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ABSTRACT

Background: Public health measures in response to the COVID-19 pandemic forced individuals to spend more time at home. We sought to investigate the relationship between housing characteristics and sleep duration in the context of COVID-19.
Methods: Our exploratory study was part of the *COvid-19: Health and Social Inequities across Neighborhoods* (COHESION) Study Phase-1, a pan-Canadian population-based cohort involving nearly 1300 participants, launched in May 2020. Sociodemographic, household and housing characteristics (dwelling type, dissatisfaction, access to outdoor space, family composition, etc.), and self-reported sleep were prospectively collected through COHESION Study follow-ups. We explored the associations between housing and household characteristics and sleep duration using linear regressions, as well as testing for effect modification by income satisfaction and gender.
Results: Our study sample involved 624 COHESION Study participants aged 50 ± 16 years (mean ± SD), mainly women (78%), White (86%), and university graduates (64%). The average sleep duration was 7.8 (1.4) hours. Sleep duration was shorter according to the number of children in the household, income dissatisfaction, and type of dwelling in multivariable models. Sleep was short in those without access to a private outdoor space, or only having a balcony/terrace. In stratified analyses, sleep duration was associated with housing conditions dissatisfaction only in those dissatisfied with their income.
Conclusion: Our exploratory study highlights the relationship between housing quality and access to outdoor space, family composition and sleep duration in the context of COVID-19. Our findings also highlight the importance of housing characteristics as sources of observed differences in sleep duration.

Introduction

Since the beginning of the pandemic, numerous studies have reported adverse changes in sleep patterns, particularly among healthcare workers, younger adults, and those with chronic conditions.[1-3] Conversely, many studies also highlighted that some groups regarding age or sociodemographics slept more.[4,5] Many of these changes were hypothesized to be directly related to the COVID-19 disease (e.g., being sick or a family member being sick) or indirectly because of lockdowns, business or school closures, with people spending, therefore, more time at home.[1,6-10] Indeed, mandated stay-at-home orders and temporary closure of nonessential businesses and organizations left many individuals without employment and forced others to work from home, shifting socially imposed daily routines and sleep schedules.[11]

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The very existence of the pandemic, which killed many from its outbreak, but also government-imposed stay-at-home orders, telework, tele-school, and enforced social distancing likely impacted our sleep, not only through increased stress but also by affecting social and environmental cues that our internal clock relies typically on to regulate our sleep.

An early meta-analysis estimated an overall prevalence of poor sleep above 30% during the early days of COVID-19. This study included forty-four papers, involving a total of 54,231 participants from 13 countries.[1] A follow-up meta-analysis, from the same group, included two hundred and fifty studies comprising 493,475 participants from 49 countries, and found a slightly higher prevalence of sleep disturbances.[12] These two estimates should be taken with caution given the high heterogeneity observed in the pooled estimates.[1,12] An important observation from early studies on COVID-19 and sleep health was a potential differential impact across age and gender groups and socioeconomic factors. Thus, some groups have a much higher detrimental effect (e.g., healthcare workers, older adults) while others may even have improved their sleep with telecommuting and tele-schooling.[6,13,14] Although social determinants are known as strong predictors of sleep health,[15] it is important to better understand the contextual factors that may contribute to degradation of sleep health in order to identify and develop policies targeting health equity.

Given that sleep is heavily influenced by a complex interplay of behavioral, social, and environmental factors, and knowing that people have started spending more time at home, there is an opportunity to explore how housing dissatisfaction may play a role. Various pre-COVID-19 studies have already shown neighborhood and housing features associated with sleep duration and quality.[15] Living in a neighborhood perceived as unsafe is associated with a higher prevalence of self-reported and objectively measured short sleep duration.[16] Noise complaints and living in a noisy dwelling are associated with increased insomnia symptoms.[17] Living in greener neighborhoods has been associated with better sleep quality and fewer insomnia symptoms.[18] At a house level, housing characteristics such as baseline floor dampness, visible mold, mold odor at home and building quality has been associated with poor higher risk of insomnia and excessive daytime sleepiness.[19] Lastly, social factors such as feeling safe at home, social cohesion have also been associated with different sleep dimensions, such as sleep duration and quality.[20–23]

In the context of COVID-19, limited social interactions and restrictions on schooling and work activities may have amplified the role of the household and home environment on sleep duration. Understanding which household and housing characteristics are associated with sleep not only serves to understand possible sleep disparities but also helps identify potential intervention targets. In our study, we sought to explore the relationship between household and housing characteristics and sleep duration in the context of COVID-19, using data from a Canadian cohort collected in 2020 and 2021.

