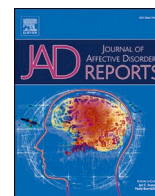




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Research Paper

COVID-19 perceived impacts on sleep, fitness, and diet and associations with mental health during pregnancy: A cross-national study

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1. Introduction

The Coronavirus-2019 (COVID-19) global pandemic has disrupted many facets of life. Among the most obvious disruptions, quarantine and physical distancing measures for COVID-19 have produced notable impacts on physical activity, sleep, and eating behaviors in the general population (Tison et al., 2020; Arora and Grey 2020). Notably, these health behaviors are known to be associated with mental health and wellbeing, with data generally linking low or inconsistent levels of physical activity, sleep, and eating to worse mental health and functioning, both in general (Firth et al., 2020; Lopresti et al., 2013) and recently during the pandemic (Ingram et al., 2020; Kocевska et al., 2020). Less well understood, however, is how COVID-19 disruptions in these key health behavior domains of physical activity, sleep, and diet may have affected one particular group—pregnant women—whose mental health is particularly critical given the potential short- and long-term impacts of psychiatric distress on both mother and child (Gentile 2017; Madigan et al., 2018). Numerous reports have now documented substantial mental health morbidity among pregnant women during the COVID-19 pandemic (Thapa et al., 2020; Zhang and Ma 2020; Wu et al., 2020), raising the need to better understand potential modifiable targets for reducing the burden of distress in this vulnerable population.

Increasingly it is recognized that exercise, sleep, and diet are not only important for physical health in pregnancy (Gavard and Artal 2008), but may also meaningfully support mental health, with pre-pandemic studies linking higher levels of physical activity and more consistent sleep and diet to more favorable mental health in pregnant women (Baskin et al., 2015; González-Mesa et al., 2019; Pauley et al., 2020;

Nakamura et al., 2019). The COVID-19 pandemic and its associated restrictions have potential to powerfully disrupt all of these health behavior domains with resulting negative impacts on perinatal mental health. Indeed, early evidence from pregnant women in China found that low exercise levels were associated with increased depressive symptoms during COVID-19 (Wu et al., 2020) and in Canada, pregnant women who engaged in higher levels of physical activity, specifically those who met weekly thresholds for moderate-intensity activity, tended to show lower symptoms of depression and anxiety (Davenport et al., 2020). However, more work is needed to examine how COVID-19 has affected exercise, sleep, and diet in pregnant women across global settings, and their associated consequences for a range of mental health outcomes. In addition, the psychological experiences that may accompany these health behavior impacts (Jans-Beken et al., 2020; Hawkey et al., 2003)—whether positive (e.g., gratitude, community) or negative (e.g., loneliness) in valence—may point to additional modifiable targets for supporting adaptive health behaviors during times of stress. Altogether, understanding the combined influence of these health behaviors on mental health, as well as their psychological correlates, could point to specific areas of impact as well as opportunities for intervening to promote the physical and mental health of pregnant women during a highly stressful pandemic.

In this online survey study of 3696 pregnant women across 12 countries recruited from a pre-existing large-scale web platform for pregnancy information during the initial months of the global COVID-19 pandemic, we aimed to describe the reported impacts of COVID-19 on sleep, fitness, and diet, and test their specific associations with elevated symptoms of depression and/or anxiety. In addition, we aimed to test the associations between COVID-19 health behavior impacts and

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potential psychological correlates, i.e., gratitude, loneliness, and sense of community, and to characterize the overall behavioral and psychological profiles of women with and without elevated distress.

2. Methods

2.1. Survey design and recruitment

An anonymous online survey, hosted on the Pregistry platform for COVID-19 studies (<https://corona.pregistry.com>), was conducted between May 26, 2020 and June 13, 2020 and has been described in detail elsewhere (Basu et al., 2021). Briefly, the cross-sectional survey targeted pregnant and recently postpartum women and was advertised in social media channels and online parenting forums and was available in twelve languages (Arabic, Chinese, English, French, German, Italian, Korean, Portuguese, Russian, Spanish, Turkish, and Urdu) by human translators. Interested participants who self-identified as 18 years or older and were either currently pregnant or had given birth within the past 6 months were invited to follow a link to take the survey, which included information about the research objectives and standards of confidentiality regarding the use of the data. The survey included sociodemographic data and questions that addressed health behavior impacts due to COVID-19, psychological risk and protective factors, and mental health. The study was classified exempt by the Harvard Longwood Campus Institutional Review Board per the regulations found at 45 CFR 46.104 (d)(2) on the basis that it posed no greater than minimal risk and the recorded data were de-identified.

Our sample consisted of 3696 pregnant women drawn from the larger Pregistry COVID-19 cohort who participated from a country with at least 200 respondents for representativeness. These countries included: Argentina, Brazil, Canada, Chile, China, Colombia, France, India, Mexico, Peru, South Africa, and the United States (for sample sizes from each country, see S1 Table A). Previous indicated minimal reported history of COVID-19 infection in this sample (Basu et al., 2021). In this study, we focused specifically on pregnant participants because behavioral changes in the postpartum period may vary widely depending on newborn caregiving needs.

