Title: Changes in physical activity and sedentary behaviour due to the COVID-19 outbreak and associations with mental health in 3,052 US adults

Short Title: Physical activity, sedentary behaviour, mental health and COVID-19

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Abstract:

Aims: The COVID-19 pandemic and associated global response have significantly altered people's behaviour, likely decreasing physical activity, increasing sitting and screen time, while simultaneously worsening mental health. The objective of this project was to evaluate the impact of COVID-19-related public health restrictions on physical activity, sedentary time, mental health, and their interrelations.

Methods: Cross-sectional data were collected from 3,052 US adults between April 3rd-7th, 2020. Participants were recruited through convenience sampling from mass emails to faculty, staff, students, and alumni of Iowa State University and additional snowball sampling resulting in responses from all 50 states and the District of Colombia. Moderate and vigorous physical activity, sitting, and screen time, both pre- and post-COVID-19-related restrictions, along with currently-followed public health restrictions were self-reported. Current mental health was reported including stress (Perceived Stress Scale-4), loneliness (3-item Loneliness), positive mental health (Short Warwick-Edinburgh Mental Wellbeing Scale), social connectedness (Lubben Social Network Scale), and depressive and anxiety symptoms (Beck Depression and Anxiety Inventories). Participants were grouped by meeting US physical activity guidelines (active/inactive), reporting ≥8 hrs/day of sitting, or ≥8 hrs/day of screen time, pre- and post-COVID-19-related restrictions.

Results: Of the 3,052 participants (62% female), age ranged from 18-24 (16.6% of sample) to 75+ (9.3%). Weekly physical activity was reduced after COVID-19-related restrictions among previously active participants (mean change: -32.3% [95% CI: -36.3%, -28.1%]) but largely unchanged among previously inactive participants (+2.3% [-3.5%, +8.1%]). Large increases in

sitting time (previously active: +26.4% [+22.6%, +30.1%]; inactive: +16.0% [+13.2%, +18.8%]) and screen time (previously active: +37.8% [+32.7%, +43.0%]; inactive: +25.3% [+21.6%, +29.1%]) were reported. No longer meeting physical activity guidelines and increased screen time following COVID-19-related restrictions were consistently associated with worse current mental health (i.e., higher depressive symptoms, loneliness, stress, lower positive mental health; all $p<0.001$). Being in self-isolation/quarantine was associated with higher depressive and anxiety symptoms compared to only social distancing (both $p<0.001$).

Conclusions: The COVID-19 outbreak has resulted in rapid, substantial changes to physical activity and sedentary behaviour. Decreased physical activity and increased screen time were consistently associated with poorer mental health. Concerted efforts to maintain and enhance physical activity participation and limit screen time during pandemic-related public health restrictions are needed to mitigate short- and likely long-term mental health consequences.

INTRODUCTION

The novel coronavirus (COVID-19) has rapidly altered many facets of life globally. In the US, all 50 states had declared a state of emergency by March 16th, 2020. In response to this global pandemic, governments have introduced diverse measures (Gostin and Wiley, 2020) designed to limit the disease transmission to prevent critically overburdening healthcare systems. These measures range from social distancing (staying ≥6 feet/2 meters away from others) to quarantining people who have been exposed to the virus for 14 days or longer. Changes in work and social environments are occurring rapidly and likely affect both behaviour and mental health, but limited data exist to determine the impact of these changes.

The effects of making pandemic-related behavioural changes on population mental health are not well documented. A 2020 rapid review (Brooks et al., 2020) found that quarantine regularly resulted in acute negative psychological effects with potentially persistent effects. Recent cross-sectional surveys from adults in China indicated high levels of depressive and anxiety symptoms likely associated with the pandemic (Huang and Zhao, 2020; Lai et al., 2020; Wang et al., 2020). Furthermore, physically active people were more impacted psychologically by COVID-19 response measures in China (Zhang et al., 2020), potentially due to limited opportunities for activity. Physical activity appears to be reduced following COVID-related public health restrictions. A recent blog post from Fitbit Inc. indicated average decreases in step count across the US during the week of March 22nd of 12%, with larger decreases across the world.(Fitbit, Inc., 2020), This is concerning as there are consistent positive benefits of regular physical activity for mental health (Raglin, 2012; Gordon et al., 2018; Ashdown-Franks et al., 2019) and reducing physical activity is likely to compound the already-problematic psychological effects of public health restrictions (Brooks et al., 2020). Finding and promoting

ways to improve or maintain psychological health are of utmost importance during this time period (Holmes et al., 2020) . Being regularly physically active pre- and/or post-pandemic could limit the impact of the pandemic on mental health. However, data are not yet available to indicate the associations between changes in physical activity and sedentary behaviour due to pandemic-related public health restrictions and mental health.