Methods

Study population and ethics

The present exploratory study was conducted in the *COvid-19: Health and Social Inequities across Neighborhoods* (COHESION) Study Phase 1, which consists of a pan-Canadian population-based prospective cohort including 1268 individuals recruited between May 2020 and September 2021.[24] Recruitment (by self-enrollment on our website) was supported by media communication (e.g., newspaper articles, radio interviews), social media promotion (e.g., Facebook, Twitter), and outreach through partners' local networks over the whole Canadian territory. Briefly, the COHESION Study Phase 1 included baseline and monthly auto-administered online questionnaires to document mental health and well-being, including key determinants of health and health inequities (e.g., activity locations, social interactions, etc.).[24]

While baseline questionnaires collected a broad range of sociodemographic information and housing characteristics, the sleep questionnaire was not included in the baseline. Data collection on sleep started during the follow-up period. The data presented in this study includes all participants who completed at least once the questionnaire on sleep administered as part of the COHESION Study Phase 1 follow-up. The institutional review board of the Centre Hospitalier de l'Université de Montréal approved this study (MP-02-2021-8924), and all participants provided electronically written informed consent before participating in the study.

Data collection

As previously described in the foundation paper,[24] at recruitment, all participants completed a comprehensive baseline questionnaire that included sociodemographic information, including age, gender, ethnicity, education level, relationship, children, employment, annual income, household composition, pet ownership, and income satisfaction (i.e., regarding their income-to-needs ratio). Housing characteristics, documented at baseline and each time that a residential move was reported, included house ownership, type (house; apartment or condo; other [mobile home or basement]), size, access to a private outdoor space (yard or nature; balcony or terrace; no access), and dissatisfaction regarding indoor space, number of bedrooms, affordability, condition, noise, and safety. Characterization of the place of residence, based on the six-digit postal code, included the urbanization degree,[25] an NDVI-based greenness measure[26] and dissemination-area level material and social deprivation score.[27] Additionally, throughout the follow-up, we regularly documented participants' psychological distress symptoms using the standardized Psychological Distress Scale (Kessler-6).[28]

Sleep duration and quality were assessed during the follow-up period only. The follow-up period started immediately after each participant's baseline questionnaire completion and continued until September 2021. If a participant completed the sleep questionnaire several times during the follow-up, we included the first entry in this study. We assessed sleep duration through the follow-up (not at baseline) using the first three items of the standardized Pittsburgh Sleep Quality Index (PSQI) questionnaire,[29] which asked for the past month: "What time have you usually gone to bed at night?," "How long has it usually taken you to fall asleep each night?" and "What time have you usually gotten up in the morning?" Sleep duration was computed as the time spent in bed minus the average sleep latency. Sleep quality was assessed using the ninth item of the PSQI questionnaire: "During the past month, how would you rate your sleep quality overall: very good, fairly good, fairly bad, or very bad?." If a participant completed the sleep questionnaire through the follow-up several times, we included the first entry in this study.

Statistical analysis

We calculated the time between the completion dates of the baseline questionnaire and the first completed sleep questionnaire. Answers to Kessler-6 questionnaire items were summed and categorized as "low" (0-5), "moderate" (6-12), and "severe" (13-24) psychological distress symptoms, as recommended.[28]

To study housing determinants of sleep, we conducted a cross-sectional analysis based on baseline information and the first filled-out sleep questionnaire over the prospective follow-up. ANOVAs (and Welch's alternative ANOVAs for unequal variances) were applied to compare sleep duration (continuous variable) means between potential risk factor groups (detailed in Table 1 and Table S1).