2.2. Measures

2.2.1. Health behavior impact due to COVID-19

Participants were asked “To what extent has COVID-19 negatively impacted the following areas of your life?” and to indicate their responses for various potential areas of impact including “sleep”, “diet”, and “fitness”—each with their own Likert-scale response options (ranging from “not at all,” “a little bit,” “moderately,” to “a lot”). A cumulative health behavior impact score was calculated by summing the three items, ranging from 3 to 12, with highest scores reflecting greatest perceived impact across the health behavior domains.

2.2.2. Mental health distress

Mental health distress was assessed using the Patient Health Questionnaire-4 (PHQ-4) (Kroenke et al. 2009), which consisted of four items on a four-point Likert scale (0=not at all, 1=several days, 2=more than half the days, 3=nearly every day). The first two anxiety-related items were drawn from the Generalized Anxiety Disorder-7 scale (GAD-7) (Löwe et al., 2008) and the latter depression-related items from the Patient Health Questionnaire-9 (PHQ-9) (Kroenke et al., 2001). All four items were summed into an index of overall mental health distress, while each of the two items were summed to index anxiety and depression symptoms, respectively. A score of ≥ 6 on the overall PHQ-4 score, and a score of ≥ 3 on each subscale, were considered to reflect elevated symptoms per established criteria.

2.2.3. Psychosocial measures

Loneliness was evaluated using the UCLA Three-Item Loneliness

Scale (UCLA-3) (Hughes et al., 2004), which consisted of three questions assessing feelings of loneliness specifically since the start of the COVID-19 pandemic for this survey, which were each rated as 1 (hardly ever), 2 (some of the time), or 3 (often). All three items were summed into an overall loneliness score where a score of 3 was considered low, 4-5 medium, and ≥ 6 high levels of loneliness. Sense of community was measured using an adapted six-item scale from the Keyes Social Well-Being Study (Keyes 1998), which assesses five dimensions of community including social integration, coherence, contribution, actualization, and acceptance. Participants were asked to rate their perceived sense of community in the past seven days from 1 (strongly disagree) to 7 (strongly agree). All six items were summed to create an overall sense of community score. Sense of gratitude during COVID-19 was assessed using the Gratitude Adjective Checklist (GAC) (McCullough et al., 2002). The GAC consisted of three items assessing whether participants identified with the following three gratitude-related adjectives—grateful, thankful, and appreciative—with each item rated on a seven-point scale ranging from 1 (strongly disagree) to 7 (strongly agree). The three items were summed into an overall gratitude score.

2.2.4. Sociodemographic factors

Participants provided self-reported information on their age; education (categorized as never attended school, elementary school, some high school, high school graduate or general equivalency diploma (GED), some college/university, college diploma or university degree, master's degree, professional degree, doctoral degree); self-identified race/ethnicity (categorized as White/Caucasian, Latina/Hispanic, Asian, South Asian, Black, Middle Eastern, Native Hawaiian or Other, Pacific Islander, American Indian or Alaska Native, Other/Multiracial); employment status (healthcare worker in a hospital or clinic, worked in a nursing home, essential/key worker as defined by the government, none of these, don't know); and marital status (married, living with partner, divorced, separated, single, widowed). They also provided data on the number of weeks pregnant (first trimester categorized as 0 to <13 weeks, second trimester 13 to <28 weeks, third trimester 28+ weeks) and also their medical insurance coverage status. Self-reported country of residence was further classified by region (Africa, Asia and Pacific, Europe, Middle East, North America, South/Latin America) for analytic purposes.

2.3. Statistical analyses

Variable missingness was generally low; for all analyses, we retained 3696 participants who had complete data available. All analyses were conducted in R. First, we conducted descriptive analyses to characterize the study sample in terms of demographic characteristics, reported health behavior impacts, mental health outcomes, and potential psychosocial correlates. We also examined correlations within health behavior impact variables and psychosocial correlates, using Pearson and Spearman correlations for continuous and ordinal variables, respectively. Second, we used logistic regressions to test associations between the cumulative health behavior impact score and each mental health outcome of interest. Third, we tested the logistic regression associations between each lifestyle impact domain and the mental health outcomes, with each domain separately and in the same model. In these models, the reference group for each domain was those reporting the lowest level of impact (i.e., “no impact”). Finally, we examined the associations between our psychosocial correlates—reported gratitude, sense of community, and loneliness—and the endorsed health behavior impacts. All regression analyses were adjusted for the covariates described above, including age, pregnancy trimester, marital status, educational attainment, healthcare worker status, insurance coverage, and geographical region. Preliminary associations between these covariates in relation to overall health behavior impact are presented in the supplementary materials (S1 Table B), where older age and identifying as Black or Latino/Hispanic were associated with higher reported

overall impact, while having medical insurance coverage was associated with reporting lower overall impact.

3. Results

3.1. Sample characteristics

Sociodemographic characteristics are summarized for the overall sample in Table 1. Most participants were either in their second ($n = 1508$) or third ($n = 1305$) trimester of pregnancy (S1 Table C). Women reported an average age of 31.2 (SD=4.9), with the majority (73%) under the age of 35, and either married (61%) or living with a partner (30%). Most participants reported having attended at least some college (86%) and having medical insurance coverage (73%), and 26% reported being either an essential worker or working in healthcare/nursing home. All global regions were represented except the Middle East based on our inclusion criteria.

