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Health behaviors and mental health during the COVID-19 pandemic:

A longitudinal population-based survey

Abstract

Objective: To understand the mental health response to repeated and prolonged stress during the COVID-19 related lockdown and the role of specific health behaviors to buffer against this stress.

Methods: In a longitudinal study with several measurement points covering three months during the COVID-19 pandemic, about 3,500 randomly selected participants representative of the German population reported on their mental health (anxiety, depression, loneliness) and health behaviors (screen time, snack consumption, physical activity).

Results: Symptoms of anxiety, depression, and loneliness were highest shortly after the lockdown came into effect. Over time, the symptoms were stable or went down slightly, corresponding to patterns of habituation. Among people with higher vulnerability to poor mental health during the lockdown (e.g., women), the proportion with high levels of anxiety, depression, and loneliness was considerably larger. These groups also reported fewer health-promoting behaviors. More screen time, more snacking, and less physical activity were related to higher symptoms of anxiety, depression, and loneliness across all time points. Changes in health behaviors over time mostly did not predict changes in mental health symptoms.

Conclusions: Mental health and engagement in protective health behaviors was lowest at the start of the lockdown. Health behaviors mostly returned to pre-lockdown levels within three months. Engaging in healthier behaviors was associated with better mental health. Policy implications of these findings are discussed. This study provides important insights into (unintended) side effects of an international crisis and can contribute to a better understanding of how to preserve mental health.

Keywords: mental health, physical activity, snacking, screen time, COVID-19

How can people protect their health and well-being in situations of stress? This is one of the central questions in health psychology, medicine, and related sciences. The impact of the 2020 lockdown of public life around the world due to the coronavirus pandemic (COVID-19) has been compared to that of ecological disasters, political coups, and terrorist attacks (Baker et al., 2020). The COVID-19 pandemic thus presents a unique opportunity to study how stress induced by such a situation affects mental health, and what behaviors protect and preserve it.

COVID-19, lockdowns, and mental health

The COVID-19 outbreak was associated with a lot of individual stress, including fear of infection with COVID-19 (Brooks et al., 2020), quarantine/isolation, health complications, and death. In response to this outbreak, general policy measures were put into effect to protect the population. Such measures can have unintended side effects. In Germany, by Mid-March 2020, the 16 German federal states had closed all schools and daycares (except for emergency care), and put social distancing requirements into effect. Importantly, despite some variability in the quantity of enforced lockdown measures, those measures with likely the most drastic impact—including closures of schools and daycares and restrictions on the number of people allowed to meet—continued in place over long periods of time (Steinmetz et al., 2020). Such measures have effects on various levels: In addition to reducing social and physical contact, which strongly impacts mental health, including depression, anxiety, and loneliness (Buecker et al., 2020; Leigh-Hunt et al., 2017), they also affected the working situation of most adults, with a significant proportion now in short-time work, unemployed, furloughed, or working remotely from home (Möhring et al., 2020). Such changes are associated with high financial stress, as well as social stress due to stigma or less personal contact with co-workers. Further, these policies are commonly associated with a loss of usual routines, which is associated with boredom and frustration (Brooks et al., 2020).

Given that the COVID-19-related policy measures have affected so many aspects of daily life over a period of several months, they likely do not lead to *one* major stressful life

event but rather to a number of repeated stressors, including numerous smaller daily life stressors. Importantly, repeated daily life stressors, such as problems juggling work and family demands, have a cumulative effect and impair health and well-being (Almeida, 2016). This effect of stress on mental health can change with repeated exposure to stressful experiences due to two general learning processes: habituation and sensitization (Eisenstein & Eisenstein, 2006). Habituation refers to a decreased level of response to a repeated stimulus, the more often a person is exposed to a stimulus, the lower the impact of the stressor on mental health; sensitization is defined as an increased level of response to a repeated (stressful) stimulus, leading to reinforcement of the effect of the stressor on mental health with increasing number of exposures (Eisenstein & Eisenstein, 2006). While people without a specific vulnerability to mental health disorders are likely to respond with habituation to repeated stressors—that is, they report fewer symptoms of mental health impairment (e.g., depression or anxiety)—those with vulnerabilities either show a stronger response and little or no habituation or even respond with sensitization—that is, they report even stronger mental health impairments. For example, a higher risk of developing major depressive disorder in individuals with a genetic risk of depression was found only if they had been exposed to repeated (two or more) stressful life events (Caspi et al., 2003). Similarly, people with higher vulnerability to depression showed increased negative affect in response to a repeated stressor (suggesting sensitization), whereas participants in a healthy control group showed signs of habituation (Mata et al., 2013).

Certain groups are more strongly affected by policy measures in general and might be at increased risk of experiencing diminished mental health in the face of COVID-19-related stressors: For instance, women have been especially impacted by the COVID-19-related economic downturn (Alon et al., 2020) and by massively increased childcare demands due to closed schools. Importantly, women are also more likely to experience distress (Kimhi et al., 2020) and symptoms of mental health problems including depression and anxiety (Connor et al., 2020). Thus, they are more vulnerable to poorer mental health as a consequence of COVID-

19-related stressors (see Pierce et al., 2020 for such findings in the United Kingdom). Others strongly affected by policy measures are those whose employment is insecure, for example, because they are working fewer hours, have been furloughed, or have lost their job; such people experience particularly high stress due to financial insecurity, loss of routine, and social stigma (Drydakis, 2015). Last, people in poor health may be particularly stressed in the current crisis, because the potential health consequences of a COVID-19 infection can be more severe. They are also more likely to be in stricter isolation, which is associated with poorer mental health (Brooks et al., 2020).