Given the rapidly evolving response to COVID-19 and the paucity of current data, the present study was designed and conducted to evaluate three hypotheses: 1) that self-reported changes in physical activity, sitting time, and screen time after the pandemic would occur relative to the degree of COVID-related public health restrictions that were followed, 2) that self-reported current mental health would be associated with the degree of changes in physical activity, sitting time, and screen time (a) and COVID-related public health restrictions (b), and, 3) that the association between changes in physical activity and current mental health would be moderated by the degree of COVID-related public health restrictions that were followed. Evaluating these hypotheses will critically inform current and future policy approaches related to pandemics.

METHODS

The design of the *COVID-19 and Wellbeing* study includes cross-sectional and longitudinal components which were approved as an exempt project by the local Institutional Review Board and is associated with a broader cross-national collaborative effort focused on self-isolation. Cross-sectional data were investigated herein. Convenience sampling using mass emails that included a link to an anonymous online survey to Iowa State University students, faculty, staff,

and alumni, snowball sampling, and posts to social media pages were used to recruit self-selected participants (Figure 1). Data analysed were collected April 3rd-8th, 2020. This study adhered to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (von Elm et al. 2007).

Inclusion criteria were age of ≥18 years and current US residence. Potential participants provided informed consent and confirmed inclusion criteria before starting the survey. Participants self-reported demographic information, health history, COVID-19-related restrictions they were following, COVID-19-related health behaviours and their changes, and mental health questionnaires.

Demographics and health history

Participants self-reported age, gender, sex, race, education, marital status, occupational status, height and weight. Health history included self-reported current chronic health conditions based on a list of common illnesses.

COVID-19-related public health restrictions

Participants indicated which public health restrictions they were currently following by selecting all that applied: quarantined or self-isolating, under a shelter-in-place or stay-at-home order, and social distancing.

COVID-19-related health behaviours and change

Participants reported current smoking status. Participants reported average daily time spent sitting, engaged in moderate and vigorous physical activity (reported separately), and average

daily screen-time. These were reported based on asking about these behaviours both pre- and post-restrictions.

Mental health

The 4-item Perceived Stress Scale-4, (range: 0-16) assessed stress; higher scores indicate greater perceived levels of stress (α=0.60-0.82) (Lee, 2012).

The 3-item Loneliness scale examined loneliness (range 0-3); higher scores indicate greater loneliness. This measure has demonstrated high internal consistency in previous studies (α = 0.72) (Hughes et al., 2004).

The Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS-7; range 7-35) examined positive mental health (PMH); higher scores indicate more positive mental health. This scale has demonstrated high internal consistency in other populations (Cronbach's α=0.83-0.87) (Haver et al., 2015).

Social engagement was assessed using a 3-item form of the Lubben Social Network Scale-6 that combined friends and relatives in individual questions (range 0-15); higher scores indicate greater social engagement (Lubben et al., 2006).

The psychometrically strong (α=0.91) (Dozois et al., 1998) 21-item Beck Depression Inventory-II (BDI) (Beck et al., 1996), excluding the suicidality question (20 items total), assessed depressive symptoms. Total scores were divided by 20, then multiplied by 21. Individuals were classified: minimal depressive symptoms (0-13), mild depressive symptoms (14-19), moderate depressive symptoms (20-29), or severe depressive symptoms (30-63).

The psychometrically strong (α=0.92, r=0.75) 21-item Beck Anxiety Inventory (BAI) assessed anxiety symptoms (Beck et al., 1988). Scores range from 0 to 63. Individuals were classified: low anxiety (0-21), moderate anxiety (22-35), or potential concerning anxiety levels (36-64).

Statistical analysis

Analyses were performed using Stata (v14.2; Stata Corp., USA). Participant characteristics were described by means and standard deviations (SDs) for continuous variables and proportions for categorical variables. Participants were categorized according to meeting US Physical Activity Guidelines (US Department of Health and Human Services, 2018), reporting ≥8 hrs/day of sitting, or reporting ≥8 hrs/day of screen time (as in (Ekelund et al. 2016)) both pre-/post-COVID-19 public health restrictions. Participants were then classified as "maintaining low physical activity" if they did not adhere to the guidelines at either timepoint, as "increasing physical activity" if they did not adhere to the guidelines prior to restrictions but did afterwards, etc. Participants were similarly classified for sitting and screen time.