3.2. Description of impact on COVID-19 health behavior domains

33% of women reported at least “moderate” impact of COVID-19 on sleep, 27% on diet, and 44% on fitness, while 12% of women reported at least “a lot” of impact of COVID-19 on sleep, 8% on diet, and 23% on fitness. Reported impacts in each domain (sleep, diet, fitness) were moderately intercorrelated, with the strongest correlation between fitness and diet domains ($r = 0.44, p < 0.001$), followed by diet and sleep domains ($r = 0.39, p < 0.001$), and sleep and fitness domains ($r = 0.30, p < 0.001$). The mean cumulative health behavior impact score was 6.5 (SD=2.3).

3.3. Health behavior impact associations with mental health outcomes

Pregnant women reporting greater cumulative health behavior impact across sleep, diet, and fitness domains related to COVID-19 showed higher odds of mental health distress (OR=1.42, 95% CI=1.37, 1.47, $p < 0.001$, for every unit increase in the cumulative impact score).

When examining each health behavior domain in separate covariate-adjusted models, reported impacts consistently showed a dose-response relationship with clinically elevated mental health distress (see Fig. 1 and Tables S1, D), with the highest odds observed for pregnant women reporting the greatest level of impact (i.e., “a lot”) compared to no impact: OR=11.40 for sleep (95% CI=8.73, 14.98, $p < 0.001$), OR=4.72 for diet (95% CI=3.58, 6.22, $p < 0.001$), and OR=3.35 for fitness (95% CI=2.72, 4.15, $p < 0.001$) on mental health distress.

When considering health behavior domains together, all three domains remained associated with mental health distress across all levels of reported impact (Table 2), although for fitness impact, only women reporting the highest impact—and not more moderate levels of impact—were at significantly higher odds of distress compared to those without any such impact. When mental health distress was further divided into depression and anxiety sub-outcomes (Table 2), those reporting the highest level (i.e., “a lot”) of fitness impact were still at significantly higher odds of either elevated depression or anxiety symptoms (OR=1.87, 95% CI=1.46, 2.40, $p < 0.001$; OR=1.52, 95% CI=1.20, 1.92, $p < 0.001$, respectively) compared to those reporting no impact, but women who reported even “moderate” impact in the fitness domain showed higher odds of depressive symptoms (OR=1.48, 95% CI=1.16, 1.89, $p = 0.003$) though not anxiety (OR=0.94, 95% CI=0.75–1.18). On the other hand, individuals reporting impacts on diet and sleep were at significantly higher odds of both elevated depressive and anxiety symptoms across all levels of reported impact, including “a little bit” and “moderately.”

Table 1

Descriptive statistics for survey respondents in the analytic sample.

Variable	(n = 3696)
Age in years (years)	
Mean (SD)	31.2 (4.90)
Median [Min, Max]	31.0 [18.0, 44.0]
Region	
Africa	452 (12.2%)
Asia & Pacific	385 (10.4%)
Europe	271 (7.3%)
Middle East	0 (0%)
North America	986 (26.7%)
South/Latin America	1602 (43.3%)
Self-reported race/ethnicity	
White	1530 (41.4%)
Latin/Hispanic	1061 (28.7%)
Asian	362 (9.8%)
Black	328 (8.9%)
South Asian	55 (1.5%)
Middle Eastern	13 (0.4%)
Native/Indigenous	12 (0.3%)
More than 1 race/ethnicity	195 (5.3%)
Other	122 (3.3%)
Not reported	18 (0.5%)
Marital status	
Married	2247 (60.8%)
Living with partner	1097 (29.7%)
Other	352 (9.5%)
Level of education	
High school graduate or less	515 (13.9%)
Some college	593 (16.0%)
College graduate	1238 (33.5%)
Graduate school or more	1350 (36.5%)
Employment status	
Worked in healthcare or nursing home	413 (11.2%)
Essential worker	555 (15.0%)
Other	2728 (73.8%)
Medical coverage status	
Yes	2712 (73.4%)
Sleep	
Not at all	1041 (28.2%)
A little bit	1422 (38.5%)
Moderately	792 (21.4%)
A lot	441 (11.9%)
Diet	
Not at all	1428 (38.6%)
A little bit	1276 (34.5%)
Moderately	709 (19.2%)
A lot	283 (7.7%)
Fitness	
Not at all	1026 (27.8%)
A little bit	1061 (28.7%)
Moderately	764 (20.7%)
A lot	845 (22.9%)
Lifestyle impact score	
Mean (SD)	6.52 (2.32)
Median [Min, Max]	6.00 [3.00, 12.0]
Mental health distress	
<6	2460 (66.6%)
>=6	1236 (33.4%)
Loneliness score	
<6	1719 (46.5%)
>=6	1977 (53.5%)
Gratitude score	
Mean (SD)	17.8 (3.53)
Median [Min, Max]	18.0 [3.00, 21.0]
Community score	
Mean (SD)	26.4 (6.13)
Median [Min, Max]	26.0 [7.00, 42.0]

