and evening diurnal preference is associated with a decrease in COVID-19 infection. Neither working day nor night shifts were linked to an increase in prevalence of COVID-19 infection. However, COVID-19 infection was more likely in those working a mixture of shifts, with the greatest risk conferred on those with a morning chronotype. These findings may be informative for developing measures for greater COVID-19 surveillance of shift workers with a morning chronotype, particularly as first responders in healthcare and other settings are often engaged in shift work.

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Table 1: Associations Between COVID-19 Infection Status, Diurnal Preference, Shift Work, and Co-morbid Medical, Demographic and Social Characteristics

		COVID-19 Negative (N=11889)		COVID-19 Positive (N=7932)		Overall (N=19821)	
	N	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age (y) [*]	19812	50.4	18.0	40.2	15.8	46.3	17.9
Body Mass Index (kg/m^2) [*]	19578	28.3	7.8	28.7	10.3	28.5	8.9
No. Comorbidities [*]	19821	0.8	1.2	1.7	2.4	1.2	1.9
Remote Work (%)[*]	11057	32	38	36	34	34	36
Sleep Duration Self-Report (h)[*†]	14409	6.9	1.6	6.6	1.8	6.8	1.7
		N	*%*	*N*	*%*	*N*	*%*
Sex	19665						
Male		5752	48.6	3871	49.4	9681	48.9
Female		6080	51.4	3962	50.6	10042	51.0
Race/Ethnicity [*]	19821						
White		7832	65.9	4691	59.1	12523	63.2
Black		1248	10.5	841	10.6	2089	10.5
Hispanic		1493	12.6	1720	21.7	3213	16.2
Other		1316	11.1	680	8..6	1996	10.1
Employment [*]	19821						
Retired		3659	30.8	988	12.5	4647	23.4
Not Retired		8230	69.2	6944	87.5	15174	76.6
Education	19821						
High School or Less		3187	26.8	2137	26.9	5324	26.9
Some College		8702	73.2	5795	73.1	14497	73.1
Income (Yearly) [*]	18990						
< $50,000		5421	48.0	3219	41.9	8640	45.5
≥ $50,000		5882	52.0	4468	58.1	10350	54.5
Diurnal Preference [*]	19821						
Definitely Morning Type		3739	31.4	2588	32.6	6327	31.9
Definitely Evening Type		2481	20.9	1367	17.2	3848	19.4
Not Definitely Morning or Evening Type		5669	47.7	3977	50.1	9646	48.7
Work Shift Category [*]							
Retired/Not Working	19818	6210	52.2	2550	32.2	8760	44.2
Day Shift Only		4170	35.1	3430	43.3	7600	38.3
Day and/or Some Evening Shifts		976	8.2	1334	16.8	2310	11.7
Day/Evening and Some Night Shifts		290	2.4	393	5.0	683	3.4
Night Shifts Only		242	2.0	223	2.8	465	2.3

Vaccination #[*]	19926						
0		2659	22.3	1795	22.5	4454	22.4
1		692	5.8	1272	15.9	1964	9.9
2		3047	25.5	2712	34.0	5759	28.9
3		4385	36.7	1855	23.2	6240	31.3
4		1162	9.7	347	4.3	1509	7.6
Vaccination Boosted[*]	19926						
No (≤2 Vaccinations)		6398	53.6	5779	72.4	12177	61.1
Yes (>2 Vaccinations)		5547	46.4	2202	27.6	7749	38.9

[*]p≤0.001, significant differences in means or proportions
[†]participants with self-reported sleep duration <3 or >12 hours were excluded as improbable

Table 2: Odds Ratio (adjusted) for Reporting One or More COVID-19 Infections Based on Circadian Preference (N=19821)

Model	Morningness		Eveningness	
	aOR	95% CI	aOR	95% CI
Baseline	1.07	1.03-1.12[*]	0.86	0.81-0.90[*]
+Demographics[†]	1.21	1.15-1.26[*]	0.76	0.73-0.81[*]
+Comorbidities and Vaccination Status[‡]	1.23	1.16-1.31[*]	0.77	0.72-0.83[*]
+Socioeconomic[§]	1.20	1.13-1.28[*]	0.80	0.74-0.86[*]
+Shift Work	1.21	1.14-1.29[*]	0.79	0.73-0.85[*]
+Self-Reported Sleep Duration and % Remote Work	1.23	1.15-1.31[*]	0.78	0.73-0.85[*]

The baseline model includes only definitely morning or definitely evening preference. Subsequent models are additive to their immediate predecessor and are adjusted as indicated below (see text for covariate definitions) with the fully adjusted model reflecting demographic, comorbid disease, socioeconomic characteristics, and the occurrence of shift work.
[†]age, sex, race
[‡]BMI, vaccination status (boosted vs. not boosted), # of the following conditions: diabetes, asthma, sickle cell disease, cardiovascular disease, hypertension, cancer, chronic kidney disease, liver disease, chronic obstructive pulmonary disease
[§]education, income, employment