To test hypothesis 1, differences in physical activity, sitting time, and screen time pre-/post-COVID-19 public health restrictions, stratified by physical activity status prior to the restrictions, were quantified by Hedges' *g* effect sizes and associated 95% confidence intervals (95% CIs), and calculated with increased time in each behaviour represented as a positive effect size (Hedges, 1981). These were converted to percentages of pre-COVID-19 behaviour times for ease of interpretation in Figure 2. Differences were categorized as "clinically meaningfully" when *g* was ≥0.50 (Norman et al., 2003). To test hypotheses 2a and 2b, multivariable linear regression quantified associations (adjusted unstandardized betas (b) and associated SEs) of

groups based on change in physical activity, sitting time, and screen time, and public health restrictions, with continuous depressive symptoms, anxiety symptoms, loneliness, stress, social network, and PMH. To test hypothesis 3, multivariable linear regressions were re-run including interaction terms (physical activity change X public health restrictions, sitting time change X public health restrictions, and screen time change X public health restrictions).

Multicollinearity was determined as likely if two covariates had a correlation ≥0.8, the mean variance inflation factor was ≥6, or the highest individual variance inflation factor was ≥10. For the present study, the highest correlation between two covariates was 0.52, the mean variance inflation factor was 2.56, and the highest individual variance inflation factor was for education at 15.7. Consequently, education was excluded from the linear regressions. Robust standard errors, which are robust to heteroscedasticity, were also used in the multivariable linear regressions. To adjust for multiple testing (hypotheses 2a and 3: three independent variables and six dependent variables; hypothesis 2b: one independent variable and six dependent variables), statistical significance was established as $p<0.00833$ for hypotheses 2a and 3 and $p<0.00278$ for hypothesis 2b.

RESULTS

Participant characteristics

As of 9:30a Central Daylight Time on April 8th, a total of 4,542 entries had been started, with 3,242 participants consenting and completing the project and, after excluding those missing exposure or outcome data, a total of 3,052 with complete data were analysed (Figure 1) for a completion rate of 71.4% with 67.9% after exclusions. Participant characteristics are presented in Table 1. Briefly, participants (n=3,052; 62% female) were relatively evenly dispersed from ages

18-75+, predominantly white and educated, and overweight but mostly without any chronic conditions. Mean±SD outcome scores in the total population were: depressive symptoms (9.44±8.49), anxiety symptoms (7.29±8.08), loneliness (5.12±1.81), stress (6.07±3.00), social network (8.52±2.64), and PMH (24.30±4.65).

Change in physical activity, sitting time, and screen time

Mean percentage change in physical activity, sitting time, and screen time among participants who met and did not meet minimum recommended levels of physical activity prior to COVID-19 restrictions are presented in Figure 2, and stratified by the levels of restrictions they are experiencing. Among active participants pre-COVID-19 restrictions, those in social isolation showed the largest (and clinically meaningful) drop in physical activity (g=-0.913 [95%CI: -1.088 to -0.739]) and increase in sitting (g=0.698 [0.526 to 0.869]) and screen time (g=0.653 [0.482 to 0.823]). Among those with stay-at-home and social distancing restrictions, changes in physical activity (stay-at-home: g=-0.555 [-0.667 to -0.443]; social distancing: g=-0.514 [-0.647 to -0.381]), sitting time (stay-at-home: g=0.485 [0.374 to 0.597]; social distancing: g=0.511 [0.378 to 0.643]), and screen time (stay-at-home: g=0.529 [0.417 to 0.640]; social distancing: g=0.559 [0.426 to 0.692]) were comparable.

Among inactive participants pre-COVID-19 restrictions, no change in physical activity was observed (self-isolation: g=-0.101 [-0.269 to 0.067]; stay-at-home: g=0.071 [-0.026 to 0.167]; social distancing: g=0.022 [-0.092 to 0.135]). The largest and clinically meaningful increases in sitting (g=0.565 [0.393 to 0.735]) and screen time (g=0.589 [0.417 to 0.760]) were seen among those in self-isolation. Among those with stay-at-home and social distancing restrictions, changes in sitting (stay-at-home: g=0.391 [0.294 to 0.488]; social distancing:

g=0.311 [0.196 to 0.426]) and screen time (stay-at-home: *g*=0.437 [0.340 to 0.535]; social distancing: *g*=0.421 [0.306 to 0.536]) were comparable.

Associations between changes in behaviour, COVID-19 public health restrictions, and mental health

Associations between changes in physical activity, sitting time, and screen time pre-/post-COVID-19 related public health restrictions and mental health outcomes in the total population are presented in Table 2. Statistically significant results are outlined here. Compared to those who maintained adherence to the physical activity guidelines, those who decreased (i.e., moved from active to inactive) had stronger/higher depressive symptoms (adjusted unstandardized beta: b=1.960; p<0.001), loneliness (b=0.340; p<0.001), and stress (b=0.522; p<0.001), and lower PMH (b=-1.010; p<0.001). Those who maintained low physical activity levels had lower levels of social network (b=-0.389; p=0.001) and PMH (b=-0.629; p<0.001) and higher levels of stress (b=0.377; p=0.002).

