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A systematic survey of adults' health-protective behavior use during early COVID-19 pandemic in Canada, Germany, United Kingdom, and the United States, and vaccination hesitancy and status eight months later

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ABSTRACT

Adoption of health-protective behaviors, including social distancing measures, are a mainstay of mitigating pandemics, so it is important to understand the characteristics associated with those who use them or not. We aimed to delineate local and personal factors associated with self-reported use of health-protective behaviors (HPB) in response to COVID-19, among adults across 4 economically developed countries.

We conducted an exploratory, cross-sectional, representative, on-line survey of adults in Canada, Germany, U.K., or the U.S. during the COVID-19 pandemic (June–July 2020) with two and eight month follow-ups. All countries were experiencing the initial waves of the COVID-19 pandemic. We obtained N = 6,990 participants, who reported 20 specific health-protective behaviors (dependent measure), along with locally mandated health measures, individual characteristics and psychological scales. Using health-protective behaviors (HPB-Quartile score) was significantly associated with 28 of 35 variables studied. In stepwise logistic regression, 21 variables predicted 23.51 % of the variance in HPB-Q scores ($p < .000$). The strongest predictors were locally mandated protective measures, immature defense mechanisms, COVID-fears, age, moving due to COVID-19, domestic violence, and perceived emotional support from significant others. HPB-Q predicted vaccination hesitancy/willingness (OR = 4.61, CI-95 %: 2.66–8.00) and adoption 8 months later. During the early pandemic, HPB use was most strongly associated with locally mandated measures, followed by psychiatric, demographic, and other personal factors. Considering these empirically derived characteristics may improve public health approaches to optimize HPB and vaccination adoption, mitigating SAR-CoV-2 transmission. Findings may also inform public health responses to future epidemics/pandemics.

1. Introduction

The COVID-19 pandemic has necessitated using preventive measures to reduce transmission of the SARS-CoV-2 virus and its emerging, increasingly contagious variants (who.int, n.d). Recent attention is divided largely between promoting personal public health preventive measures, mandated or suggested, in tandem with the development and distribution of effective vaccines. While dominant modes of transmission may vary by infective agent, prior experiences (e.g., 1918 flu pandemic (Morens et al., 2021), 2014 Ebola epidemic (Tiffany et al., 2017) have demonstrated that the implementation of personal health-protective behaviors (HPB), such as social distancing and wearing masks, is crucial for reducing transmission. Non-compliance with using such behaviors is a major barrier, thus it is necessary to delineate factors associated with HPB adoption. Taking an exploratory perspective, we sought to delineate local and personal factors that influenced the use of 20 health-protective behaviors across adults in four economically developed countries. From the perspective of social aspects of disease transmission (Buckee et al., 2021), our results seek to inform efforts to reduce transmission in the ongoing pandemic, as well as future such events.

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2. Materials and methods

2.1. Design

We administered an exploratory, cross-sectional, self-report survey, assessing factors associated with health-protective behavior use early during COVID-19 in Canada, Germany, the UK and the USA, 4 countries that scored among the top 10 on the Global Health Security Index. (Bell and Nuzzo, 2021) We included 5 possible locally mandated public health measures, demographics, stress-related factors, psychiatric history and current symptoms, defense and coping mechanisms which might influence HPB use. Follow-up administrations (2 and 8 months) were conducted but only findings limited to vaccination are included here. This study meets the guidelines for protection of human subjects concerning safety and privacy and was approved by the Yeshiva University's Institutional Review Board.

2.2. Participants

Participants were aged 18 and above, gave informed consent and remained anonymous. Of 8,413 potential participants, 7,846 (93.26 %) gave consent. 145 completed no items, 59 finished the survey in less than 1 min, and 571 completed no scale items. Eighty did not reside in the 4 countries and 1 gave impossible answers, leaving 6,990 (83.09 %) usable respondents.

2.3. Measures

For a fuller description of measures including reliability (all acceptable to excellent), see Supplementary Materials. We constructed a *Health-Protective Behaviors* scale consisting of items reflecting behaviors thought to limit exposure and/or transmission of SARS-CoV-2. At the time, air-born transmission had not been established, (Greenhalgh et al., 2021) although most items speak to this, e.g., social distancing, wearing a mask. Participants endorsed the items that they employed.

Our *Local Measures* scale comprised 5 items, reflecting possibly mandated measures in the participant's locale (e.g., social distancing, closing non-essential businesses).

The *COVID-19 Fear Scale (CVDFS)* is a modification for COVID-19 of the 18-item SARS Fear Scale assessing fears in health care workers during SARS (e.g., fear of becoming infected, fear of infecting others). (Ho et al., 2005).

The *Adverse Childhood Experiences (ACE)* scale consists of 10 yes/no items reflecting physical, verbal or sexual abuse, and physical and emotional neglect during childhood. (Felitti et al., 1998).

The *Domestic Violence Scale* includes 3 yes/no items we devised, reflecting threat or occurrence of physical or sexual domestic violence, and the fear of its recurrence.