3.4. Potential psychological correlates

Gratitude, sense of community, and loneliness were correlated to a moderate extent, with the highest correlations between sense of community and loneliness ($r = -0.36, p < 0.001$) as well as gratitude and sense of community ($r = 0.32, p < 0.001$), and a lower correlation

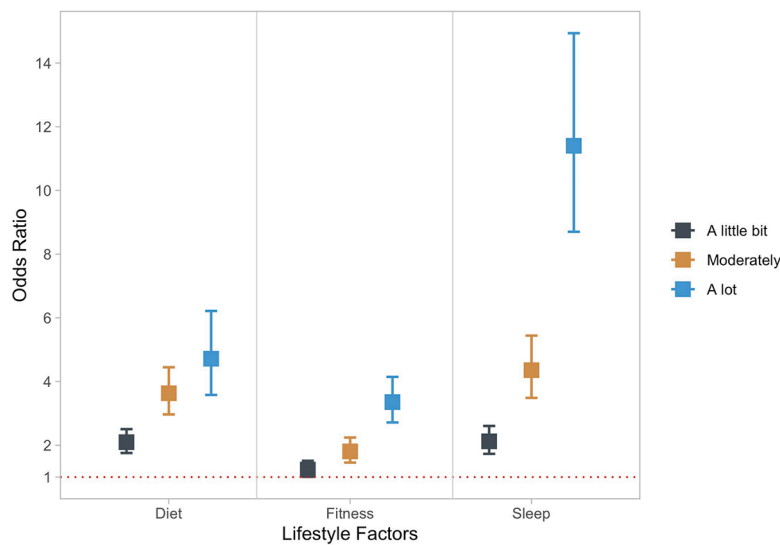


Fig. 1. Forest plot showing the odds of reporting elevated mental health distress compared to the reference group in the “not at all” category for diet, fitness, and sleep impact, examined in separate models. Null odds ratio is shown in the dotted red line. All models were adjusted for age, education, race/ethnicity, medical coverage status, survey region, marital status, and weeks pregnant.

Table 2
Results of multivariable logistic regression model for elevated anxiety and depression in relation to the three health behavior domains^a.

	Anxiety and depression (PHQ-4)	Depression (PHQ-2)	Anxiety (GAD-2)
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Sleep^b			
A little bit	1.82 (1.47 – 2.25)***	1.38 (1.11 – 1.71)**	2.09 (1.72 – 2.55)***
Moderately	3.31 (2.62 – 4.19)***	2.27 (1.79 – 2.88)***	3.78 (3.02 – 4.73)***
A lot	7.56 (5.70 – 10.09)***	4.84 (3.66 – 6.42)***	8.41 (6.33 – 11.23)***
Diet^b			
A little bit	1.56 (1.28 – 1.89)***	1.62 (1.33 – 1.97)***	1.43 (1.19 – 1.72)***
Moderately	1.93 (1.54 – 2.43)***	1.85 (1.47 – 2.34)***	1.82 (1.46 – 2.28)***
A lot	1.90 (1.38 – 2.61)***	1.97 (1.43 – 2.70)***	1.84 (1.34 – 2.53)***
Fitness^b			
A little bit	0.97 (0.78 – 1.20)	1.08 (0.86 – 1.35)	0.93 (0.76 – 1.14)
Moderately	1.12 (0.88 – 1.41)	1.48 (1.16 – 1.89)**	0.94 (0.75 – 1.18)
Fitness: A lot	1.74 (1.37 – 2.21)***	1.87 (1.46 – 2.40)***	1.52 (1.20 – 1.92)***

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Abbreviations: OR, odds ratios.

^a Adjusted for age, education, race/ethnicity, medical coverage status, survey region, marital status, weeks pregnant/postpartum.

^b Reference category: Not at all.

between gratitude and loneliness ($r = -0.16, p < 0.001$). Women reporting higher gratitude and sense of community each tended to endorse lower overall health behavior impact (beta = -0.07, 95% CI = -0.09, -0.05, $p < 0.001$; beta = -0.06, 95% CI = -0.07, -0.05, $p < 0.001$, respectively) whereas those reporting higher loneliness tended to endorse higher overall health behavior impact (beta = 0.35, 95% CI = 0.31, 0.38, $p < 0.001$). When these psychosocial correlates were examined in the same model, the associations of gratitude and loneliness with overall health behavior impact persisted, with gratitude and sense of community showing protective associations (beta = -0.03, 95% CI = -0.05, -0.01, $p = 0.004$; beta = -0.02, 95% CI = -0.04, -0.01, $p < 0.001$, respectively) and loneliness showing a risk association (beta = 0.31, 95% CI: 0.27, 0.35, $p < 0.001$) with reported COVID-19 health behavior impacts.

To further visualize the associations between mental distress and the combined profiles of reported health behavior and psychological factors, we generated a scaled radar plot to compare the scores from women meeting and not meeting the cut-off for elevated mental distress (Fig. 2). On average, women with elevated distress tended to report greater

impacts on fitness and sleep as well as loneliness, while women without elevated distress tended to report high gratitude and sense of community, and particularly low impacts on sleep and diet.