Table 1
Characteristics of COHESION Study Phase 1 participants included in the present sleep study, and differences in their sleep duration (N = 624)

Characteristics	N	Percent	Sleep duration (in hours; mean ± SD)	p-value[a]	Effect size[b] (Cohen's d)
Demographics					
Age class				.85	
15-24	42	6.7%	7.90 ± 1.56		Ref
25-34	88	14.1%	7.76 ± 1.16		Negligible (0.10)
35-44	112	17.9%	7.85 ± 1.46		Negligible (0.03)
45-54	99	15.9%	7.66 ± 1.51		Negligible (0.16)
55-64	152	24.4%	7.77 ± 1.17		Negligible (0.09)
≥65	131	21.0%	7.87 ± 1.38		Negligible (0.02)
Gender				.18	
Man	117	18.8%	7.81 ± 1.36		Negligible (0.11)
Woman	488	78.2%	7.67 ± 1.23		Ref
Other identity	19	3.0%	8.28 ± 1.77		Small (0.40)
Ethnicity				.41	
White	539	86.4%	7.81 ± 1.34		Ref
Mixed	43	6.9%	7.85 ± 1.31		Negligible (0.03)
Other	42	6.7%	7.53 ± 1.48		Small (0.20)
Education level				.45	
University grade	397	63.6%	7.84 ± 1.24		Ref
Lower grade	221	35.4%	7.74 ± 1.54		Negligible (0.07)
Unknown/Not answered	6	1.0%	7.25 ± 1.25		Small (0.47)
Employment				.26	
Employed, full-time	239	38.3%	7.66 ± 1.19		Ref
Employed, part-time	68	10.9%	7.77 ± 1.28		Negligible (0.09)
Self-employed	17	2.7%	8.07 ± 1.52		Small (0.25)
Student	13	2.1%	7.38 ± 1.34		Small (0.24)
Unemployed	77	12.3%	7.81 ± 1.77		Small (0.30)
Retired/On leave/Disabled	197	31.6%	7.96 ± 1.30		Small (0.22)
Other	13	2.1%	8.07 ± 2.00		Negligible (0.10)
Annual income				.28	
< $21,000	72	11.5%	7.97 ± 1.82		Negligible (0.12)
$21,000-$36,000	83	13.3%	7.82 ± 1.45		Negligible (0.02)
$36,000-$48,000	78	12.5%	7.44 ± 1.44		Small (0.26)
$48,000-$96,000	158	25.3%	7.79 ± 1.50		Ref
≥$96,000	137	22.0%	7.81 ± 1.07		Negligible (0.02)
Unknown/Not answered	96	15.4%	7.94 ± 1.35		Negligible (0.12)
Income satisfaction[c]				.080	
Very well	250	40.1%	7.88 ± 1.15		Ref
Well	248	39.7%	7.83 ± 1.24		Negligible (0.04)
Not well	117	18.8%	7.48 ± 1.81		Small (0.26)
Unknown/Not answered	9	1.4%	8.81 ± 1.79		Moderate (0.62)
Relationship				.81	
Single	128	20.5%	7.85 ± 1.59		Negligible (0.03)
In a relationship/Married	427	68.4%	7.80 ± 1.22		Ref
Separated/Divorced/Widowed	68	10.9%	7.69 ± 1.62		Negligible (0.07)
Other	1	0.2%	8.40		–
Children				.032	
0	365	58.5%	7.89 ± 1.37		Ref
1-2	218	34.9%	7.72 ± 1.28		Negligible (0.13)
≥3	41	6.6%	7.36 ± 1.42		Small (0.38)
Housing					
Dwelling type				.061	
House	403	64.6%	7.86 ± 1.28		Ref
Apartment/Condo	216	34.6%	7.70 ± 1.46		Negligible (0.12)
Other (mobile home or basement)	5	0.8%	6.66 ± 1.58		Large (0.84)
Private outside space				.076	
Yard or nature	468	76.7%	7.87 ± 1.26		Ref
Balcony or terrace	118	19.3%	7.56 ± 1.43		Small (0.23)
No	24	3.9%	7.36 ± 2.25		Small (0.28)
Housing dissatisfaction - Indoor space				.17	
Yes	62	9.9%	7.51 ± 1.74		Small (0.21)
No	562	90.1%	7.83 ± 1.30		Ref
Housing dissatisfaction - Number of bedrooms				.12	
Yes	36	5.8%	7.46 ± 1.62		Small (0.24)
No	588	94.2%	7.82 ± 1.33		Ref
Housing dissatisfaction - Affordability				.074	
Yes	47	7.5%	7.36 ± 1.75		Small (0.31)
No	577	92.5%	7.83 ± 1.31		Ref
Housing dissatisfaction - Conditions				.10	
Yes	68	10.9%	7.48 ± 1.73		Small (0.24)
No	556	89.1%	7.84 ± 1.29		Ref
Housing dissatisfaction - Noise				.99	
Yes	109	17.5%	7.80 ± 1.55		Negligible (0.00)
No	515	82.5%	7.80 ± 1.31		Ref