Results were similar for screen time. Compared to those who maintained screen time <8 hours/day (i.e., maintained "low" screen time), those who increased had higher depressive symptoms (b=1.924; p<0.001), loneliness (b=0.340; p<0.001), and stress (b=0.590; p<0.001), and lower PMH (b=-0.920; p<0.001). Sitting time was not significantly associated with any outcome.

Compared to those social distancing, those in self-isolation had higher depressive (b=1.427; p<0.001) and anxiety symptoms (b=1.640; p<0.001; Table 3). Full model results are in Supplementary Table 1. Analyses for the third hypothesis showed that public health restrictions

did not moderate associations between activity behaviours and mental health (all $p \geq 0.003$; Supplementary Table 2.

DISCUSSION

To the authors' knowledge, this is the first investigation of changes in physical activity, sitting time, and screen time as a result of COVID-19 public health restrictions, and their associations with mental health. The current findings confirm: 1) the anticipated reductions of physical activity and increases in sedentary time across the population and particularly among previously physically active and self-isolated/quarantined individuals; 2) the associations between reductions in physical activity and increases in screen time with higher negative mental health and lower positive mental health; and, 3) more severe anxiety and depressive symptoms for self-isolation compared to less restrictive situations, which were not moderated by changes in physical activity or sedentary behaviour. Some models suggest persistent physical distancing may be required for three months, and possibly for eighteen months, to mitigate the peak effects of COVID-19 on health systems (Ferguson et al., 2020). The current findings strongly support the need to facilitate and promote increases in physical activity and limit increases in screen time throughout the duration of these restrictions, however long they may be required.

Participants who met the physical activity guidelines prior to COVID-19-related restrictions decreased their physical activity by an average of 32%, with those in self-isolation reporting the greatest decrease of 43%. The magnitude of changes in physical activity and screen time found here are potentially meaningful based on a commonly utilized important difference of 0.5 standard deviation unit (Norman et al., 2003). Unsurprisingly, no significant change in physical activity was seen among those who were not active prior to COVID-19-related restrictions. This

supports and extends data released by Fitbit which showed a 12% decline in step counts in the US during the week ending March 22, 2020 (Fitbit, Inc., 2020). However, these data were not stratified based on prior physical activity levels. Concerningly, previous research has shown that exercise withdrawal was consistently associated with increases in depressive and anxiety symptoms, with larger increases seen when withdrawal lasted more than two weeks (Weinstein et al., 2017). Thus, maintaining or increasing physical activity during the restrictions that are required to limit the disease transmission could have profound effects on sustaining the mental health of the population.

Physical activity has well-established inverse associations with anxiety and depressive symptoms (Raglin, 2012; Gordon et al., 2018; McDowell et al., 2019), and recent evidence showed inverse associations between physical activity and depressive symptoms among Vietnamese adults with suspected COVID symptoms (Nguyen et al., 2020). However, dynamic associations between physical activity and mental health over time are less studied. Previous prospective cohort studies demonstrated physical activity and mental health associations over prolonged periods of time; however, such rapid, large, potentially clinically meaningful changes to physical activity as shown herein and on a population scale is unprecedented, and the health effects are relatively unknown. Previously, experimentally decreasing physical activity among active adults can have significant impacts on depression and mood after just one week (Edwards and Loprinzi, 2016). Consistent with these previous findings, previously active participants in the present study who were no longer active following COVID-19-related public health restrictions reported worse mental health across almost all evaluated dimensions compared to those who maintained their activity level. The present findings support concerted efforts to promote opportunities for regular physical activity to preserve mental health among previously

physically active adults and potentially enhance mental health among both physically active and inactive adults. Potential approaches could include telehealth interventions or public broadcasting time devoted to promotion/implementation of home-based physical activity to facilitate activity among vulnerable populations and those isolating.

Much past research has conceptualized mental health based on presence/absence of negative symptoms (e.g., depressive and anxiety symptoms); the positive mental health benefits of physical activity have largely remained unstudied. A recent study of 5,090 Finnish adults reported that physical inactivity overall (and particularly leisure-time physical inactivity) and long screen time at home, were associated with higher odds of low positive mental health (Tamminen et al., 2020). The present results expand past associations by indicating that people whose screen time increased, or whose physical activity decreased or remained low, had lower positive mental health. As 68.9% of the present sample either decreased activity or maintained low activity, the lower positive mental health in these groups is of public health concern.