4. Discussion

This multinational online survey study of 3696 pregnant women recruited during COVID-19 characterizes negative perceived impacts on sleep, fitness, and diet in pregnant women during the pandemic. In this study, one in three pregnant women met established criteria for elevated symptoms of mental health distress (specifically anxiety and depression), and roughly 30–45% of them reported at least moderate if not high negative impacts in each of these health behavior domains as a result of the pandemic. Overall health behavior impacts showed a dose-response relationship with mental health distress, with those individuals reporting the greatest level of overall impact in health behaviors also showing the highest odds of clinically elevated symptoms of mental health distress. COVID-19 impacts on sleep, diet, and fitness were moderately intercorrelated, but their associations with mental health

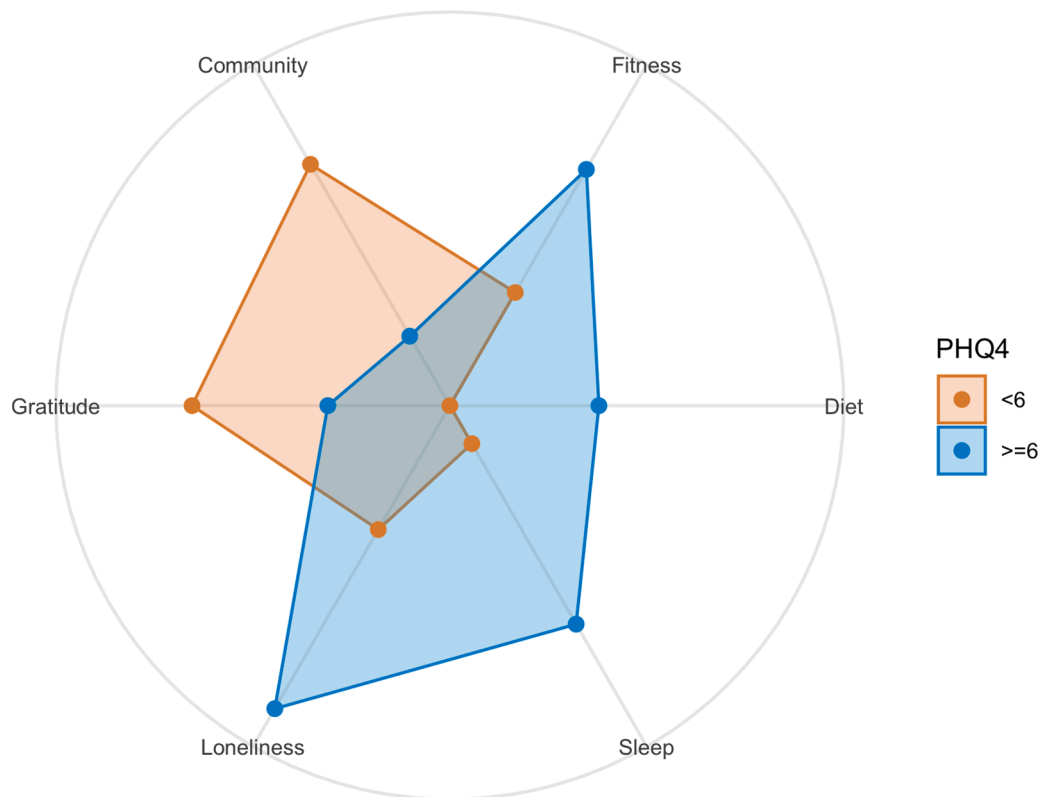


Fig. 2. Comparison of lifestyle and psychosocial factors in women with elevated mental distress (PHQ4 \geq 6) to women without elevated mental distress (PHQ4<6). For visualization, continuous loneliness, community, and gratitude scores were scaled to match the range of values of the lifestyle factors.

distress persisted even when accounting for other domains, suggesting unique contributions of each domain and a need to consider these health behavior impacts in combination.

Adjusting for a range of sociodemographic factors, we observed that sleep had the strongest association with mental health distress, with pregnant women reporting the highest negative impacts in this domain showing 11-fold odds of elevated symptoms compared to those reporting no impact. This association persisted even after accounting for reported impacts on diet and fitness. Given that sleep disturbance is a common feature of mental health problems (Anderson and Bradley 2013), it is perhaps unsurprising to observe these strong associations, although the large effect size is nonetheless notable. Interestingly, when examining mental health sub-outcomes, sleep impact during the pandemic appeared to be particularly associated with concurrent anxiety more so than depression, which suggests that sleep disturbances may be linked to worry and anxiety related to COVID-19 among pregnant women. This is consistent with emerging COVID-19 research suggesting that sleep quality can be predicted by worries (Kocevska et al., 2020) related to COVID-19 and its associated adversities (Wright et al., 2020). Numerous interventions have been developed to address sleep problems during pregnancy, including cognitive-behavioral, mindfulness, and relaxation-based approaches (Bacaro et al., 2020), and brief virtual modalities of sleep intervention for pregnant women (Felder et al., 2020) are now particularly crucial.