The *Impact of Events Scale-6* is an abbreviated 6-item version (Thoresen et al., 2010) of the widely used IES-R. (Weiss et al., 1997; Creamer et al., 2003) It reflects three aspects of distress in response to traumatic events: intrusion (e.g., intrusive thoughts), avoidance (e.g., of feelings), and hyperarousal (e.g., feeling on-guard).

The *Patient Health Questionnaire* (PHQ) (Spitzer et al., 1999) is a popular scale for psychiatric symptoms. (Kroenke et al., 2010) We selected 4 subscales. The *PHQ-15 (PHQ-Somatic)* for 15 somatic symptoms over the past 4 weeks. The *PHQ-9 (PHQ-Depression)* for 9 depressive symptoms over the past two weeks. The *PHQ-GAD-7 (PHQ-Anxiety)* for 7 general anxiety symptoms over the past 2 weeks. (pcpcc.org, n.d) Finally, the *PHQ-Alcohol/Drug (PHQ-Alc/Drug)* with 6 items, for excessive alcohol and/or substance abuse. Here we combined scores to make an ordered class variable from *none* to *high-use*.

The *Defense Mechanisms Rating Scales-Self-Report-30 (DMRS-SR-30;* DiGiuseppe et al., 2020; Prout et al., 2022) is a self-report inventory of 28 individual defenses, derived from the observer-rated Defense Mechanisms Rating Scales (Perry et al., 2004). Defense mechanisms are automatic psychological responses to internal and external stressors and conflict (American Psychiatric Association, 1994) that underlie or mediate many psychological phenomena, both healthy and pathological. The self-report items reflect conscious derivatives of defenses. Defense mechanisms are hierarchically arranged based on their degree of adaptiveness in three categories from most to least adaptive: high adaptive (mature), mental inhibitions (neurotic), and immature (American Psychiatric Association, 1994; Perry et al., 2012). Category scores are expressed as a percentage of all defense scores reported.

The *Coping Action Pattern Self-Report-36 (CAPSR-36)* comprises 36 items assessing 12 coping mechanisms, derived from the observer-rated CAP measure (Starrs et al., 2018; Perry et al., 2008) based on a comprehensive review of coping measures by Skinner et al. (2003). (Starrs and Perry, 2018) Each CAP is the sum of its affective, behavioral, and cognitive manifestations. The CAPSR-36 includes 6 generally adaptive coping strategies (e.g., Self-Reliance) and 6 generally maladaptive patterns (e.g., Helplessness). We report the percentage of all positive coping endorsed by the participant.

2.4. Sampling and procedures

The survey was translated into French and German, and tested and revised using a large convenience sample. The present survey was presented in all 4 countries with a choice of language. We engaged a market research company to select participants from on-line panels in each country, using stratified quota sampling which we specified a priori to match the gender, age, ethnic status, and regional distributions within each country. One exception was the U.S., where we over-sampled for ethnic minorities (x2), as one aim for another report is to examine the mental health impact on minorities. Interested participants were directed to an online Qualtrics platform where they received detailed information about the study and provided informed consent before starting to complete the online survey. Participants were compensated by the market research company and remained anonymous. After scoring demographic and HPB items, participants completed the standardized measures in random order. Data were collected from June 12 to July 3, 2020 with follow-ups 2 (August 20 to September 17) and 8 (March 6 to 28, 2021) months later, but respondents were non-incentivized to respond.

2.5. Data analysis

Analyses were conducted using SAS v9.4 for Windows. Our main dependent measure, the sum of 20 Health-Protective Behaviors (HPB), was non-normally distributed, so we created quartiles (HPB-Q) which provide better prediction than dichotomization (Susser et al., 2006, p. 79). We conducted logistic regression by variable (class and continuous) to predict HPB-Q scores, yielding an Odds Ratio, 95 %-CI, and raw R-square. A positive OR indicates association with a higher quartile score, i.e., greater HPB use than the lowest-use quartile (base). Whenever the independent variable is a continuous scale score, the Odds Ratio is interpretable as the increase for 1 scale-point. We then re-ran each model entering the 7 demographic variables hierarchically to yield an adjusted-OR (aOR). Significant findings refer to the aORs, except as noted. Some variables had reduced n's when not applied to all participants, e.g., work-related questions. Given the large sample and the exploratory aim of the study, we kept alpha at 0.05. Finally, we completed stepwise multiple logistic regressions to determine those variables adding unique variance in HPB-Q.

3. Results

The HPB Scores were not normally distributed (see Table 1, bottom, for HPB scores by quartile). Percentages of variance explained in HPB-Q are noted in parentheses, whenever >1 %. Table 1 shows that locally mandated HPB had the largest association with HPB use (7.1 %). For

Table 1
Association between demographic, local measures, and Health-Protective Behavior-Quartile (HPB-Q) score.