Similarly, substantial increases in sitting and screen time were observed. Evidence regarding the mental health impacts of sitting and screen time is mixed, and the effects of such large, acute increases in sedentary behaviours are unknown. Presently, participants who increased their screen time reported higher negative mental health and lower positive mental health across almost all evaluated dimensions compared to those who maintained lower levels. However, no associations between sitting time and mental health were observed. It is plausible that the differing mental health effects of mentally-active and mentally-passive sedentary behaviours explain this distinction. In a cohort of 24,000 Swedish adults, substituting mentally-active sedentary behaviour for mentally-passive behaviour was associated with a reduced risk of developing major depression over thirteen years (Hallgren et al., 2019). Screen time is

commonly defined as a mentally-passive sedentary behaviour, potentially explaining the consistent observed associations between screen time and mental health. The large and rapid changes in screen time reported herein (over weeks rather than years) indicate potential acute health-related effects of increased screen time. There are likely required increases in screen time due to shifts from in-person to remote, screen-based work to adhere to COVID-19 restrictions. Therefore, limiting non-work/school screen time and balancing increased screen usage with opportunities to be active will be paramount for maintaining mental health.

Strengths and Limitations

Findings should be considered in the context of strengths and limitations. Strengths include data on physical activity and sedentary behaviour pre- and post-COVID-19 public health restrictions, evaluation of both physical activity and sedentary behaviour, and the use of well-validated measures of mental health in a large sample of US males and females across broad age demographics. Nonetheless, the cross-sectional design precludes inference of causality, the sample is predominantly well-educated and white and so not reflective of the total US population, and behaviours were self-reported and included a recall of pre-COVID-19 activity, potentially subject to misreporting. The self-selection of participants to complete the survey may also affect the results, although a >70% completion rate for those who began the survey is high. This study also did not examine composition of screen time, which likely incorporated greater exposure to “negative” news which may also influence mental health. Further, while it was expected that certain demographic factors (e.g. female, age, chronic conditions) were associated with mental health, the influence of changing employment status should be further explored.

Conclusion

The current findings strongly support the need to implement and support measures that promote physical activity while limiting screen time throughout the duration of COVID-19 restrictions, however long these restrictions are necessary. Potentially effective methods to do so may be through enhanced telehealth or public broadcasting time devoted to promotion/implementation of home-based physical activity. Future research should replicate these findings in other large samples, investigate potential cross-national differences, longitudinally assess dynamic relationships between these factors, and integrate device-based measures.

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Conflicts of Interest

MT receives funding from the HSC Research and Development Directorate of the Public Health Agency (Northern Ireland) as Director of the Northern Ireland Public Health Research Network. MT is an unpaid member of the Public Health Agency (Northern Ireland) COVID-19 Scientific and Technical Cell. All other authors declare no conflicts of interest.

Ethical Standards

The study was approved as an exempt project by the Iowa State University Institutional Review Board (Nr. 20-144-00). The authors assert that all procedures contributing to this work comply with the ethical standards of the committee of the Medical University of Vienna in accordance with the Helsinki Declaration of 1975, as revised in 2008.

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Figure Legends:

Figure 1. Flow chart of participant selection.

Figure 2. Mean percentage change (95%CI) in behaviours from before to after COVID-19 related public health restrictions in those who were previously A) active and B) inactive.

Panel A shows those who met the minimum recommended physical activity levels prior to the restrictions (n=1361) by public health restriction category (i.e., self-isolation: n=278; stay at home: n=635; social distancing: n=448), while Panel B shows those who did not meet the minimum recommended physical activity levels prior to the restrictions (n=1691) by public health restriction category (i.e., self-isolation: n=272; stay at home: n=827; social distancing: n=592.

Table 1. Participant characteristics

	N (%) or mean±SD
Age	
18-24	508 (16.64)
25-34	470 (15.40)
34-44	419 (13.73)
45-54	376 (12.32)
55-64	474 (15.53)
65-74	522 (17.10)
75+	283 (9.27)
Sex	
Male	1151 (37.63)
Female	1897 (62.01)
Transgender	4 (0.13)
Race (white)	2848 (93.10)
BMI	26.84±5.64
Smoker	80 (2.62)
Marital status	
Married/in a relationship	2070 (67.67)
Widowed	93 (3.04)
Separated/divorced	178 (5.82)
Never married	711 (23.24)
Education	
Up to high school graduate	56 (1.83)
Up to college graduate	1656 (54.14)
Graduate degree	1340 (43.81)
Employment	
Employed	1747 (57.11)
Retired	785 (25.66)
Unemployed	403 (13.17)
Other	97 (3.17)
Chronic conditions	
0	2163 (70.71)
1	263 (8.60)
2+	626 (20.46)
Depression	
Minimal	2368 (77.59)
Mild	375 (12.29)
Moderate	217 (7.11)
Severe	92 (3.01)
Anxiety	
Low	2836 (92.92)
Moderate	183 (6.00)
High	33 (1.08)

BMI=body mass index; SD=standard deviation

Table 2. Adjusted associations between changes in behaviour from before to after COVID-19 related public health restrictions and mental health