(*continued on next page*)

Table 1 (*continued*)

Characteristics	N	Percent	Sleep duration (in hours; mean ± SD)	*p*-value[a]	Effect size[b] (Cohen's *d*)
Housing dissatisfaction - Safety				.99	
Yes	13	2.1%	7.79 ± 2.03		Negligible (0.00)
No	611	97.9%	7.80 ± 1.34		Ref
Mental health/Sleep quality					
Kessler-6 Psychological Distress Scale				.59	
No	211	57.8%	7.84 ± 1.18		Ref
Moderate	106	29.0%	7.77 ± 1.36		Negligible (0.06)
Severe	48	13.2%	7.56 ± 1.87		Negligible (0.18)
Sleep quality				< .001	
Very good	75	12.0%	8.16 ± 1.00		Ref
Fairly good	360	57.7%	7.91 ± 1.23		Small (0.22)
Fairly bad	159	25.5%	7.56 ± 1.44		Small (0.48)
Very bad	30	4.8%	6.73 ± 2.13		Large (0.86)

[a] ANOVA (and Welch's alternative ANOVA for unequal variances).
[b] Effect size may be negligible, small, moderate, or large for a Cohen's *d* within 0-0.2, 0.2-0.5, 0.5-0.8, and ≥0.8, respectively.
[c] That is, satisfaction regarding their income-to-needs ratio.

We furthermore calculated Cohen's *d* for each factor to better appreciate the related effect size; the latter may be negligible, small, moderate, or large for a Cohen's *d* within 0-0.2, 0.2-0.5, 0.5-0.8, and >0.8, respectively. The selection of the variables included in our multivariable linear model was informed by a combination of exploratory analyses and based on known variables traditionally associated with sleep health outcomes. In addition to the determinants of interest, our initial model adjusted for age, gender, and the sleep questionnaire wave used (in total, the sleep questionnaire was administered nine times throughout the COHESION Study Phase 1 follow-up). Our second model adjusted for mental health symptoms, including people who answered both sleep and mental health questionnaires concomitantly. The following sensitivity analyses were performed: (i) adjusting the final model with sleep quality, (ii) excluding participants who filled out the sleep questionnaire more than 3 months after completing the baseline questionnaire, and (iii) adjusting for multiple comparison. Lastly, we explored the potential modifying effects of gender, income level, income satisfaction, and number of children.

All statistical analyses were performed using R software version 4.0.4 (R Foundation for Statistical Computing, Vienna, Austria).