Demographic variable	N	Raw R^2	Raw OR CI-95 %	aOR CI-95 %
Country	6,990	0.0152		
USA (base)	1,762		1.00	1.00
Canada	1,713		1.41 1.25–1.58	1.21 1.06 – 1.38
Germany	1,793		0.76 0.68–0.86	0.66 0.58–0.76
United Kingdom	1,722		1.10 0.98–1.24	1.02 0.90–1.17
Age	6,990	0.0393		
18 – 24 (base)	902		1.00	1.00
25 – 34	1,459		0.92 0.79–1.06	0.88 0.72–0.99
35 – 44	1,400		1.06 0.94–1.24	0.98 0.83–1.15
45 – 54	1,127		1.57 1.34–1.83	1.55 1.30–1.84
55 – 64	1,126		1.98 1.69–2.32	2.03 1.69–2.42
65 – 74	781		2.40 2.02–2.86	2.38 1.95–2.91
75 and up	195		2.55 1.93–3.38	2.49 1.84–3.38
Sex	6,990	0.0121		
Male (base)	3,438		1.00	1.00
Female	3,528		1.47 1.35–1.60	1.53 1.41–1.67
Other	24		2.56 1.23–5.32	3.36 1.60–7.05
Ethnicity	6,990	0.0052		
Caucasian (white, base)	4,622		1.00	1.00
Black (Afro-Am/Can/Euro)	713		0.69 0.60–0.79	0.78 0.67–0.91
Hispanic/Latinx	410		0.77 0.65–0.93	0.93 0.76–1.13
Asian	871		1.00 0.88–1.14	1.10 0.95–1.26
Other	374		0.78 0.64–0.94	0.87 0.72–1.06
Education	6,990	0.0036		
1 High School or less (base)	1,874		1.00	1.00
2 Some post-HS/2-yr degree	1,836		1.12 0.99–1.25	1.06 0.95–1.20
3 Bachelor/master	3,001		1.22 1.10–1.36	1.26 1.13–1.41
4 Doctorate, e.g., MD, PhD	279		0.84 0.67–1.05	1.00 0.79–1.27
SES	6,990	0.0061		
1 lowest	448		0.60 0.47–0.76	0.67 0.56–0.81
2 low-Middle	1,543		1.05 0.94–1.16	1.07 0.96–1.19
3 Middle (base)	3,628		1.00	1.00
4 upper-middle	1,154		1.07 0.95–1.21	1.10 0.97–1.24
5 highest	217		0.65 0.54–0.77	0.67 0.56–0.81
Marital/civil status	6,990	0.0122		
Single/never married (base)	2,254		1.00	1.00
Married/domestic partner	3,406		1.51 1.38–1.67	1.15 1.03–1.28
Divorced/separated	667		1.32 1.15–1.54	0.82 0.70–0.98
Widowed	194		1.92 1.47–2.50	0.90 0.67–1.19
In a relationship	460		1.12 0.94–1.34	1.18 0.98–1.42
Other	9		0.79 0.24–2.55	0.63 0.19–2.07
Locale Variable	N	Raw R^2	Raw OR CI-95 %	aOR CI-95 %
Local Measures (number)	6,990	0.0713		
0 (base)	321		1.00	1.00
1	1,126		1.18 0.94–1.48	1.15 0.91–1.45
2	797		2.15 1.79–2.72	2.02 1.58–2.57
3	759		3.22 2.54–4.10	2.83 2.22–3.61
4	884		3.81 3.01–4.82	3.19 2.51–4.05
5	3,103		4.11 3.32–5.09	3.38 2.72–4.20
Dependent Variable	N	Median	Mean SD	Range
Health-protective Behaviors	6,990	11	10.29 5.41	1 – 20
1st Top Quartile	1,819	17	16.91 1.55	15 – 20
2nd	1,782	13	12.61 1.12	11 – 14
3rd	1,740	8	8.12 1.43	6 – 10
4th Bottom	1,649	3	2.77 1.48	1–5

country of residence (1.5 %), Canada used more HPB, and Germany fewer, compared to the U.S. For age-group (3.9 %), compared to the 18–24 group, the 23–34 group used less, whereas 45–54 and above used increasingly more. For gender (1.2 %), female, and non-binary groups used more HPB than males. For ethnicity, compared to Whites, Blacks used fewer HPB. For education, greater use of HPB was associated with having a bachelor's or master's degree. For socio-economic status, the lowest and highest groups endorsed using fewer HPB. For marital/civil status (1.2 %), married individuals used more, whereas divorced/separated people used fewer HPB, compared to those single/never married.

Table 2 displays 8 variables reflecting objective personal factors associated with HPB-Q. A greater number of types of home-mates (e.g., partner, children, roommates) was associated with greater HPB use. Having moved due to COVID-19 (2.1 %) was associated with fewer HPB. Those reporting "*poor and very poor*", or "*good and very good*" prior health reported higher HPB, compared to those reporting "*neither good nor bad*" health. Chronic illness was associated with greater HPB use. Compared to those not reporting a psychiatric diagnosis, those with one used fewer, and those with two or more used more. Those who knew someone infected reported greater HPB, whereas knowing someone who died from SARS-CoV-2 was not associated with HPB. Finally, the 72 individuals who reported SARS-CoV-2 infection used fewer HPB.