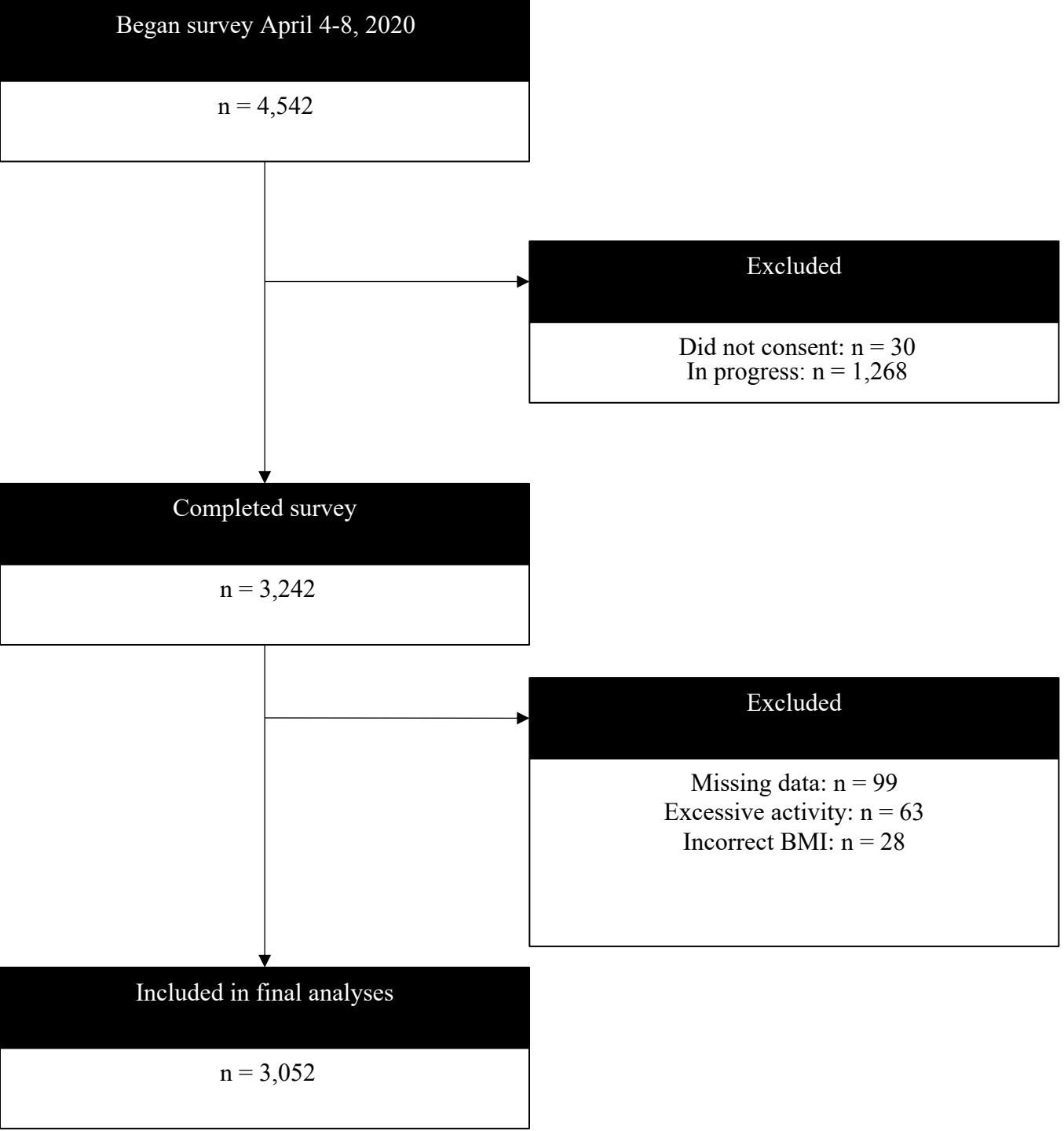
		Depression		Anxiety		Loneliness		Stress		Social network		Positive mental health	
		Adjusted R^2	P-value	Adjusted R^2	P-value	Adjusted R^2	P-value	Adjusted R^2	P-value	Adjusted R^2	P-value	Adjusted R^2	P-value
Goodness of fit		0.268	<0.0001	0.219	<0.0001	0.168	<0.0001	0.202	<0.0001	0.046	<0.0001	0.255	<0.0001
	n	**b (SE)**	**P-value**	**b (SE)**	**P-value**	**b (SE)**	**P-value**	**b (SE)**	**P-value**	**b (SE)**	**P-value**	**b (SE)**	**P-value**
Physical activity													
Maintained high	798	REF		REF		REF		REF		REF		REF	
Increased	152	-0.505 (0.645)	0.434	0.066 (0.677)	0.923	0.001 (0.136)	0.996	-0.133 (0.244)	0.585	0.305 (0.222)	0.169	0.189 (0.345)	0.585
Decreased	563	1.960 (0.417)	<0.001	0.596 (0.411)	0.148	0.340 (0.096)	<0.001	0.522 (0.155)	<0.001	-0.269 (0.149)	0.072	-1.010 (0.230)	<0.001
Maintained low	1539	0.629 (0.318)	0.048	0.248 (0.320)	0.439	0.078 (0.075)	0.302	0.377 (0.124)	0.002	-0.389 (0.119)	0.001	-0.629 (0.182)	<0.001
Sitting time													
Maintained low	1041	REF		REF		REF		REF		REF		REF	
Decreased	85	0.587 (0.972)	0.546	1.497 (0.944)	0.113	-0.067 (0.197)	0.728	-0.015 (0.329)	0.964	0.074 (0.273)	0.786	-0.122 (0.505)	0.809
Increased	582	0.918 (0.441)	0.037	0.946 (0.445)	0.034	0.195 (0.097)	0.045	0.253 (0.154)	0.102	-0.163 (0.149)	0.275	-0.673 (0.234)	0.005
Maintained high	1344	-0.199 (0.348)	0.566	-0.064 (0.344)	0.852	0.046 (0.078)	0.554	-0.068 (0.131)	0.604	-0.040 (0.126)	0.750	-0.036 (0.192)	0.853
Screen time													
Maintained low	1512	REF		REF		REF		REF		REF		REF	
Decreased	45	-0.623 (1.095)	0.569	0.345 (1.203)	0.774	-0.495 (0.198)	0.013	-0.261 (0.468)	0.577	0.762 (0.393)	0.052	0.412 (0.641)	0.520
Increased	562	1.924 (0.441)	<0.001	1.341 (0.454)	0.003	0.340 (0.095)	<0.001	0.590 (0.154)	<0.001	-0.069 (0.145)	0.632	-0.920 (0.239)	<0.001
Maintained high	933	0.375 (0.392)	0.339	0.474 (0.375)	0.206	0.146 (0.085)	0.087	0.126 (0.137)	0.361	-0.156 (0.133)	0.243	-0.451 (0.202)	0.026