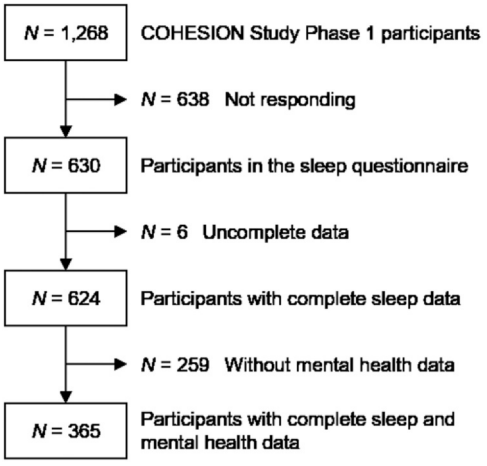

Fig. 1. Flow chart of the sleep study participants

Results

Study population characteristics

The present study included 624 people who filled out at least one sleep questionnaire and provided exploitable sleep data (6 participants with incomplete sleep data were excluded) (Fig. 1). Their mean age was 50.2 ± 15.9 years (mean ± SD), about four-fifths were women (78%), they were mainly White (86%), and nearly two-thirds were university graduates (64%; Table 1). Compared to COHESION Phase 1 participants not included in this study (*N* = 644), those included were older, less employed and more frequently retired, on leave, or disabled, and better satisfied regarding income (Table S1). The median time between baseline and sleep questionnaire completion dates was 46 days (Q1-Q3, 26-80). Sleep duration ranged from 2.5 to 12.2 hours (median = 7.9, IQR = 1.7) and was in average 7.8 hours (SD = 1.4). The average Kessler-6 score for the 365 participants who completed the mental health questionnaire was 5.9 (SD = 5.5).

Sleep duration determinants

Table 1 and Table S2 show the characteristics of COHESION Study Phase 1 participants included in the present sleep study, and their associations with sleep duration in univariate analyses. Several demographics-related (gender, income satisfaction, and number of children), housing-related (dwelling type, private outside space, and housing dissatisfaction regarding indoor space, number of bedrooms, affordability, and condition), and neighborhood-related (surrounding greenness) factors appeared associated with sleep duration ($p < .25$) and were tested in multivariable analyses. However, based on Cohen's *d* values, these associations had for the most part a small nominal effect size.

The sleep questionnaire wave and age were not associated with sleep duration but were kept in the final multivariable model as adjusting factors. Sleep duration was also strongly related to sleep quality ($p < .001$, see Table 1) but not to psychological distress.

Table 2 shows associations reported with sleep duration in multivariable analyses. Participants dissatisfied regarding income tended to sleep 15 minutes less (− 0.25 hour, 95% CI, − 0.57, 0.08; $p = .13$) than satisfied participants. A gradient of decrease in sleep duration regarding the number of children [− 15 minute (− 0.25 hour, 95% CI, − 0.50, − 0.01; $p = .044$) and − 40 minute (− 0.67 hour, 95% CI, − 1.13, − 0.21; $p = .004$) for 1-2 and 3+ children, respectively, in comparison to no children] was also observed. Concerning housing characteristics, participants living in an "other" type of dwelling (i.e., mobile home or basement) slept 75 minutes less (− 1.25 hour, 95% CI, − 2.48, − 0.03; $p = .046$) than ones living in a house, although the group in this category was very small. Compared to participants with access to a private yard or nature, those having access to a balcony/terrace only or no access to a private outside space reported shorter sleep duration [− 25 minute

Table 2
Multivariable analysis of factors associated with sleep duration in COHESION Study Phase 1 participants included in the present sleep study ($N = 601$)

Factors	β	(95% CI)	p-value	
			Nominal	Adjusted[b]
Income satisfaction[a]				
Very satisfied	Ref			
Satisfied	0.07	(− 0.17, 0.32)	.56	.62
Dissatisfied	− 0.25	(− 0.57, 0.08)	.13	.23
Children				
0	Ref			
1-2	− 0.25	(− 0.50, − 0.01)	.044	.12
≥3	− 0.67	(− 1.13, − 0.21)	.004	.040
Dwelling type				
House	Ref			
Apartment/Condo	− 0.02	(− 0.31, 0.26)	.88	.88
Other (mobile home or basement)	− 1.25	(− 2.48, − 0.03)	.046	.12
Private outside space				
Yard or nature	Ref			
Balcony or terrace	− 0.42	(− 0.76, − 0.09)	.014	.070
No	− 0.44	(− 1.03, 0.14)	.14	.23
Housing dissatisfaction - Affordability				
No	Ref			
Yes	− 0.23	(− 0.66, 0.21)	.31	.39
Housing dissatisfaction - Condition				
No	Ref			
Yes	− 0.25	(− 0.61, 0.12)	.19	.27

Model adjusted for age, gender, the used sleep questionnaire wave, and all variables listed in this table.
[a] That is, satisfaction regarding their income-to-needs ratio.
[b] Applying Benjamini-Hochberg procedure (False Discovery Rate).