Table 2 also presents 8 variables reflecting subjective factors associated with HPB-Q. Greater belief that one could protect others from infection led to greater HPB use, except at the highest score. Believing oneself at higher risk for infection was associated with much greater use of HPB, (2.36 %). Compared to those not following COVID-19 news, attending in any amount was associated with greater HPB (3.40 %), increasing with the number of hours per day. Those reporting "*above average*" or "*excellent*" emotional support employed more HPB, (1.81 %), compared to "*average*" support. Participants experiencing "*slightly more*" loneliness used fewer HPB, those reporting "*very much more*" used more, compared to those not reporting loneliness (1.02 %). By contrast, feeling more connected with friends and family was generally associated with greater HPB. Compared to those noting no change, those reporting economic worsening used more HPB, whereas those reporting improved household economics endorsed fewer. Compared to those possessing sufficient resources, reporting insufficient resources for current bills was associated with lower use of HPB.

Table 3 displays 7 psychological measures, only one of which, PHQ-Depression was not associated with HPB. Three variables were associated with greater use of HPB: COVID Fears (1.6 %), even more strongly so in the adjusted model (2.50 % incremental variance), Impact of Events Scale-6, and PHQ-Anxiety (adjusted models only). Two scales predicted lower HPB, Adverse Childhood Experiences and PHQ-Somatic. Domestic Violence had low homogeneity, so the cumulative scores were analyzed as class values in multilevel logistic regression, and higher scores were associated with decreasing HPB use (2.13 %). Finally, PHQ-Alc/Drug demonstrated a curvilinear association to HPB-Q (2.4 %): mild symptoms predicted greater use, whereas moderate to heavy symptoms predicted less use, compared to those endorsing no use.

Table 3 also presents results for defenses and coping. The Mature defense category and Overall Positive Coping were associated with greater HPB (3.70 % and 2.41 % respectively), whereas the percentage of Immature defenses (3.87 %) was associated with less HPB. The Neurotic category was non-significant.

Table 4 presents 11 items applicable to those currently working (n = 3,625, 51.86 %). Five items were associated with greater HPB use, including the number of persons in daily contact at work (4.57 %), working 16 + hours per week, workplace being more stressful, choosing to work at home (2.29 %), or being required to work at home (2.84 %). By contrast, those able to work at home but choosing not to, used fewer HPB. Other factors associated with less HPB use included working outside of home, reporting that caretaking duties interfered with working at home, being a frontline healthcare worker (1.55 %), or being designated an essential worker. Interestingly, contact with COVID-19

Table 2
Participant characteristics associated with Health Protective Behavior-Quartile score.