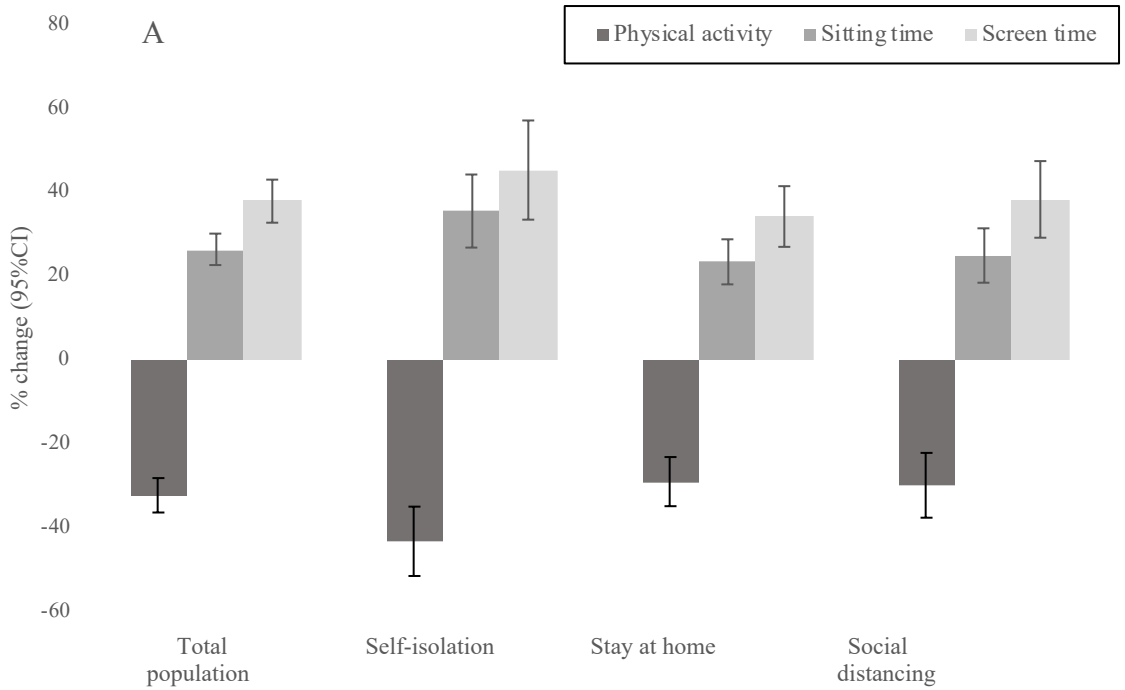
Physical activity, sitting time, and screen time were entered in the model simultaneously and adjusted for age, sex, race, smoking, relationship status, employment, chronic illnesses, and COVID-19 public health restrictions. Education was excluded due to multicollinearity. b = adjusted unstandardized beta; SE = standard error.
Statistical significance set at $p<0.00278$