Perceived COVID-19 impacts on diet were also notable and showed the second strongest pattern of association with mental health distress in our pregnant sample. Epidemiological evidence from large cohorts of adults such as the UK Biobank has linked inconsistent dietary patterns with depression risk though not necessarily causally (Choi et al., 2020); instead, this relationship may reflect life stressors such as unpredictable schedules or financial difficulties or underlying mental health

vulnerability leading to inconsistent routines. Notably, women who did not meet cut-offs for elevated mental health distress tended to report minimal impacts on diet, as shown in Fig. 2. Thus, assessment of overall dietary patterns during antenatal visits may help to flag pregnant women at mental health risk during pandemic situations and prompt further discussion about the specific reason(s) underlying dietary pattern changes and inform relevant psychosocial guidance.

We also observed that reported fitness impacts were associated with elevated mental health distress, which aligns with a large base of evidence linking physical activity and mental health in the general population and during pregnancy (Nakamura et al., 2019; Firth et al., 2020). However, in this pregnant sample during COVID-19, the effect of fitness impacts partially attenuated when accounting for diet and sleep impacts, suggesting that perceived disturbances in other health behavior domains had stronger influences on mental health. It may be that pregnant women had already reduced their physical activity in general and therefore any changes in fitness opportunities due to the pandemic were less drastic. On the other hand, descriptive statistics of reported impacts (Table 1) show that a higher proportion of participants actually endorsed the highest level of impact on fitness (23%) compared to diet (8%) and sleep (12%) due to COVID-19, suggesting that physical activity disruptions during COVID-19 may have been more commonplace whereas women reporting large changes in diet and sleep may be the more vulnerable groups. When examining mental health sub-outcomes, it is notable that fitness impact showed stronger associations with depression than anxiety, in that even moderate levels of reported fitness impact were associated with depression risk whereas only the highest levels of fitness impact were associated with anxiety risk, requiring a more stringent threshold of impact. This is consistent with literature that has now identified physical activity as a likely protective factor for low mood and specifically depression (Schuch et al., 2018; Choi et al., 2019),

whereas more work may be needed to understand the complex relationships between physical activity and anxiety in general and during pregnancy, whereby being physically active may reduce anxiety but high levels of anxiety may also drive fitness behavior.

In our study, we were also able to examine a number of positive psychological correlates—gratitude, and sense of community—which appeared to be associated with lower reported health behavior impacts. On the other hand, loneliness emerged as a potential risk factor for increased reported negative impacts. Although it is not possible to establish the direction of these relationships between psychological factors and health behavior impacts, the data indicate that they certainly co-occur and could be potential targets to explore further. Loneliness has been shown to predict reduced physical activity (Hawkey et al., 2009) and may affect other health behaviors as well, whereas positive states such as gratitude may drive sustained engagement in health behaviors or at least perceptions thereof (Jans-Beken et al., 2020). We also used these behavioral and psychological variables to establish group profiles as shown in Fig. 2. Pregnant women in our sample with elevated mental health distress during COVID-19 tended to report greater impacts on fitness and sleep as well as loneliness, while women without elevated distress tended to report high gratitude and sense of community, and particularly low impacts on sleep and diet. This points to a specific combination of risk factors among pregnant women who experience mental health distress during the COVID-19 pandemic, and another combination of protective factors that may cluster in pregnant women who maintain low levels of distress despite the pandemic.

While providing numerous insights, this study had a number of key limitations to note. First, the online survey was cross-sectional in its design, and therefore no causality or directional relationships can be inferred. Indeed, it could be that poor mental health is leading to perceived changes in fitness or sleep, or perhaps a third variable (e.g., life stressors or demands) is causing both poor mental health and changes in perceived fitness or sleep. Nonetheless, these associations point to the importance of paying attention to how a global crisis may alter health behaviors as well as mental health among pregnant women, and that these experiences must all be addressed together. This integrated approach is also valuable because these same lifestyle factors—i.e., diet, fitness, and sleep—are also very relevant for physical health, particularly during pregnancy. Second, due to the brief nature of this online survey designed to recruit a large number of women across global settings, we employed a relatively basic measure of health behavior impacts. This measure documented any changes in health behaviors but did not obtain information on the specific directions of impact, i.e., increasing or decreasing, and in what specific domains, e.g., types of fitness or sleep. Further work will need a greater level of granularity, but this work provides a compelling impetus to explore further. Also, because participants reported perceived impacts in each domain of health behavior, such responses may have been biased by mood and so future work using objective sensors and other modes of data triangulation may be needed. Reported impacts in the “fitness” area are likely to reflect perceived changes in exercise engagement and physical capacity, which need to be cross-referenced with more detailed measures of physical activity and exercise. Third, we did not have information on parity to include as a covariate and women with their first pregnancy may have different experiences than women with subsequent pregnancies and other children in the home. We also lacked data on prior mental health history, and future work should explore other factors that may further influence mental health including psychosocial stressors or pregnancy complications. Fourth, this was a volunteer-based sample and therefore is not representative of all pregnant women, and captures individuals who are more healthy, older, more educated, and motivated for research participation. Nonetheless, it is notable that a substantial proportion of women—one in three—still endorsed substantial levels of mental health distress and many reported at least moderate negative health behavior impacts related to COVID-19, and we also adjusted for a range of potential confounders including educational attainment and

family status, as well as global regions.