Objective Factors	N	Raw R^2	Raw O.R. CI-95 %	aO.R. CI-95 %
Homemate Types	6,990	0.0047		
0 lives alone (base)	1,532		1.00	1.00
1 type	3,284		1.20 1.07–1.33	1.27 1.12–1.46
2 types	2,053		1.34 1.19–1.51	1.72 1.46–2.03
3 or more types	121		1.99 1.42–2.78	2.52 1.77–3.60
Moved due to COVID	6,990	0.0207		
No (base)	6,364		1.00	1.00
Yes	626		0.38 0.33–0.45	0.49 0.42–0.58
Poor Quality of health	6,990	0.0036		
Very bad or bad	646		1.15 0.97–1.35	1.19 1.01–1.40
Neither good nor bad (base)	1,639		1.00	1.00
Good or very good	4,705		1.29 1.17–1.43	1.27 1.15–1.41
Have a chronic illness	6,990	0.0059		
No (base)	5,061		1.00	1.00
Yes	1,929		1.36 1.24–1.50	1.24 1.12–1.36
Have a psychiatric Diagnosis	6,990	0.0057		
None (base)	6,067		1.00	1.00
One	391		0.55 0.46–0.66	0.62 0.52–0.75
Two or more	592		1.04 0.89–1.22	1.18 1.01–1.39
Know person(s) with COVID	6,990	0.0022		
No	5,570		1.00	1.00
Yes	1,420		1.23 1.11–1.36	1.30 1.16–1.44
Know person(s) died COVID	6,690	0.0000		
No (base)	6,329		1.00	1.00
Yes	661		1.01 0.88–1.17	1.00 0.87–1.16
Personally contracted COVID	6,990	0.0030		
No (base)	6,918		1.00	1.00
Yes	72		0.36 0.24–0.56	0.44 0.28–0.68
Subjective Factors	**N**	**Raw R^2**	**Raw O.R. CI-95 %**	**aO.R. CI-95 %**
Protect others from COVID	6,990	0.0018		
1 Not at all (base)	328		1.00	1.00
2 Slightly	741		1.28 1.02–1.62	1.29 1.02–1.63
3 somewhat	2,211		1.38 1.12–1.69	1.24 1.00–1.54
4 a lot	2,182		1.41 1.14–1.73	1.34 1.08–1.65
5 very much	1,528		1.26 1.02–1.56	1.18 0.95–1.47
Feel at high risk for COVID	6,990	0.0236		
1 Very Low (base)	975		1.00	1.00
2 Low	2,078		1.83 1.60–2.10	1.63 1.42–1.88
3 Neither high nor low	2,710		2.04 1.79–2.33	1.91 1.67–1.19
4 High	994		2.69 2.30–3.16	2.58 2.19–3.04
5 very High	233		2.55 1.97–3.30	2.60 2.00–3.39
Hours/day on COVID news	6,990	0.0340		
None (base)	548		1.00	1.00
1 h or less	2,624		2.61 2.20–3.09	2.37 2.00–2.82
Between 1 and 2 h	2,187		2.88 2.42–3.42	2.80 2.35–3.34
Between 3 and 5	1,058		3.02 2.50–3.65	2.86 2.35–3.47
6 or more	573		5.37 4.32–6.67	4.71 – 3.77–5.88
Emotional support	6,990	0.0181		
Very poor	327		0.79 0.64–0.97	0.86 0.70–1.06
Poor	539		0.90 0.76–1.06	0.99 0.84–1.16
Average (base)	3,259		1.00	1.00
Above average	1,673		1.50 1.35–1.67	1.51 1.35–1.68
Excellent	1,192		1.65 0.47–1.86	1.65 1.46–1.86
More lonely during COVID	6,990	0.0102		
Not at all (base)	2,372		1.00	1.00
Slightly	1,633		1.02 0.91–1.14	1.06 0.94–1.19
Somewhat	1,748		0.69 0.62–0.78	0.82 0.73–0.92
Considerably more	794		0.88 0.76–1.02	1.06 0.92–1.23
Very much more	443		1.34 1.11–1.60	1.63 1.35–1.97
More connected during COVID	6,990	0.0038		
Not at all (base)	1,613		1.00	1.00
Slightly	1,530		1.17 1.03–1.33	1.18 1.04–1.34
Somewhat	2,339		0.94 0.84–1.06	0.97 0.86–1.09
Considerably more	1,064		1.11 0.97–1.28	1.21 1.05–1.40
Very much more	444		1.38 1.14–1.67	1.54 1.27–1.87
Household economics	6,990	0.0062		
Worse than before COVID	2,263		1.24 1.13–1.25	1.31 1.19–1.44
Same as before (base)	4,355		1.00	1.00
Better than before COVID	372		0.67 0.57–0.81	0.71 0.59–0.86
Sufficient resources for bills	6,990	0.0088		
Not at all	487		0.62 0.52–0.74	0.72 0.60–0.86
Slightly	1,031		0.65 0.57–0.74	0.71 0.62–0.82
Somewhat	2,381		0.78 0.70–0.86	0.84 0.72–0.92
A lot	756		0.76 0.66–0.88	0.78 0.67–0.91
All or nearly all (base)	2,335		1.00	1.00

patients was associated with fewer HPB, but became non-significant after adjustment. Two items were not significant after adjusting: having lost a job or having one's work hours reduced due to COVID-19.

We entered the 28 significant variables from Tables 1-3 into a stepwise multiple logistic regression. Twenty-one variables predicted a cumulative 23.51 % of the variance in HPB-Q ($N = 6{,}057$, $df = 56$, $\chi^2 = 1401.08$, $p < .000$; see Table in Supplementary Materials). In descending order of variance explained, the first 7 variables were: Local measures (6.92 %), percentage of immature defenses (2.96 %), COVID-Fears (2.15 %), age (2.22 %), having moved due to COVID (1.53 %), Domestic Violence (1.31 %), Emotional support from family (1.01 %). The remaining variables, each predicting under 1 % of variance, were: hours per day of COVID news, gender, PHQ-Somatic, PHQ-Alc/drug, COVID

Table 3
Psychological variables associated with Health-Protective Behavior Quartile scores.