The role of health behaviors for mental health (in the face of stress)

As described above, the type and duration of policy measures implemented to protect the population from COVID-19 likely negatively affect mental health. Investigators examining factors involved in the onset of mental health disorders, such as depression, have focused on the interaction of stress and vulnerability or protective factors (Caspi et al., 2003). Vulnerability–stress models posit that the development of a mental health disorder is due to the interaction of stressful events with one or more vulnerability factors. Similarly, protective models focus on factors that may neutralize or reduce the impact of adverse experiences on the development of impaired mental health (Fergus & Zimmerman, 2005). Health behaviors can be such protective factors. In this study, we focus on health behaviors that are comparatively easy to change (i.e., cheap, low-threshold) and can be promoted by policy measures (e.g., open parks or playgrounds): screen time, snacking, and physical activity. Importantly, these health behaviors and mental health are linked to each other. For example, longer screen times are related to poorer mental health and less physical activity (Allen et al., 2019; Wang et al., 2019). Negative mood leads to increased food intake (of mostly sweet snack food, see Cardi et al., 2015 for a meta-analysis). Physical activity in people with high vulnerability to depression is related to higher positive affect, depressive and anxiety symptoms (Mata et al., 2010, 2012; see Rebar et al., 2015 for a meta-analysis). The negative associations between COVID-19-related

stressors and mental health should be particularly pronounced in people who report fewer snacks and shorter screen time and are more physically active. While the public health consequences of social isolation have been reported in preliminary systematic reviews, more research on the association between social isolation and health behaviors is strongly needed (Leigh-Hunt et al., 2017). It is largely unknown how health behaviors can promote mental health in the face of a crisis such as the COVID-19 pandemic.

Health behaviors during times of high stress (COVID-19)

Little research on engaging in health-promoting behaviors during times of high stress and social confinement is available to date. A recent study on the effects of the COVID-19 pandemic on physical activity, using an international convenience sample of smartphone application-users, showed that within 10 days of the World Health Organization's (WHO) declaration of a pandemic in 2020, the mean value of daily steps decreased by about 6%, and within 30 days by about 27% (Tison et al., 2020). Early cross-sectional data, collected within 2 weeks of the start of the lockdown, showed that 31% of Germans reduced their leisure-time sports activity (Mutz & Gerke, 2020; see Schnitzer et al., 2020, for similar results in Austria). These early findings suggest that a loss of usual routines, such as would be expected from the COVID-19-related policy measures, leads to a reduction in health-promoting behaviors and particularly physical activity. First, mostly cross-sectional studies show an increase in screen time (Sultana et al., 2021) and in snacking or general food intake (Deschasaux-Tanguy et al., 2021).

Research questions

The current study addressed (a) how the lockdown during the COVID-19 pandemic in Germany affected mental health and health behaviors, considering changes across time (i.e., repetition of stress; these questions will be tested in Hypotheses 1 and 2 below), and (b) how

health behaviors are related to mental health, specifically, if increases in screen time or snacking could be a risk and if maintenance of or an increase in physical activity could protect mental health in the face of lockdown-related stress (see Hypotheses 3 and 4 below). These questions were examined both for the entire sample and for specific groups, separated by gender, employment situation, age, and taking care of children. This study contributes to existing research in important ways: First, this study is based on a large probability sample representing the population of Germany. Mental health and health behaviors were assessed within a week of the COVID-19 lockdown in Germany. Second, it is a longitudinal study with three measurement points, allowing to observe changes over time. Third, the potential role of health behaviors in improving or deteriorating mental health has not been investigated.

Hypotheses

On the basis of the literature reviewed above, the following hypotheses are proposed:

(1) The lockdown will be associated with more symptoms of anxiety, depression, and loneliness such that the number of symptoms will be highest at the start of the lockdown and will decrease with repeated exposure (i.e., consistent with a pattern of habituation). The following groups will experience more symptoms at the start of the lockdown and will show stable or even increasing levels of anxiety, depression, and loneliness (i.e., consistent with a pattern of sensitization): (1a) women, (1b) individuals taking care of children, (1c) people who work short-time, are furloughed, or unemployed, and (1d) people with poor health. (2) The lockdown will be associated with significant increases in screen time and snacking and with decreases in physical activity. (3) Individuals who report lower levels of screen time, lower levels of snacking, or higher levels of physical activity will report fewer symptoms of anxiety, depression, or loneliness. (4) There will be a dose–response effect between health behaviors and mental health: Individuals who decrease their screen time, decrease snacking, or increase their physical activity during lockdown (compared to pre-lockdown), will report a smaller increase in symptoms of anxiety, depression, or loneliness as an immediate response to the

lockdown and a stronger decrease in symptoms than those who maintain levels of screen time, snacking, or physical activity. This difference in increase in mental health symptoms will be even more pronounced compared to those who increase levels of screen time, snacking, or decrease physical activity.