(− 0.42 hour, 95% CI, − 0.76, − 0.09; $p = .014$) and − 26 minute (− 0.44 hour, 95% CI, − 1.03, 0.14; $p = .14$), respectively]. Adjusting for Kessler-6 score weakened the association with dwelling type [$\beta = -1.25$ hour (95% CI, − 2.48, − 0.03) and − 0.59 hour (95% CI, − 2.08, 0.90; $p = .43$) before and after adjustment, respectively] (Table S3). Table 2 also shows that most associations were no longer statistically significant after adjusting for multiple comparisons. Further, all associations were diminished slightly to the null when including sleep quality in the final multivariable model (Table S4) and excluding participants with a long time of answer (Table S5).

In stratified analyses (Table 3) the relationship between housing conditions and sleep duration was more pronounced in participants that reported not being satisfied with their income (see Fig. 2): among those dissatisfied with their housing conditions, sleep was 1.13 hours shorter (95% CI, − 2.08, − 0.17) in participants dissatisfied with their income whereas there was differences in sleep duration in regard to housing conditions in those satisfied with their income [+ 0.14 hour (95% CI, − 0.27, 0.54), p-interaction = .002]. Stratified analyses according to gender showed sensibly stronger associations of the number of children and the access to a private outside space

Table 3
Multivariable analysis of factors associated with sleep duration in COHESION Study Phase 1 participants included in the present sleep study, stratifying on income satisfaction[a] ($N = 601$)

	Income satisfaction								
	Satisfied (N = 486)[b]				Dissatisfied (N = 115)				
Factors	N (%)	β	(95% CI)	p-value	N (%)	β	(95% CI)	p-value	p-interaction[c]
Children									.36
0	274 (56.4%)	Ref			75 (65.2%)	Ref			
1-2	179 (36.8%)	− 0.26	(− 0.51, − 0.02)	.034	34 (29.6%)	− 0.14	(− 1.04, 0.75)	.76	
≥3	33 (6.8%)	− 0.56	(− 1.01, − 0.11)	.016	6 (5.2%)	− 1.06	(− 2.77, 0.65)	.23	
Dwelling type									.073
House	328 (67.5%)	Ref			59 (51.3%)	Ref			
Apartment/Condo	156 (32.1%)	− 0.05	(− 0.34, 0.23)	.71	53 (46.1%)	0.15	(− 0.89, 1.19)	.78	
Other (mobile home or basement)	2 (0.4%)	− 0.12	(− 1.79, 1.54)	.88	3 (2.6%)	− 3.08	(− 5.85, − 0.32)	.032	
Private outside space									.60
Yard or nature	390 (80.2%)	Ref			71 (61.7%)	Ref			
Balcony or terrace	85 (17.5%)	− 0.47	(− 0.82, − 0.13)	.007	31 (27.0%)	− 0.36	(− 1.45, 0.72)	.51	
No	11 (2.3%)	− 0.25	(− 1.00, 0.49)	.51	13 (11.3%)	− 0.78	(− 2.07, 0.51)	.24	
Housing dissatisfaction - Affordability									.96
No	464 (95.5%)	Ref			92 (80.0%)	Ref			
Yes	22 (4.5%)	− 0.38	(− 0.92, 0.16)	.17	23 (20.0%)	− 0.11	(− 1.04, 0.81)	.81	
Housing dissatisfaction - Condition									.002
No	445 (91.6%)	Ref			91 (79.1%)	Ref			
Yes	41 (8.4%)	0.14	(− 0.27, 0.54)	.50	24 (20.9%)	− 1.13	(− 2.08, − 0.17)	.023	

Model adjusted for age, gender, the used sleep questionnaire wave, and all variables listed in this table.
[a] That is, satisfaction regarding their income-to-needs ratio.
[b] "Very satisfied" and "Satisfied" strata were grouped in this analysis.
[c] Chi-square test for interaction.