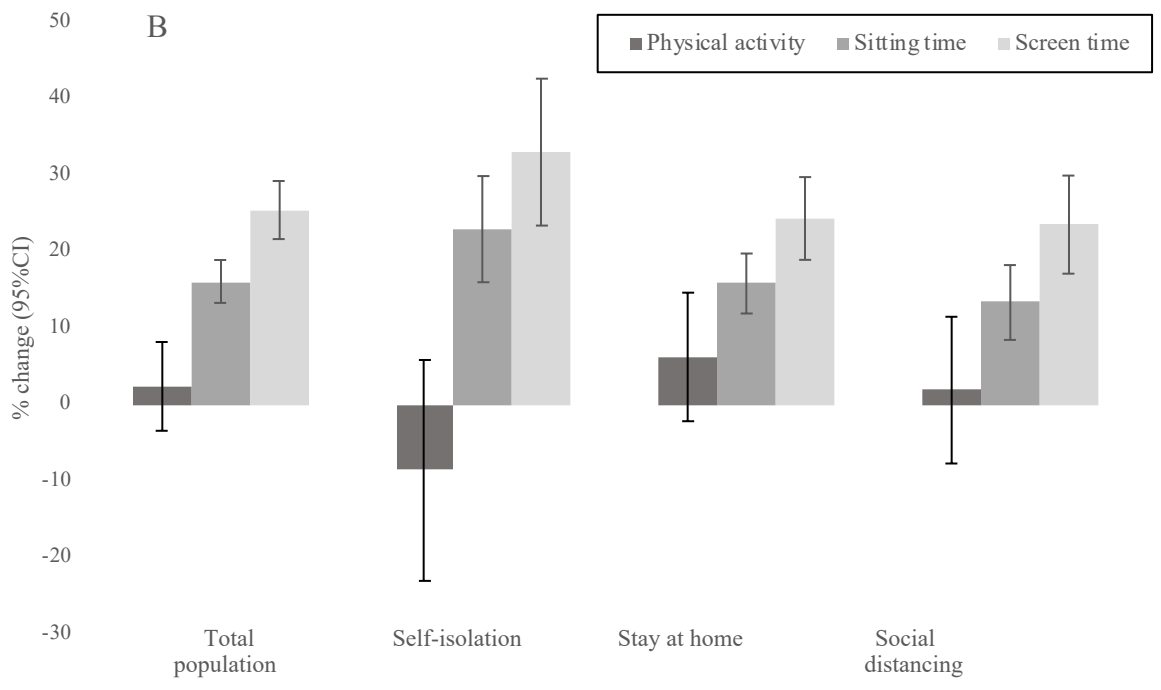
Table 3. Adjusted associations between COVID-19 related public health restrictions and mental health

		Depression		Anxiety		Loneliness		Stress		Social network		Positive mental health	
	n	**b (SE)**	**P-value**	**b (SE)**	**P-value**	**b (SE)**	**P-value**	**b (SE)**	**P-value**	**b (SE)**	**P-value**	**b (SE)**	**P-value**
Public health restrictions													
Social distancing	550	REF		REF		REF		REF		REF		REF	
Stay at home	1462	0.320 (0.297)	0.282	0.491 (0.285)	0.085	-0.019 (0.067)	0.778	0.169 (0.111)	0.127	0.220 (0.105)	0.035	-0.058 (0.162)	0.718
Self-isolation	1040	1.427 (0.424)	<0.001	1.640 (0.440)	<0.001	0.082 (0.090)	0.364	0.250 (0.146)	0.086	0.084 (0.142)	0.557	-0.171 (0.226)	0.451

Adjusted for age, sex, race, smoking, physical activity, sitting time, screen time, relationship status, employment, and chronic illnesses. Education was excluded due to multicollinearity. b = adjusted unstandardized beta; SE = standard error.
Statistical significance set at $p<0.00833$


Began survey April 4-8, 2020
n = 4,542
Excluded
Did not consent: n = 30
In progress: n = 1,268
Completed survey
n = 3,242
Excluded
Missing data: n = 99
Excessive activity: n = 63
Incorrect BMI: n = 28
Included in final analyses
n = 3,052


A
Physical activity
Sitting time
Screen time
% change (95%CI)
80
60
40
20
0
-20
-40
-60
Total population
Self-isolation
Stay at home
Social distancing


B
Physical activity
Sitting time
Screen time
% change (95%CI)
50
40
30
20
10
0
-10
-20
-30
Total population
Self-isolation
Stay at home
Social distancing