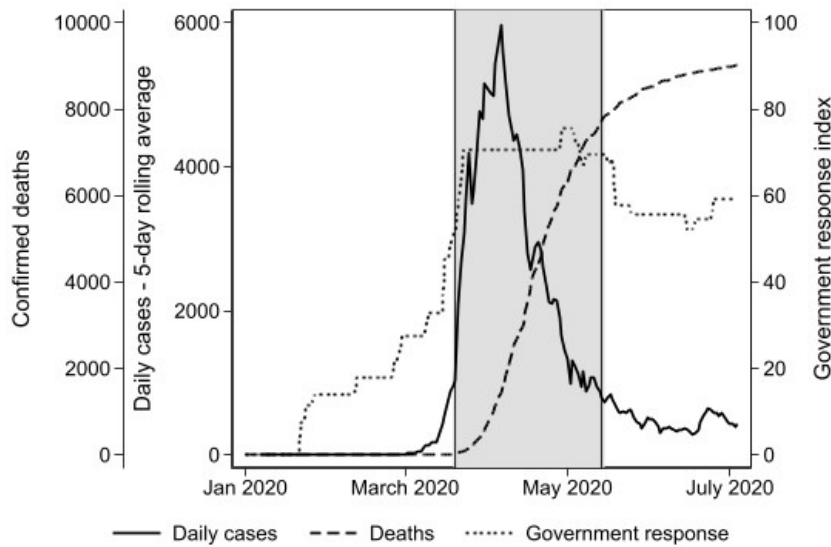
Methods

Data

The data were drawn from the Mannheim Corona Study of the German Internet Panel (GIP; Blom et al., 2015, 2020). Participants were recruited offline in 2012 with random probability sampling of the general population aged 16 to 75 years in Germany, with refreshment samples included in 2014 and 2018. The Mannheim Corona Study contains questions about the social and economic situation of participants (e.g., childcare, work) and the impact of the pandemic-related political measures on social interactions, mental health, and health behaviors. The study started on March 20, 2020, that is, within a week of schools and daycares closing (see Figure 1).

All active participants of the GIP (n=5449) were invited to take part in the Mannheim Corona Study (Table 1 for participant details). This sample was divided into eight random subsamples: Subsamples 1 to 7 were assigned to a specific weekday; Subsample 8 was a control group and did not take part in the Corona Study. On each weekday, participants of the respective subsample received an e-mail with a link to the current survey. They had up to 48 h to fill out the questionnaire and were explicitly encouraged to do so within the first 24 h.

Figure 1. COVID-19 related lockdown measures in Germany, confirmed cases and deaths, and measurement period of the survey in grey.



Note. Grey area represents timing of the three measurement points. Figure based on the Oxford COVID-19 Government Response Tracker (https://github.com/OxCGRT/covid-policy-tracker/blob/master/documentation/index_methodology.md)

Within any one week, the questionnaire was identical for all participants; most questions were identical across all measurements, but some measures (including health behaviors) were asked about once a month, allowing observation of intra-individual changes over time.

Here, we rely on three waves of the Mannheim Corona Study from April 2020 ($n=3516$), May 2020 ($n=3409$) and June 2020 ($n=3334$). Response rates in each wave vary between 69% and 73%. We used weights (based on age, gender, employment, occupational sector, marital status, highest level of education, household size, and federal state) to project the characteristics of the Mannheim Corona Study participants to the general GIP (i.e., accounting for non-participation) and to extrapolate the characteristics of GIP-participants to those of the general population (Blom et al., 2020, for details). The Mannheim Corona Study is regularly controlled by the University's Data Protection Officer and fulfills the standards of the European Union

General Data Protection Regulations (GDPR), which is equivalent to an approval by an Institutional Review Board.

Table 1. *Sociodemographic Characteristics of the Sample (weighted)*

Variable	Weighted percentage
Age (years)	
18–35	21.1%
36–59	48.6%
60+	30.3%
Gender	
Female	50.2%
Male	49.8%
Employment situation (in January 2020)	
Working	57.3%
Unemployed	2.3%
Retired	18.5%
Not working for pay (e.g., studying, on leave, housework)	21.9%
Employment situation (in April 2020)	
Working at the workplace	33.4%
Remote work	14.4%
Short-time work, furloughed, unemployed	15.7%
Retired	18.7%
Not working for pay (e.g. studying, on leave, housework)	17.8%
Subjective health status (in January 2020)	
Very good	12.5%
Good	53.7%
Sometimes good, sometimes bad	27.6%
Bad	5.1%
Very bad	1.2%
Education (highest level of school education)	
Low	27.2%
Middle	31.8%
High	40.9%
Family situation	
No children in household	77.7%
Couple with child(ren) in household	19.7%
Single parent	2.6%

Note. Percentages do not always add up to 100.0% due to rounding. Education low = without or with basic school-leaving qualification; middle = intermediate school-leaving qualification; high = higher education entrance qualification. We follow the International Labour

Organization definition of unemployment, which does not include mini-jobs (i.e., a type of employment without social security or tax obligations; about 7 million people in Germany work in a mini-job; German Federal Employment Agency, 2021). This largely explains the lower unemployment rate in our sample compared to the German official unemployment rate that counts mini-jobs as unemployment.

Control variables

Analyses will consider socio-demographic characteristics of the sample (Table 1), because health behaviors and mental health vary by gender, family situation, employment status and subjective health (see Introduction), as well as by age (e.g., Jones et al., 2013; Saint Onge et al., 2017) and education (Hoebel, Maske, Zeeb, & Lampert, 2017; Pampel, Krueger, & Denney, 2010). Aspects such as the number of policy measures in effect during lockdown (e.g., closure of schools) and weather, an important predictor for physical activity (Schüttoff & Pawlowski, 2017), will be controlled for by adding the time variable in all analyses.