Measure	N	Type [1]	Mean SD Range	Raw R^2	OR CI-95 %	aOR CI-95 %
COVID Fear scale	6,789		20.87 11.94 0–54	0.0156	1.02 1.02–1.02	1.03 1.02–1.03
Adverse Child. Experiences	6,776		1.75 2.25 0–10	0.0037	0.95 0.93–0.97	0.98 0.96 – 1.00
Domestic Violence Total	6,765	Class		0.0213		
0 none (base)	9,028				1.00	1.00
1	359				0.86 0.71–1.04	0.86 0.71–1.04
2	243				0.36 0.29–0.46	0.44 0.34–0.56
3	135				0.22 0.16–0.31	0.28 0.20–0.39
Impact of Events – 6	6,779		7.47 5.50 0–24	0.0001	1.00 0.99–1.01	1.02 1.01–1.03
PHQ-Somatic Scale	6,790		5.03 4.85 0–26	0.0090	0.96 0.96–0.97	0.98 0.97 –0.98
PHQ-Anxiety Scale*	6,767		4.00 3.58 0–14	0.0000	1.00 0.99–1.01	1.02 1.01–1.04
PHQ-Depressive Scale	6,781		6.24 6.34 0–27	0.0029	0.99 0.98–0.99	1.00 1.00–1.01
PHQ-Alcohol-Drug Scale	6,744	Class		0.0237		
0 symptoms (base)	2,997				1.00	1.00
Mild (1 or 2 symptoms)	3,289				1.48 1.36–1.62	1.39 1.27–1.52
Moderate-Heavy (3–6 sx)	458				0.54 0.45–0.64	0.64 0.53–0.77
Defense Mechanisms	6,361					
High Adaptive %			42.3 20.2 0.0–100	0.0370	5.77 4.61–7.23	3.39 2.67–4.29
Neurotic %			13.2 9.9 0.0–100	0.0002	0.78 0.50–1.21	0.88 0.56–1.38
Immature %			36.3 16.6 0.0–100	0.0387	0.11 0.09–0.15	0.21 0.16–0.28
Overall Coping functioning	6,415					
Positive coping %			62.2 21.2 0.0–100	0.0241	3.81 3.08–4.69	2.45 1.96–3.06

[1] All measures continuous except where noted.

high risk self-assessment, country, household economics, insufficient resources for the month, PHQ-Anxiety, percentage of positive Overall Coping, Socio-economic Status, being more connected with family/friends, prior health, and having had COVID-19.

A separate stepwise analysis, entering the 10 significant work variables, demographic and local measures variables, predicted a cumulative 20.11 % of variance ($\chi^2 = 722.48$, df = 40, n = 3,608, p <.000, see Table in Supplementary Materials). In descending order of variance explained, the most explanatory variables were: Local measures (8.44 %), number of contacts at work (3.56 %), age (1.86 %), and workplace stress (1.70 %). The remaining variables, each predicting under 1 % of variance, were: gender, healthcare provider, work hours greater than 15 per week, country, working remotely, working at home by choice, marital/civil status, working outside the home, and socioeconomic status.

3.1. HPB-use, vaccination hesitancy and status on follow-up

We next examined the stability of HPB scores among respondents giving follow-up responses. HPB was highly stable at 2 and 8 months (Spearman ρ = 0.71, n = 901; Spearman ρ = 0.73, n = 487, both p <.000).

While vaccination was only recently available, at 8-month follow-up, 120 (24.64 %) of respondents reported receiving at least one vaccination. HPB-quartiles 1 through 3 had similar percentages vaccinated (25.93 % to 27.03 %). A 2x2 table compared the combined top 3 HPB-Quartiles to the 4th HPB-Quartile at baseline by 8-month vaccination status. Of 403 respondents in the top quartiles, 107 (26.65 %) were vaccinated, versus 13 (15.48 %) of 84 in the 4th HPB-Quartile (OR = 1.97, CI-95 % 1.05–3.71, p =.03). The 8-month follow-up asked those not yet vaccinated (n = 367) about their planning/willingness to get vaccinated (1 = definitely not to 5 = yes, definitely; dichotomized into Hesitant = 1 to 3 vs Willing = 4 & 5). The top 3 HPB-Quartiles were more likely to endorse Willingness to get vaccinated (242 81.76 %) than the bottom 4th quartile (35 49.30 %): OR = 4.61, CI-95 %: 2.66–8.00, p <.000.

4. Discussion

Use of health-protective behaviors early in the pandemic varied widely within our sample. Twenty-eight of 35 independent variables had significant associations with HPB-Q, and 21 made unique contributions in our stepwise analysis, cumulatively explaining 23.51 % of the variance. Local mandated measures was overwhelmingly the largest factor, yet individual-specific factors together explained over twice as much variance. As the pandemic's phases and SARS-CoV2 variants have evolved, and effective vaccines became available, locally mandated HPB and HPB use may have varied (Berg and Lin, 2020; Goldfarb et al., 2021). However, in our sample, HPB use was stable at 2 and 8 months, suggesting that studying the early phase of the pandemic should inform our understanding of later behavior.