In conclusion, given the elevated mental health morbidities such as depression and anxiety documented in general and among pregnant women during the COVID-19 pandemic (Thapa et al., 2020; Zhang and Ma 2020; Wu et al., 2020), understanding potential modifiable factors at a behavioral and psychological level may offer insights into how best to support the well-being of pregnant women during this vulnerable time. Our study points to a need for more detailed longitudinal work but confirms the high documented rates of mental health distress and provides promising evidence from a large-scale survey of pregnant women across global settings to support the interrelationships between mental health and health behaviors impacted by the pandemic, suggesting that attention to sleep, diet, and fitness-related disruptions—and particularly sleep—may be important for mental health promotion during pregnancy in the midst of a major stressor.

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CRediT authorship contribution statement

Karmel W. Choi: Formal analysis, Supervision, Writing – review & editing. **Hannah H. Kim:** Formal analysis, Supervision, Writing – review & editing. **Archana Basu:** Formal analysis, Supervision, Writing – review & editing. **Alex S.F. Kwong:** Formal analysis, Writing – review & editing. **Sonia Hernandez-Diaz:** Formal analysis, Writing – review & editing. **Diego F. Wyszynski:** Formal analysis, Writing – review & editing. **Karestan C. Koenen:** Formal analysis, Supervision, Writing – review & editing.

Declaration of Competing Interest

DFW is the founder and CEO of Pregistry, a company providing medical information for pregnant women. The other authors have no conflicts of interest to disclose.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jadr.2021.100288](https://doi.org/10.1016/j.jadr.2021.100288).

References

- Anderson, K.N., Bradley, A.J., 2013. Sleep disturbance in mental health problems and neurodegenerative disease. *Nat. Sci. Sleep* 5 (May), 61–75.
- Arora, T., Grey, I., 2020. Health behaviour changes during COVID-19 and the potential consequences: a mini-review. *J. Health Psychol.* 25 (9), 1155–1163.
- Bacaro, V., Benz, F., Pappaccogli, A., De Bartolo, P., Johann, A.F., Palagini, L., Lombardo, C., Feige, B., Riemann, D., Baglioni, C., 2020. Interventions for sleep problems during pregnancy: a systematic review. *Sleep Med. Rev.* 50 (April), 101234.
- Baskin, R., Hill, B., Jacka, F.N., O’Neil, A., Skouteris, H., 2015. The association between diet quality and mental health during the perinatal period. a systematic review. *Appetite* 91 (August), 41–47.
- Basu, A., Kim, H.H., Basaldua, R., Choi, K.W., Charron, L., Kelsall, N., Hernandez-Diaz, S., Wyszynski, D.F., Koenen, K.C., 2021. A cross-national study of factors associated with women’s perinatal mental health and wellbeing during the COVID-19 pandemic. *PLoS ONE* 16 (4), e0249780.
- Choi, K.W., Chen, C.Y., Stein, M.B., Klimentidis, Y.C., Wang, M.J., Koenen, K.C., Smoller, J.W., Major Depressive Disorder Working Group of the Psychiatric