Measures

Anxiety, Depression, and Loneliness

Anxiety was assessed with two items from the German version of the State-Trait Anxiety Inventory short scale (Englert et al., 2011). The two statements “I am nervous” and “I am worried that something could go wrong” are rated on a 4-point scale from *not at all* to *very much*. They are the two items with the highest factor loading on “worry” and “emotionality,” respectively. Cronbach’s alpha for the two items was 0.77. We use the mean of the two items as our dependent variable for anxiety ($M=1.74$, $SD=0.64$, range = [1,4]).

Starting in Week 5 (April 18–25, 2020), three items on depression and loneliness were added (in response to the request by the COVID-19 and Mental Health Measurement Working Group of the Johns Hopkins Bloomberg School of Public Health from March 18, 2020; using the same measures allows comparing findings across studies and countries). Depression was

assessed with two items from the Patient Health Questionnaire (PHQ-2; Löwe et al., 2010): “In the last 7 days, how often have you felt down, depressed or hopeless?” and “In the last 7 days, how often have you had little interest or pleasure in doing things?” Cronbach’s alpha was 0.84. Loneliness was measured by asking, “In the last 7 days, how often have you felt lonely?” (adapted from the Center for Epidemiologic Studies Depression Scale; Radloff, 1977). All answers were given on a 4-point scale from 1 (*not at all or less than one day*) to 4 (*on 5–7 days*). We use the mean of the two depression items as our dependent variable for depression ($M=1.45$, $SD=0.69$, $range=[1,4]$) and leave the loneliness item in its original coding ($M=1.32$, $SD=0.68$, $range = [1,4]$). See Table S1 for further distributional properties of the dependent variables.

In contrast to the health behavior items described below, aspects of anxiety, depression, and loneliness were not assessed retrospectively (to get a “pre-COVID-19 baseline”), because retrospective memory bias is particularly prominent in emotions (Fahrenberg et al., 2007), whereas memories of health behaviors such as physical activity have been found to be valid for longer retrospective periods (Godin & Shephard, 1985).

Screen time

Screen time was assessed for weekdays only, because screen time on weekdays is substantially lower than during weekends, and for the majority of participants, the lockdown more strongly affected weekday activities such as work or school. At the first measurement point, participants reported how many hours and minutes in total they spent on an average weekday with computers, smartphones, gaming, watching TV or streaming, and with other electronical devices (Przybylski & Weinstein, 2019), for both the week before the lockdown and the past week. At the following two measurements, participants reported on the past week.

Snacks

Participants reported how many snacks they ate per day (i.e., amount of foods high in sugar, salt, or fat consumed outside of meals, such as chocolate, ice cream, chips, etc.; Flueckiger et al., 2017). At the first measurement point, they again reported on the week before the lockdown and the past week; at the following measurements only on the past week.

Physical activity

Participants reported for how long (hours and minutes) they had engaged in moderate (not exhausting, e.g., fast walking), or vigorous physical activity (heart beats fast, e.g., fast jogging; adapted from Godin & Shephard, 1985). At the first measurement point, participants reported their activity in the week of March 2–8, that is, the week before the lockdown measures in Germany, and in the past week (April 3–10; Table S1 for an overview of measurement dates). At the following two measurement points, participants described only the past week. We transformed time spent in vigorous and moderate exercise into MET minutes (MET = metabolic equivalent of task); minutes spent in vigorous activity were multiplied by 8, minutes spent in moderate activity by 4 (following Haskell et al. (2007) to assess whether physical activity was as high as recommended by the WHO guidelines, i.e., at least 600 MET minutes of moderate and/or vigorous activity per week). Importantly, meeting the WHO guidelines (2010) is associated with significantly lower risks of noncommunicable disease mortality and is therefore informative for policy makers. Thus—in contrast to screen time and snacks where comparable evidence-based guidelines are not available—for physical activity we report the percentage of participants meeting the WHO guidelines.

Statistical analyses

We rely on longitudinal, individual-level panel data, that is, the same individuals answered the survey at three time points during the first lockdown; items on depression and loneliness are only available for two waves. Multilevel mixed-effects linear regression models with random effects were estimated to account for the nested structure of the data (i.e., several observations over time are nested within one respondent) to test Hypotheses 1–3. The analyses

controlled for age, gender, employment status, health, education, and family situation. We also included a dummy variable for time trend in the dependent variables. The following model is estimated:

$$\begin{aligned} health_{ij} = & \beta_0 + \beta_1 behaviors_{ij} + \beta_2 control\ variables_{ij} + \beta_3 time_{ij} + \mu_{j0} \\ & + \mu_{j1} behavior_{ij} + \varepsilon_{ij} \end{aligned}$$

Where i denotes the measurement nested in person j , the vectors *behavior* and *control variables* capture individual characteristics that might vary over time, μ_{j0} and μ_{j1} are individual-specific residuals (random effects) and ε_{ij} are residuals at the measurement occasion level. *Time* is added as an additional control variable.

To test within-person changes in mental health and their relation to changes in health behaviors (Hypothesis 4), a first-difference model was used: For both the dependent and the independent variable, the respondent's prior value was subtracted and examined whether changes in health behavior are related to changes in mental health. These models offer good protection against bias due to observed and unobserved time-constant heterogeneity (Vaisey & Miles, 2017). Thus, there is no need to add time-constant control variables to the model. All analyses were conducted with STATA 16. The respective do-File is available in the Supplemental Materials; the data are freely available for scientific use (for requests: <https://www.uni-mannheim.de/en/gip/for-data-users/>).