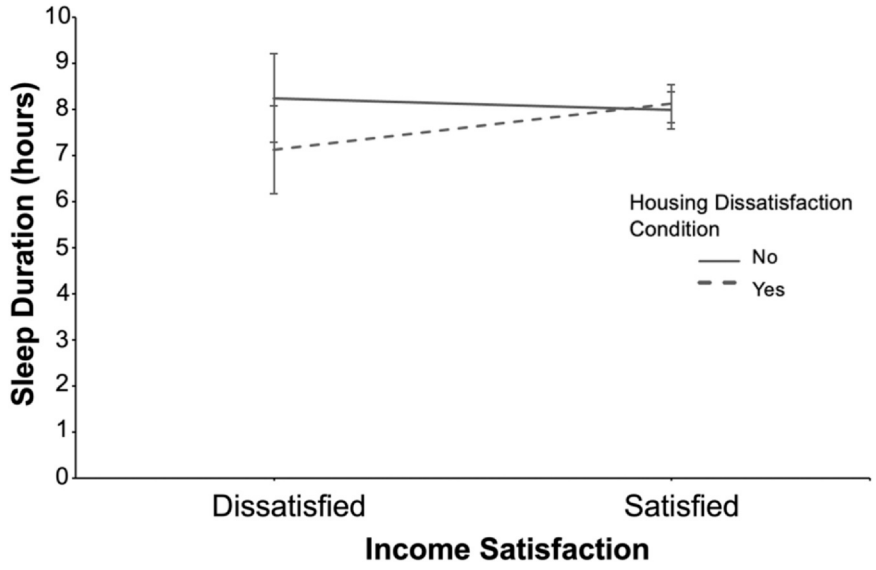

Fig. 2. Effect modification of the relationship between sleep duration and housing conditions by income satisfaction (p-interaction = .002)

with sleep duration among women than men, though this difference was not statistically significant (p-interaction = .49 and .42, respectively; Table S6). We found no modifying effect of income level or children number (data not shown).

Discussion

In our study, we found that housing and household characteristics were associated with sleep duration in the context of COVID-19 in a pan-Canadian cohort. Not having access to a private outdoor space or nature was associated with shorter sleep duration. Additionally, sleep duration was particularly shorter in those dissatisfied with their housing conditions in those dissatisfied with their income level. Having children at home was also associated with shorter sleep duration, and this relationship appeared stronger among women.

People with access to a private yard or nature slept almost half an hour longer than those without access. This finding is consistent with other work that has shown that access to neighborhood parks is associated with better sleep quality and longer sleep duration.[18] Interestingly, our finding was independent of depression, suggesting access to outdoor space may impact sleep via pathways other than depression. It is possible that in the context of COVID-19 and restrictions on socialization, having a private outdoor space offered additional opportunities to do activities outside, to be more exposed to sunlight, or to socialize with others. During specific periods of confinement, private gatherings were allowed in private outdoor areas. In other words, access to socialization opportunities may have been different depending on this housing feature. It has been shown that socialization can act as a zeitgeber, similarly to light, which allows the internal biological clock to stay re-entrained within the 24-hour clock, helping to maintain a healthier sleep.[30] Pre- and during-pandemic research has shown a link between higher socialization, better sleep, and better mental health.[31]

People who reported living in "other" type of dwellings, such as a mobile home or a basement, slept significantly less than people living in a house, an apartment, or a condominium. It would be reasonable to assume that the latter types of dwelling are likely more comfortable environments than basement/mobile homes, which would explain the differences in sleep duration. Additionally, living in a less common type of dwelling could be a marker of a less favorable socioeconomic situation, generally linked to adverse sleep health outcomes. It was worth noting the low number of participants living in an "other" type of dwelling in our study limits the scope of these results.

Housing dissatisfaction was associated with shorter sleep duration but only among those dissatisfied with their income. Dissatisfaction with housing could reflect undesirable house characteristics such as an environment that is too hot or cold, poorly insulated, too bright at night or dark during the day, damp, or poorly maintained. Our overall finding is also consistent with the notion that higher financial means may act as moderating factor in the relationships between housing and neighborhood environment to sleep.[15] In other words, some detrimental housing factors may be less critical for sleep among those with a financial advantage. It is also possible that the underlying construct of "housing dissatisfaction" may have different meanings across different economic circumstances. Housing dissatisfaction among those with higher income could underlie aspects that are less likely to impact sleep (e.g., esthetics).