Country made a modest contribution to HPB. Follow-up may inform whether this reflects a transient or stable attitude toward public health messaging, as demonstrated for mask-wearing (Badillo-Goicoechea et al., 2021). Female and non-binary individuals employed more HPB, consistent with findings that females more often seek health and preventive care (Bertakis et al., 2000; Pinkhasov et al., 2010). Similarly, gender and sexual minorities have been shown to experience difficulties accessing healthcare, plausibly resulting in more self-initiated use of preventive measures (McKay, 2011; Quinn et al., 2021). Participants under 45 years used fewer HBP. Epidemiologic modeling suggested that 20–49 year olds were the source of 65 % of new U.S. infections by October 2020 (Monod et al., 2021), and a *meta*-analysis found that, among confirmed cases, more young adults have asymptomatic presentations, hence likely adding to community transmission (Ma et al., 2021). Another survey also found lower HPB use in men and younger age groups (Solomou and Constantinidou, 2020). As studies suggest that only 15 % or less of those infected may be responsible for up to 80 % of subsequent infections (Jones et al., 2021), widespread adoption of HPB use among the younger, still unvaccinated may reduce potential super-spreader effects.

Characteristics associated with greater HPB use represent 'virtuous factors', wherein targeted public health approaches may meet with greater success. Those who live with more home-mate types, know someone who is infected, believe that they can protect others from infection, feel more connected with family/friends, or report greater emotional support, all appear more inclined to protect others. Similarly, attending to pandemic-related news likely reflects interest in prevention. It is also possible that those reporting prior good health may pay more attention to staying well through prevention. Conversely, reporting very poor health, chronic illness, multiple psychiatric diagnoses, feeling at high risk for infection, experiencing more loneliness, and worsened finances appear to reflect a sense of personal vulnerability associated with greater HPB use. This also holds for those with high

Table 4
Factors related to working associated with Health-Protective Behavior-Quartile.

Work Variable	N	Raw R^2	OR CI-95 %	aOR CI-95 %
Hours of work per week	3,608	0.0074		
Part-time-1 (<15, base)			1.00	1.00
Part-time-2 (16–34)			1.31	1.43
			1.10–1.56	1.19–1.70
Full-time (35 or more)			1.46	1.55
			1.27–1.69	1.34–1.79
Work outside of home?	3,625	0.0029		
No (base)	1,901		1.00	1.00
Yes	1,724		0.83	0.87
			0.73–0.93	0.77–0.98
Number of daily contacts	3,625	0.0457		
None (base)	815		1.00	1.00
One or two	468		0.64	0.62
			0.52–0.79	0.51–0.77
Three or more	2,342		0.39	0.44
			0.34–0.45	0.38–0.52
Workplace more stressful	3,625	0.0080		
Not at all (base)	940		1.00	1.00
Slightly	911		1.12	1.19
			0.95–1.32	1.01–1.41
Somewhat	971		0.89	1.02
			0.76–1.05	0.87–1.21
Considerably more	506		1.22	1.37
			1.01–1.49	1.12–1.68
Very much more	297		1.61	1.81
			1.27–2.03	1.42–2.31
Can work remotely	3,625	0.0229		
No cannot (base)	1,276		1.00	1.00
Yes, currently remote	1,585		1.41	1.45
			1.24–1.61	1.26–1.67
Yes, but chose not	492		0.66	0.78
			0.54–0.79	0.64–0.94
Yes, already remote	272		0.76	0.79
			0.60–0.96	0.62–1.00
Lost job	6,990	0.0009		
No (base)	6,404		1.00	1.00
Yes	586		0.82	0.91
			0.71–0.96	0.78–1.07
Work hours decreased	6,990	0.0001		
No	2,367		1.00	1.00
Yes	1,258		0.96	0.91
			0.85–1.08	0.82–1.01
Caretaking interfering	3,625	0.0064		
No (base)	2,751		1.00	1.00
Yes	874		0.72	0.71
			0.62–0.82	0.62–0.80
Chose to work at home	3,608	0.0033		
No (base)	2,860		1.00	1.00
Yes	748		1.29	1.16
			1.12–1.49	1.02–1.32
Work at home, required	3,608	0.0284		
No (base)	2,659		1.00	1.00
Yes	949		1.99	1.58
			1.74–2.28	1.40–1.78
Frontline Healthcare worker	3,625	0.0155		
No	3,091		1.00	1.00
Yes	534		0.53	0.55
			0.44–0.62	0.46–0.65
Contact COVID patients	534	0.0109		
No	336		1.00	1.00
Yes	198		0.67	0.82
			0.49–0.92	0.58–1.17
Essential worker	3,625	0.0028		
No	2,108		1.00	1.00
Yes	1,517		0.83	0.85
			0.73–0.93	0.76–0.96

COVID-fears, post-traumatic stress or anxiety symptoms.

Factors associated with lower HPB use present far greater challenges. Economic factors suggest external constraints on employing some HPB, for example insufficient resources for bills, or requiring public transportation. A diminished general belief in the ability to protect oneself may develop from other factors, such as a history of childhood adversity or current domestic violence. Those reporting somatic symptoms may feel physically unable to tolerate some HPB, like wearing a mask. Others may escape infection-related worry through excessive alcohol or substance use.

Individuals employing immature defenses and negative coping strategies appear resistant to public health messaging. Our findings suggest that they may deny, distort, or "shoot the messenger" (e.g., denial, devaluation, passive-aggression), or give-up, avoid or resist (e.g., helplessness, escape, opposition), instead, relying on widely available misinformation to support their stances. Rapid countering of misinformation is clearly essential.[35] Equally, addressing perceptions of injustice, burden, and loss of freedom may increase the effectiveness of HPB messaging.