The extent of missing data due to item non-response was quite small— below 1% for anxiety, depression, loneliness, screen time, and snacks, 5.8% for physical activity. Missing data were handled using listwise deletion. This is in line with available guidelines (Cheema, 2014). Given that our sample was large even after the exclusion of incomplete cases, imputation was not necessary to increase statistical power. Moreover, we use weights which account for non-participation. The sample analyzed was slightly older and better educated than the 441 participants that were excluded for not participating in any of the three waves.

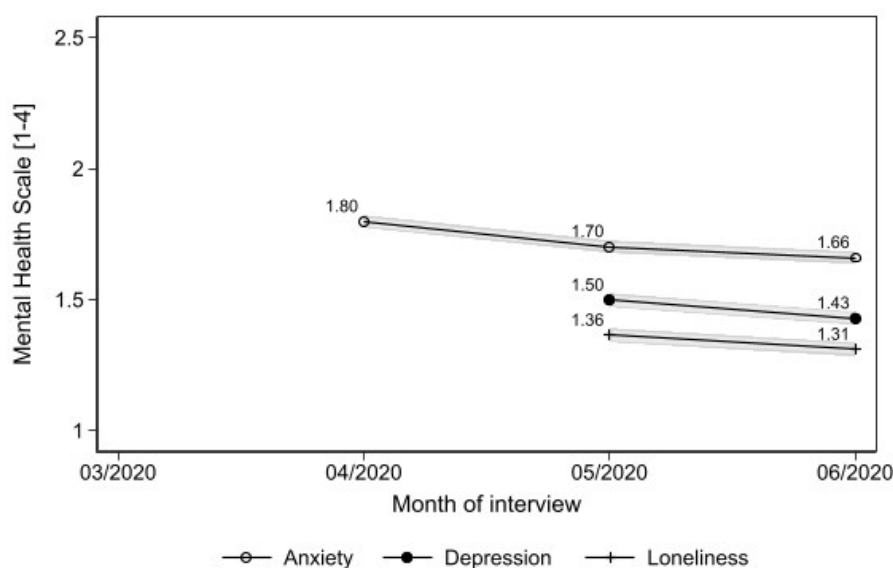
Results

To examine how much of the variance in health behaviors and mental health was due to person characteristics versus within-person changes over time, intraclass correlations were calculated. For screen time, 36% of the variance was due to person characteristics, for snacks 40%, exercise (the sum of moderate and vigorous activity) 45%, anxiety 72%, depression 76%, and loneliness 75%. Thus, all variables of interest showed a considerable within-person variation over time and multilevel modeling was used.

Mental health during the lockdown (Hypothesis 1)

Symptoms of anxiety, depression, or feelings of loneliness were not assessed pre-lockdown; therefore, we report changes in symptoms during the lockdown. As expected, symptoms of anxiety, depression, and loneliness were highest directly after the start of the lockdown and then went slightly down (see negative coefficients of the time variables in Table 2), corresponding to a pattern of habituation (Figure 2).

Figure 2. Changes in mental health during the lockdown (estimates from multilevel regressions with adjusted values that take changes in control variables into account).



Note. On the y axis, 1 = not at all, 2 = a little bit, 3 = considerably, 4 = very much for anxiety;

for depression and loneliness: 1 = not at all or less than one day, 2 = on 1–2 days, 3 = on 3–4 days, 4 = on 5–7 days. Estimates are adjusted values based on multilevel models with control variables (Table 2); all continuous control variables are set to their mean values. Gray shadings show 95% confidence intervals.

Table 2. *Health Behaviors and Mental Health: Results of Multilevel Mixed-Effects Linear Regression Models with Random Effects*

	Anxiety	Depression	Loneliness
Screen time (in hours)	0.00034 (0.0014)	0.005* (0.0019)	0.004* (0.0018)
Snacks	0.020*** (0.0045)	0.028*** (0.0075)	0.015* (0.0073)
Physical Activity	-0.011 (0.0136)	-0.053** (0.0194)	-0.019 (0.0192)
04/2020	Reference category		
05/2020	-0.084*** (0.0114)	Reference category	Reference category
06/2020	-0.12*** (0.0123)	-0.056*** (0.0109)	-0.060*** (0.0116)
Constant	1.63*** (0.0351)	1.48*** (0.0263)	1.34*** (0.0259)
Control variables		Yes	Yes
Observations	9746	6546	6544
<i>N</i>	3842	3707	3707