[*]$p<0.001$

Table 3: Associations Between COVID-19 Infection Status, Diurnal Preference, Shift Work, and Co-morbid Medical, Demographic and Social Characteristics in Employed Participants

		COVID-19 Negative (N=5678)		COVID-19 Positive (N=5379)		Overall (N=11114)	
	N	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age (y) [*]	11028	43.7	14.9	37.3	12.6	40.6	14.2
Body Mass Index (kg/m^2) [†]	10826	27.8	7.8	28.2	10.9	28.0	9.4
No. Comorbidities [*]	11036	0.6	1.3	1.9	2.6	1.3	2.2
Remote Work (%)	11036	32	38	36	34	34	36
Sleep Duration Self-Report (h) [*‡]	10375	6.8	1.5	6.6	1.8	6.7	1.7
		N	*%*	*N*	*%*	*N*	*%*
Sex [*]	10950						
Male		2829	50.1	2932	55.3	5761	52.6
Female		2820	49.9	2369	44.7	5189	47.4
Race/Ethnicity [*]	11036						
White		3476	61.2	3082	57.5	6555	59.4
Black		663	11.7	579	10.8	1247	11.3
Hispanic		849	15.0	1256	23.4	2105	19.1
Other		687	12.1	447	8.3	1134	10.3
Education	11036						
High School or Less		1254	22.1	1177	21.9	2431	22.0
Some College		4418	77.9	4187	78.1	8605	78.0
Income (Yearly) [*]	10751						
< $50,000		2226	40.5	1729	32.9	3955	36.8
≥ $50,000		3264	59.5	3532	67.1	6796	63.2
Diurnal Preference [*]	11036						
Definitely Morning Type		1856	32.7	1960	36.5	3816	34.6
Definitely Evening Type		1156	20.4	780	14.5	1936	17.5
Not Definitely Morning or Evening Type		2660	46.9	2624	48.9	5284	47.9
Work Shift Category [*]	11036						
Day Shift Only		4168	73.5	3421	63.8	7589	68.8
Day and/or Some Evening Shifts		974	17.2	1330	24.8	2304	20.9
Day/Evening and Some Night Shifts		288	5.1	392	7.3	680	6.2
Night Shifts Only		242	4.3	221	4.1	463	4.2

[*] $p<0.001$

[†] $p<0.05$

[‡] Participants with self-reported sleep duration <3 or >12 hours were excluded as improbable

Vaccination #[*]	11036							
0		1317	55.8	1045	44.2	2362	21.4
1		417	29.6	990	70.4	1407	12.7
2		1663	45.8	1968	54.2	3631	32.9
3		1961	61.4	1231	38.6	3192	28.9
4		314	70.7	130	29.3	444	4.0
Vaccination Boosted[*]	11036						
No (≤2 Vaccinations)		3397	45.9	4003	54.1	7400	67.1
Yes (>2 Vaccinations)		2275	62.6	1361	37.4	3636	32.9

[†]$p<0.05$, [*]$p\leq0.001$, significant differences in means or proportions

Table 4: Odds Ratio (adjusted) in Fully Adjusted Model[*] with Interactions for Reporting One or More COVID-19 Infections Based on Circadian Preference and Shift Work (N=9877)

	aOR	95%CI
Diurnal Preference		
Neither Morning nor Evening Preference	Referent	
Definite Morning Preference	1.18	1.09-1.27
Definite Evening Preference	0.84	0.76-0.92
Work Shift Category		
Day Shift Only	Referent	
Day and/or Some Evening Shifts	1.25	1.10-1.41
Day/Evening and Some Night Shifts	1.18	0.97-1.44
Night Shifts Only	0.95	0.75-1.20
Diurnal Preference x Work Shift Interactions		
Neither Morning nor Evening Preference x Day Shift Only	Referent	
Morning Preference x Day and/or Some Evening Shifts	1.87	1.28-2.74
Morning Preference x Day/Evening and Some Night Shifts	1.72	0.98-3.02
Morning Preference x Night Shifts Only	0.93	0.47-1.84
Evening Preference x Day and/or Some Evening Shifts	0.89	0.59-1.33
Evening Preference x Day/Evening and Some Night Shifts	0.68	0.39-1.24
Evening Preference x Night Shifts Only	0.79	0.41-1.52

[*]Fully adjusted model includes age, sex, race, BMI, vaccination status (boosted vs. not boosted), # of the following conditions: diabetes, asthma, sickle cell disease, cardiovascular disease, hypertension, cancer, chronic kidney disease, liver disease, chronic obstructive pulmonary disease, education, income, employment, sleep duration, percent time working remotely