Work-related factors mirrored those of the whole sample. Participants with greater numbers of daily work contacts used fewer HPB, as did healthcare providers, likely reflecting workplace constraints on social distancing. Those working fewer hours and those in the lowest economic group also used fewer, with low resources possibly constraining their HPB choices. By contrast, those required by employer mandates to work remotely used more HPB, whereas those opting not to work remotely used less, perhaps reflecting a discounting of personal infection risk.

Health-protective behaviors, testing, tracing, quarantining, and widespread vaccination, all reduce risk of infection and the evolution of more dangerous or infectious variants. Historically, substantial public health messaging and measures (masks, limited gatherings, social distancing) during the 1918 flu pandemic in Milwaukee, Wisconsin were associated with far lower death rates than in other major US cities. (Scales et al., 2021) A *meta*-analysis of studies of public health measures found good evidence for the effectiveness of hand-washing, mask-wearing and physical distancing, (Judith Walzer Leavitt, 2021) although isolating the effect of co-occurring individual measures is difficult. (Talic et al., 2021) A *meta*-analysis of the implementation of mandated physical distancing measures up to May 2020 in 149 countries found a 13 % reduction in incidence of COVID-19 compared to before implementation. (Glaziou et al., 2021) A report modeling U.S. countrywide mandated measures (masks, confinement, interstate travel ban) in lieu of state-by-state variation, estimated that two-thirds of U.S. deaths by November 2020 could have been prevented. (Islam et al., 2020 Jul) Another statistical examination revealed a negative relationship between U.S. state/county mandated HPB measures and COVID-19 case rates and mortality, with a two to four week lag in response to imposing/easing restrictions (Avery et al., 2021). (Renne et al., 2020) Similarly, we found that employer requirements to work remotely were associated with greater HPB use.

The follow-up data found that not only was HPB use highly stable at 2 and 8 months, but baseline HPB use was associated with vaccination status at 8 months, and highly associated with willingness to be vaccinated. Those in the lowest HPB-Quartile reported the lowest percentage vaccinated and the highest hesitancy.

Study limitations include the self-report and cross-sectional design, although our follow-up data informed on HPB stability and vaccination adoption and willingness. Self-reported HPB use approximates real-world behavior and three-quarters of the variance in HPB remained unexplained. Of all variables examined, our 5-item locally mandated measures scale showed the strongest effect; however, it might have performed even better had it included more items. Although we collected a large international sample stratified by age, gender, ethnicity, and region within each country, this only approximates a probability sample in each country, thus potentially affecting generalizability. Finally, it is uncertain how well our findings generalize to countries at different stages of the pandemic, different levels of resources or public health systems.

Future studies should explore other potential contributors, such as exposure to misinformation or affiliation with groups promoting versus

disparaging HPB use. Our finding that HPB use was associated with subsequent vaccine adoption, suggests that public health messaging might target them together. Documented breakthrough infections in healthcare workers (Bergwerk et al., 2021) and others (Rosenberg et al., 2021) indicate that vaccination may protect against severe illness better than infection or transmission. A recent CDC study noted that decreasing vaccine efficiency against infection over time supports the need for "… including other approaches such as masking and physical distancing" (Rosenberg et al., 2021). Depending on case incidence-rates, some HPB use among the vaccinated appears warranted, as suggested by the CDC (CDC, 2021). Finally, epidemics/pandemics will recur, as will the need for public health measures to mitigate them, such as HPB.

5. Conclusion and public health implications

- Whereas optimum levels of HPB use may vary with respondent locale, work, living situation, physical/mental health, and vaccination status, along with local case incidence rates, findings indicated that those in the lowest quartile were significantly different from those using higher HPB levels.
- Locally mandated social distancing was most strongly associated with self-reported HPB use.
- Greater use of HPB was associated with specific demographic, stress-related, and psychological factors, explaining more than twice the variance of local mandates.
- Baseline HPB use early in the pandemic (June-July 2020) predicted HPB use 2 and 8 months later, suggesting a durable personal characteristic mitigating transmission.
- Baseline HPB use was associated with vaccine willingness/hesitancy, and status at 8 month follow-up, despite limited availability. The lowest quartile of HPB use was associated with the lowest percentage vaccinated and highest vaccine hesitancy.
- As vaccination becomes widely available, indications of breakthrough infection suggest the need for continued public health attention to HPB messaging and local social distancing measures.
- Understanding factors associated with HPB use may inform public health messaging, measures and mandates with COVID-19, and future epidemic/pandemics.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Vera Bekes and Claire J. Starrs have no competing interests. J. Christopher Perry owns common stock in the following health-care related companies: Biogen, Evolus, Hologic, Illumina, Moderna, Thermo-Fischer, Veeva Systems.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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