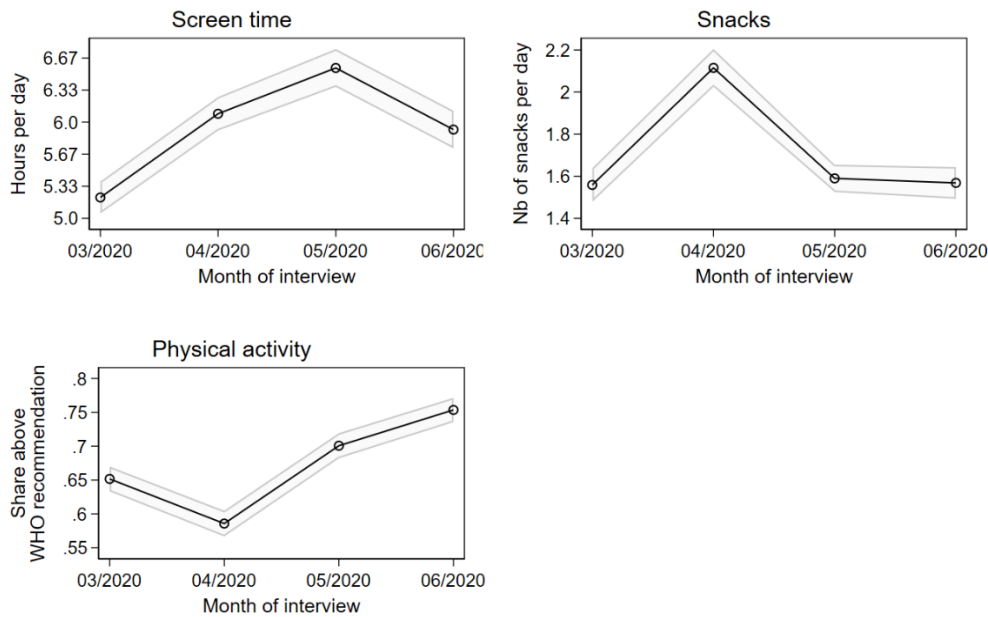
Note. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Observations are the number of observations in the analyses; *N* = number of participants in the analyses. Control variables=age (centered around the mean), gender, employment situation, subjective health status, education, and family situation. Variable names in bold: Coefficients present relation between variables (e.g., screen time in hours and depression = 0.005) between persons and above and beyond the time trend. Variables 05/2020 and 06/2020 show changes over time compared to the first measurement in 04/2020, holding all other variables constant (see also

Figure 2). Constant represents average of items for anxiety, depression, and loneliness, respectively, at first measurement (=reference category). Continuous variables (i.e., screen time, snacks and age) are centered around the mean.

Next, we examine differences in mental health between vulnerable and non-vulnerable groups relying on the same multilevel models (Figure S2): Women, people who were unemployed, furloughed, or in short-time work, and those with poor general health showed higher levels of anxiety. People with poor general health showed higher levels of depression and feelings of loneliness. Couples with children felt less lonely than single parents and those without children. We replicate this pattern of results when examining which groups have the largest share of people with high average values for anxiety, depression, and loneliness (see Table S3). To explore change in mental health symptoms over time in these potentially more vulnerable groups, we added interaction terms between group indicators and time to the regression models. We present patterns in different groups, controlling for socio-demographic variables (Figure S1). Among all groups, anxiety, depression, and loneliness went slightly down corresponding to patterns of habituation rather than sensitization.

Health behaviors before and during the lockdown (Hypothesis 2)

Generally, as hypothesized, compared to levels before the lockdown, screen time and snack consumption significantly increased and physical activity decreased within the first month after the lockdown commenced. Interestingly, the amount of snacking and physical activity went back to pre-lockdown levels within two months; only screen time increased further (Figure 3). Detailed results, also for different subgroups, are described below.

Figure 3. *Changes in health behaviors before and during the lockdown.*

Note. Gray shading shows 95% confidence intervals. Nb=number; WHO = World Health Organization. Estimates are adjusted values based on multilevel models with control variables set to their mean values.

Screen time

Screen time increased from 6 hours and 10 minutes/ day to 7 hours and 2 minutes /day from March to April; this trend continued into May and June (+80 min/day and +40 min/day compared to before the lockdown, respectively; Figure 2). Across all lockdown measurement points, women, parents, and those claiming good health reported less screen time. People working remotely spent more time in front of a screen (Figure S2).

Amount of snacking

People ate on average 0.56 more snacks/day in April compared to before the lockdown. In May and June, the number of snacks per day returned to pre-lockdown levels of about 1.5 snacks/day (see Figure 3). Women, parents (but not single parents), and those with poor health

ate more snacks. Employment status was not associated with the amount of snacking (Figure S2).

Physical activity

Before the lockdown, 65.3% of all participants were as active as recommended by the WHO; a month after the lockdown this number decreased to 57.9%, but in May and June it increased and even surpassed pre-lockdown proportions with 69.2% and 76.1%, respectively (Figure 3). Women, parents, all people not working at their workplace (i.e., working remotely, furloughed or unemployed), and those with poor health were less active. Comparing these different subgroups, it is notable that particularly a lower share of women did not meet the WHO recommendations for physical activity during the entire lockdown (Figure S2).

Cross-sectional relations between health behaviors and mental health during lockdown (Hypothesis 3)

Because anxiety, depression, or feelings of loneliness were not assessed pre-lockdown, we examine their relation with health behaviors during the lockdown using multi-level modeling, with anxiety, depression, and loneliness as dependent variables, the three different health behaviors as independent variables, and the demographic variables reported in Table 1 and time as control variables. As expected, more screen time is related to more symptoms of depression (0.005) and loneliness (0.004), snacking is correlated with higher levels of anxiety (0.020), depression (0.028) and loneliness (0.015), and physical activity is related to lower levels of depression (-0.053). In three instances the direction of the correlation is as expected, but not significantly different from zero: Anxiety was not related to screen time, and physical activity was not related to anxiety or loneliness (see Table 2 for results).

Dose–response effects over time between amount of screen time, snacking, and physical activity and mental health symptoms (Hypothesis 4)

In the last step of our analyses, we examined whether changes in health behavior were related to changes in mental health symptoms. Did the lockdown-induced reduction in physical

activity or the increase in screen time lead to changes in mental health? Our results do not support this expectation in the short run, and a change in health behaviors generally did not predict a change in mental health symptoms (Table 3). There is one exception: An increase in the number of snacks consumed coincided with an increase in anxiety symptoms (0.013). Therefore, Hypothesis 4 is not supported for screen time and physical activity, but partially for snacking.