Living with children was associated with shorter sleep, and the higher the number of children, the shorter; this was particularly clear among women. This finding is consistent with previous work showing that the more children, the less sleep for parents.[32] Household composition is an important predictor of sleep health. A greater number of children represent an additional mental load at home, particularly with school and daycare disruptions in the context of COVID-19.[33] Women spend more hours per week on domestic activities than men and are more likely to take time off during disruptions of usual childcare arrangements than men.[34] It is possible that competing activities, such as childcare/parenting and work demands, may lead to shorter sleep duration.[34]

Our study has several strengths. COHESION Study Phase 1 is the first pan-Canadian longitudinal study focusing on housing and neighborhood determinants of sleep in the context of COVID-19. The prospective design of this epidemiological study and the use of items taken from the standardized Pittsburgh Sleep Quality Index questionnaire, which is widely used and accepted, both limit the potential for misclassification bias and hence highly contribute to the reliability of the data used in the present study. In multivariable analyses, we accounted for multiple sociodemographic confounders (e.g., age, gender, income…), but we were also able to control for mental health, an important confounder sometimes overlooked in epidemiological sleep studies. To do so, we used the 6-item Kessler questionnaire, a validated and widely adopted scale for psychological distress assessment.[28]

Our exploratory study has some limitations as well. Our sample size of over six hundred individuals was older, less employed, and more satisfied regarding incomes than COHESION participants not included in the present sleep study. Our sample's characteristics could be a source of lack of statistical power due to the poor cell sizes of related groups. Furthermore, our study sample had a higher number of women, White people, and individuals of higher income. It thus was not representative nor as diverse as the general population in Canada, which may limit the generalization of our findings. Our calculation of sleep duration relied on questions on bedtime, wake-up time and sleep latency and did not include a question on wake after sleep on set. Additionally, the sleep questionnaire was not administered at baseline (at recruitment) when most demographics (age, gender, employment, income, etc.) were documented. Even though the latter factors could have changed in the time between data points, given the intrinsic stability of these factors over time and the small average timespan between baseline and sleep questionnaire completion dates in our study (46 days), we estimate these changes to be negligible. Moreover, our results changed very little when excluding participants with the longest timespans between completion dates (more than 3 months). The risk for the related misclassification bias should therefore be limited. It concerns demographic factors only; indeed, housing-related factors – of central interest in the present study – were documented at baseline and then prospectively updated. In terms of follow-up work, adding objective measures of sleep (i.e., actigraphy) could help understand the relationship between different sleep dimensions (e.g., timing, continuity, regularity, etc.) and housing factors. Qualitative research would also be warranted, as it could shed light on the underlying mechanisms linking housing and neighborhood conditions and sleep health. Finally, it would have been very relevant to have pre-COVID-19 data to contextualize our results better. However, our research question was not to precisely document the effect of the pandemic on sleep duration but to explore the role of household and housing dissatisfaction and neighborhood features in this context.

Conclusion

In summary, we identified housing and household factors as potential sources of sleep disparities in the context of COVID-19. Prospective public health and government public health measures should (i) consider the importance of the home and housing environment and its association with a healthy sleep and (ii) aim to minimize sources of sleep disparities stemming from such interventions (i.e., unintended consequences). Moreover, beyond the crisis context of the COVID-19 pandemic, our study highlights the importance that urban interventions could play in promoting better sleep by targeting satisfaction with housing conditions. For instance, this could be achieved by granting construction permits conditional on building common spaces to encourage social interactions and outdoor access. It could also be achieved through affordable pricing policies in the sale of buildings that would give developers more flexibility to use sustainable materials that promote thermal and sound insulation, factors often associated with housing (dis)comfort.

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Author contributions

Stephan Gabet: Writing- Original draft preparation, Formal Analysis. **Anthony Levasseur:** Writing- Original draft preparation. **Benoit Thierry:** Data curation, Formal Analysis. **Rania Wasfi:** Writing- Reviewing and Editing. **Yan Kestens:** Conceptualization, Writing- Reviewing and Editing. **Gregory Moullec:** Conceptualization, Writing- Reviewing and Editing. **Guido Simonelli:** Conceptualization, Writing original draft, Reviewing and Editing.

Declaration of conflicts of interest

None of the authors has any relevant conflicts of interest to report.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.sleh.2024.05.008.

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