- Genomics Consortium, 2019. Assessment of bidirectional relationships between physical activity and depression among adults: a 2-sample mendelian randomization study. *JAMA Psychiatry* 76 (4), 399–408.
- Choi, K.W., Stein, M.B., Nishimi, K.M., Ge, T., Coleman, J.R.L., Chen, C.Y., Ratanatharathorn, A., et al., 2020. An exposure-wide and mendelian randomization approach to identifying modifiable factors for the prevention of depression. *Am. J. Psychiatry* 177 (10), 944–954.
- Davenport, M.H., Meyer, S., Meah, V.L., Strynadka, M.C., Khurana, R., 2020. Moms are not ok: COVID-19 and maternal mental health. *Front. Glob. Women's Health* 1 (June). <https://doi.org/10.3389/fgwh.2020.00001>.
- Felder, J.N., Epel, E.S., Neuhaus, J., Krystal, A.D., Prather, A.A., 2020. Efficacy of digital cognitive behavioral therapy for the treatment of insomnia symptoms among pregnant women: a randomized clinical trial. *JAMA Psychiatry* 77 (5), 484–492.
- Firth, J., Solmi, M., Wootton, R.E., Vancampfort, D., Schuch, F.B., Hoare, E., Gilbody, S., et al., 2020. A meta-review of 'lifestyle psychiatry': the role of exercise, smoking, diet and sleep in the prevention and treatment of mental disorders. *World Psychiatry Off. J. World Psychiatr. Assoc.* 19 (3), 360–380.
- Gavard, J.A., Artal, R., 2008. Effect of exercise on pregnancy outcome. *Clin. Obstet. Gynecol.* 51 (2), 467–480.
- Gentile, S., 2017. Untreated depression during pregnancy: short- and long-term effects in offspring. a systematic review. *Neuroscience* 342 (February), 154–166.
- González-Mesa, E., Cuenca-Marín, C., Suarez-Arana, M., Tripiñana-Serrano, B., Ibrahim-Díez, N., Gonzalez-Cazorla, A., Blasco-Alonso, M., 2019. Poor sleep quality is associated with perinatal depression. a systematic review of last decade scientific literature and meta-analysis. *J. Perinat. Med.* 47 (7), 689–703.
- Hawkey, L.C., Burleson, M.H., Berntson, G.G., Cacioppo, J.T., 2003. Loneliness in everyday life: cardiovascular activity, psychosocial context, and health behaviors. *J. Personal. Soc. Psychol.* 85 (1), 105–120.
- Hawkey, L.C., Thisted, R.A., Cacioppo, J.T., 2009. Loneliness predicts reduced physical activity: cross-sectional & longitudinal analyses. *Health Psychol.* <https://doi.org/10.1037/a0014400>.
- Hughes, M.E., Waite, L.J., Hawkey, L.C., Cacioppo, J.T., 2004. A short scale for measuring loneliness in large surveys: results from two population-based studies. *Res. Aging* 26 (6), 655–672.
- Ingram, J., Maciejewski, G., Hand, C.J., 2020. Changes in diet, sleep, and physical activity are associated with differences in negative mood during COVID-19 lockdown. *Front. Psychol.* 11 (September), 588604.
- Jans-Beken, L., Jacobs, N., Janssens, M., Peeters, S., Reijnders, J., Lechner, L., Lataster, J., 2020. Gratitude and health: an updated review. *J. Posit. Psychol.* 15 (6), 743–782.
- Keyes, C.L., 1998. Social well-being. *Soc. Psychol. Q.* 61 (2), 121–140.
- Kocevska, D., Blanken, T.F., Someren, E.J.W.V., Rösler, L., 2020. Sleep quality during the COVID-19 pandemic: not one size fits all. *Sleep Med.* 76 (December), 86–88.
- Kroenke, K., Spitzer, R.L., Williams, J.B., 2001. The PHQ-9: validity of a brief depression severity measure. *J. Gen. Intern. Med.* 16 (9), 606–613.
- Kroenke, K., Spitzer, R.L., Williams, J.B.W., Löwe, B., 2009. An ultra-brief screening scale for anxiety and depression: the PHQ-4. *Psychosomatics* 50 (6), 613–621.
- Lopresti, A.L., Hood, S.D., Drummond, P.D., 2013. A review of lifestyle factors that contribute to important pathways associated with major depression: diet, sleep and exercise. *J. Affect. Disord.* 148 (1), 12–27.
- Löwe, B., Decker, O., Müller, S., Brähler, E., Schellberg, D., Herzog, W., Herzberg, P.Y., 2008. Validation and standardization of the generalized anxiety disorder screener (GAD-7) in the general population. *Med. Care* 46 (3), 266–274.
- Madigan, S., Oatley, H., Racine, N., Pasco Fearon, R.M., Schumacher, L., Akbari, E., Cooke, J.E., Tarabulsky, G.M., 2018. A meta-analysis of maternal prenatal depression and anxiety on child socioemotional development. *J. Am. Acad. Child Adolesc. Psychiatry* 57 (9), 645–657 e8.
- Mccullough, M.E., Emmons, R.A., Tsang, J.A., 2002. The grateful disposition: a conceptual and empirical topography. *J. Personal. Soc. Psychol.* 82 (1), 112–127.
- Nakamura, A., van der Waerden, J., Melchior, M., Bolze, C., El-Khoury, F., Pryor, L., 2019. Physical activity during pregnancy and postpartum depression: systematic review and meta-analysis. *J. Affect. Disord.* 246 (March), 29–41.
- Pauley, A.M., Moore, G.A., Mama, S.K., Molenaar, P., Downs, D.S., 2020. Associations between prenatal sleep and psychological health: a systematic review. *J. Clin. Sleep Med. JCSM Off. Publ. Am. Acad. Sleep Med.* 16 (4), 619–630.
- Schuch, F.B., Vancampfort, D., Firth, J., Rosenbaum, S., Ward, P.B., Silva, E.S., Hallgren, M., et al., 2018. Physical activity and incident depression: a meta-analysis of prospective cohort studies. *Am. J. Psychiatry* 175 (7), 631–648.
- Thapa, S.B., Mainali, A., Schwank, S.E., Acharya, G., 2020. Maternal mental health in the time of the COVID-19 pandemic. *Acta Obstet. Gynecol. Scand.* 99 (7), 817–818.
- Tison, G.H., Avram, R., Kuhar, P., Abreau, S., Marcus, G.M., Pletcher, M.J., Olgin, J.E., 2020. Worldwide effect of COVID-19 on physical activity: a descriptive study. *Ann. Intern. Med.* 173 (9), 767–770.
- Wright, L., Steptoe, A., Fancourt, D., 2020. Are adversities and worries during the COVID-19 Pandemic related to sleep quality? Longitudinal analyses of 48,000 UK adults. *BioRxiv medRxiv.* <https://doi.org/10.1101/2020.06.02.20120311>.
- Wu, Y., Zhang, C., Liu, H., Duan, C., Li, C., Fan, J., Li, H., et al., 2020. Perinatal depressive and anxiety symptoms of pregnant women during the coronavirus disease 2019 outbreak in China. *Am. J. Obstet. Gynecol.* 223 (2), 240 e1-240.e9.
- Zhang, Y., Ma, Z.F., 2020. Psychological responses and lifestyle changes among pregnant women with respect to the early stages of COVID-19 pandemic. *Int. J. Soc. Psychiatry* 67 (4), 344–350, 20764020952116, August.