Table 3. *Dose–Response Effects Over Time Between Amount of Screen Time (in hours), Snacking, and Physical Activity and Mental Health Symptoms*

	Δ Anxiety	Δ Depression	Δ Loneliness
Δ Screen time (in hours)	-0.00027 (0.0017)	0.0025 (0.0026)	0.00098 (0.0025)
Δ Snacks	0.013** (0.0044)	0.0022 (0.0072)	0.0036 (0.0064)
Δ Physical activity (WHO recommended level)	-0.0072 (0.0184)	-0.038 (0.0270)	-0.015 (0.0241)
06/2020	0.048** (0.0174)		
Constant	-0.091*** (0.0125)	-0.067*** (0.0122)	-0.055*** (0.0125)
Observations	5760	2839	2837
N	2880	2839	2837

Notes. Results of regressions with changes in health behaviors as independent variables and changes in mental health as dependent variables (first-difference model). Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Observations are the number of observations in the analyses; N = number of participants in the analyses. Δ = Change. WHO = World Health Organization.

Discussion

This study examined the change in mental health symptoms in the face of repeated stress over time, particularly, whether and how health behaviors relate to mental health during such stress. Data came from a unique data set in which symptoms of mental health and health behaviors were regularly assessed over three months in a large, nationally representative sample of adults from Germany. As predicted, symptoms of anxiety, depression, and loneliness were highest shortly after the lockdown came into effect. The symptoms were stable or went down slightly over time, consistent with patterns of habituation to the situation. Potentially counterintuitive is the finding that—overall—participants reported good mental health during the first months of the COVID-19 pandemic. Importantly, among people with higher vulnerability to poor mental health, the proportion with high levels of anxiety, depression, and loneliness was considerably larger. These groups also reported fewer health-promoting behaviors. More screen time, more snacking, and less physical activity were related to higher symptoms of anxiety, depression, and loneliness across all time points. With the exception of an increased amount of snacking being related to an increase in anxiety symptoms, changes in health behaviors did not predict changes in mental health symptoms.

Mental health symptoms over time during the lockdown

In line with our expectations, symptoms of anxiety, depression, and loneliness in the general population correspond to patterns of habituation. However, contrary to our predictions, groups that are likely more vulnerable to poorer mental health during the prolonged lockdown did not show an increase in symptoms over time, but rather, very small decreases. This finding is in contrast to other research that showed signs of sensitization in the face of repeated stressors in vulnerable groups (Caspi et al., 2003; Mata et al., 2013). Importantly, these previous research findings are based on a—with respect to mental health—comparably homogeneous group of people: People with high vulnerability to one mental illness, major depressive disorder. The groups identified as potentially more vulnerable to lower mental health in our study were much

more heterogeneous: For example, people living in households with children vary greatly in their resources available to buffer stress resulting from lockdown policies (Prime et al., 2020). The same argument can be made for other potentially vulnerable groups, such as women or those with disrupted employment situations.

Health behaviors before and during the lockdown and their relation to mental health

As predicted, the lockdown was associated with significant increases in screen time and snacking and a decrease in physical activity. Screen time continually increased in the first two months after lockdown commenced and even after three months was still higher than before the lockdown. This is in line with other (often cross-sectional) studies that unanimously report an increase in screen time (Sultana et al., 2021), for example, in a cross-sectional convenience sample from nine European countries, reported increase in screen time was 65% (Pisot et al., 2020). Monitoring screen time is important, because it has been associated with lower well-being (Allen et al., 2019; Wang et al., 2019), less physical activity, and more snacking (Mansoubi et al., 2014)—all important predictors of mental and somatic health.

Interestingly, snacking and physical activity went back to pre-lockdown levels within two and three months after the lockdown started, corresponding to a pattern of habituation. Direct comparisons of our results with others studies on health behaviors during the COVID-19 pandemic can be difficult, because the vast majority of studies are cross-sectional or rely on two measurement points, often farther apart. One exception are the analyses by Tison and colleagues (2020) who showed a similar pattern of decline and then fast “normalization” for a variety of countries in different climate zones. A study from Italy even reported more people exercising than before the lockdown—but now at home instead of outside (Di Renzo et al., 2020). An increase in snacking in April-May 2020 has also been reported in other studies (NutriNet-Santé cohort; Deschasaux-Tanguy et al., 2021), albeit this increase is not quantified. Ecological momentary assessments of the first 30 days during the lockdown in the UK showed no change in high sugar portions per day compared to pre-lockdown levels (Naughton et al.,

2021). Importantly, patterns of physical activity and snacking were not equal across different subgroups. Similar to our findings, a US study on physical activity has shown that the discrepancy in physical activity between men and women increased over the time of the pandemic, with women becoming less active (Sher & Wu, 2021). That the proportion of women meeting physical activity recommendations stayed below pre-lockdown levels, even three months after the lockdown started, is worrisome, because it has ramifications for somatic and psychological health. Being as physically active as recommended is associated with a 31% lower overall mortality risk and to a greater than 50% risk reduction in acquiring major chronic medical conditions (Rhodes et al., 2017). Also, it buffers the effects of stress (Rebar et al., 2015), even in vulnerable groups (Mata et al., 2013). Similar gender patterns can be found for snacking, where women's increased snacking intake was not back to baseline levels three months later. In combination with lower physical activity, this has the potential to cause weight gain.

Dose–response effects over time between amount of screen time, snacking, and physical activity and mental health symptoms

In contrast to our hypothesis, we did not find a dose–response effect of more engagement in health-promoting behaviors (i.e., decrease in screen time or snacking, or increase in physical activity) and fewer symptoms of anxiety, depression, or loneliness over time—with the exception of higher snacking predicting higher anxiety at later measurements. These findings are in contrast with other experimental or intensive longitudinal studies, for example, on physical activity, which have reported a dose–response effect also in the face of stress (Ekkekakis et al., 2011; Flueckiger et al., 2016). Importantly, these studies have not necessarily tested a lagged effect (e.g., Flueckiger et al., 2016). It should also be noted that the COVID-19 pandemic has had an impact on all facets of daily life. It may be difficult to identify the impact of three distinctive health behaviors in this complex situation that has been largely driven by a multitude of external factors. Additionally, the comparably long measurement gaps

of about one month make it difficult to detect how change in a specific health behavior is related to a multicausal construct such as mental health. To better understand how changes in health behavior precede changes in mental health, more intensive designs might be necessary, such as various measurements per day over longer time periods (e.g., Naughton et al., 2021).

Strengths and Limitations of the Study

One of the great strengths of this study is its sample: Participants were recruited offline using random probability sampling to achieve the most accurate representation of the German population. The same participants reported on their mental health and health-related behaviors roughly monthly over three months during a lockdown due to a major global crisis. This longitudinal design allowed observing changes, but we cannot draw conclusions about directionality or causality for the lockdown measures. As in all longitudinal observational studies, the possibility of regression to the mean needs to be considered when interpreting change. Importantly, it seems implausible that regression to the mean was the sole driver of the patterns observed, because (a) the data were assessed at the beginning of a national lockdown, a kind of natural experiment that makes the assumption of random, natural variation in the observed patterns of symptoms and behaviors little likely, (b) the pattern of change is comparable between different health behaviors (e.g., snacking and physical activity), and (c) our findings are in line with other study findings (see above). Yet, it is not possible to entirely exclude a regression to the mean effect or estimate its possible size. Although the data are based on self-reports, the questionnaires used validated measures. While the health behaviors in the current study are clearly relevant to mental and somatic health during the COVID-19 pandemic, additional health behaviors, such as alcohol, tobacco, or drug use, would have been interesting to explore. Health behaviors before the lockdown were assessed retrospectively. While valid instruments for retrospective assessment of health behaviors are available (Godin & Shephard, 1985, for physical activity), retrospective assessments can be influenced by the situation at the time of measurement; measuring health behaviors before the lockdown would have further

strengthened the design. Indicators of mental health were assessed only after the lockdown had started. While this is sensible, given that retrospective reports on affective states are particularly error prone (Fahrenberg et al., 2007), this implies that mental health trajectories are only available for the duration of the crisis.

The COVID-19 pandemic can be seen as a kind of natural experiment, in which the impact of accompanying measures of the pandemic on mental health can be examined. While this is a unique and powerful research situation, this also comes with challenges. For example, the lockdown included a large variety of measures that likely affected people differently, depending on their age, gender, family situation, occupation, health status, or place of residence. To account for such variability, we controlled for a number of person characteristics and conducted subgroup analyses. Further, the quantity of lockdown measures in the different federal states (Steinmetz et al., 2020) was generally high throughout the measurement period and, more importantly, the measures with likely the most drastic consequences were enforced throughout the measurement period (e.g., school closures, restriction on the number of people a person is allowed to meet). Therefore, the lockdown period observed in this study can reasonably be interpreted as a time with high exposure to repeated stressors for most people. Nevertheless, the lockdown might have been a positive experience for some people.

Policy Implications

The results of the current study have several policy implications. While, generally, people seemed to adjust well to the lockdown situation, among potentially vulnerable groups such as single parents, the share with very high anxiety symptoms at the beginning of the lockdown was about twice as high as the general population. Such anxiety can spill over to children and increase the probability of child maladjustment. When parental and family well-being are preserved, children can cope better with adversities (Prime et al., 2020). Therefore, focusing on factors that promote resilience in the face of the challenges is of particular importance. Further, a decline in physical activity paired with an increase in snacking might

be buffered by finding ways to keep outdoor recreational areas (e.g., parks and playgrounds) or suppliers of fresh produce (e.g., open-air markets), open. While working at home is a central measure to reduce COVID-19 incidence and inevitably leads to the replacement of personal meetings with video calls, there are still possibilities to reduce screen time. This can include reducing meeting duration or engaging in walk-and-talk meetings via telephone, combined with a stroll outside (Levine & McCrady-Spitzer, 2018).

Conclusions

This is one of the first studies to describe the effect of a global health crisis in a large population sample over time. In contrast to the assumption that repeated exposure to stressors necessarily leads to worse health outcomes, overall, our data do not show a significant increase in symptoms of mental illness and that—with the exception of screen time—health behaviors reached pre-pandemic levels comparably quickly. Thus, the pattern of findings corresponds to habituation over the three months assessment period. Health-promoting behaviors were clearly related to indicators of mental health. More vulnerable groups were more likely to experience symptoms of poorer mental health and showed less engagement in health promoting behaviors. The crisis-related policy measures to protect the population can have unintended side effects for health with potentially long-term impact. This paper makes a unique contribution by not only describing aspects of mental health during a lockdown but also the potential for health-promoting behaviors. This crisis will have a long-term impact on ways of life and work; for example, a higher level of digitalization and remote work is likely to stay. In this paper, we identified behaviors that can promote health in such situations and beyond.

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