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COVID-19 vaccine perceptions and uptake in a national prospective cohort of essential workers

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ABSTRACT

Introduction: In a multi-center prospective cohort of essential workers, we assessed knowledge, attitudes, and practices (KAP) by vaccine intention, prior SARS-CoV-2 positivity, and occupation, and their impact on vaccine uptake over time.

Methods: Initiated in July 2020, the HEROES-RECOVER cohort provided socio-demographics and COVID-19 vaccination data. Using two follow-up surveys approximately three months apart, COVID-19 vaccine KAP, intention, and receipt was collected; the first survey categorized participants as reluctant, reachable, or endorser.

Results: A total of 4,803 participants were included in the analysis. Most (70%) were vaccine endorsers, 16% were reachable, and 14% were reluctant. By May 2021, 77% had received at least one vaccine dose. KAP responses strongly predicted vaccine uptake, particularly positive attitudes about safety (aOR = 5.46, 95% CI: 1.4–20.8) and effectiveness (aOR = 5.0, 95% CI: 1.3–19.1). Participants' with prior SARS-CoV-2 infection were 22% less likely to believe the COVID-19 vaccine was effective compared with uninfected participants (aOR 0.78, 95% CI: 0.64–0.96). This was even more pronounced in first responders compared with other occupations, with first responders 42% less likely to believe in COVID-19 vaccine effectiveness (aOR = 0.58, 95% CI 0.40–0.84). Between administrations of the two surveys, 25% of reluctant, 56% reachable, and 83% of endorser groups received the COVID-19 vaccine. The reachable group had large increases in positive responses for questions about vaccine safety (10% of vaccinated, 34% of unvaccinated), and vaccine effectiveness (12% of vaccinated, 27% of unvaccinated).

Abbreviations: **FDA**, U.S. Food and Drug Administration; **CDC**, Centers for Disease Control and Prevention; **EUA**, Emergency Use Authorization; **KAP**, Knowledge, attitudes, and practices; **HEROES**, Arizona Healthcare, Emergency Response and Other Essential Workers Surveillance **RECOVER** Study and Research on the Epidemiology of SARS-CoV-2 in Essential Response Personnel; **H-R**, HEROES-RECOVER; **HCP**, Health care personnel; **FW**, Frontline workers; **PPE**, Personal protective equipment.

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Discussion: Our study demonstrates attitudes associated with COVID-19 vaccine uptake and a positive shift in attitudes over time. First responders, despite potential high exposure to SARS-CoV-2, and participants with a history of SARS-CoV-2 infection were more vaccine reluctant.
Conclusions: Perceptions of the COVID-19 vaccine can shift over time. Targeting messages about the vaccine's safety and effectiveness in reducing SARS-CoV-2 virus infection and illness severity may increase vaccine uptake for reluctant and reachable participants.

1. Introduction

The SARS-CoV-2 pandemic has resulted in high levels of morbidity and mortality in the US [1]. In response, a global effort to develop COVID-19 vaccines generated evidence leading to the U. S. Food and Drug Administration (FDA) authorizing COVID-19 vaccines under an Emergency Use Authorization (EUA) mechanism, beginning in mid-December 2020 [2]. Essential workers, including healthcare personnel (HCP), first responders, and other frontline workers (FW), may be at an increased risk of SARS-CoV-2 infection because of their high rates of contact with patients, coworkers, and/or the general public [3–7]. They were prioritized to receive COVID-19 vaccines by the Centers for Disease Control and Prevention (CDC) Advisory Committee on Immunization Practices during initial, staggered distribution.

The COVID-19 vaccines have been shown to be safe and effective in adults and children ages 12 and older; despite this, vaccination rates are suboptimal, ranging from 40 to 75% of the surveyed population, with first responders reporting low rates of vaccine acceptance [8–18]. Common reasons for vaccine hesitancy included the novelty of the COVID-19 vaccines, concerns about potential adverse effects, and/or a distrust in government [8–13]. There is some indication that COVID-19 vaccine acceptance has changed over time, but evidence has been limited to cross-sectional surveys [11,19]. It remains unclear how individual vaccination intention has evolved as the public has gained more information regarding symptoms and outcomes of COVID-19 disease and risks and benefits of vaccinations.

Knowledge, attitudes, and practices (KAP) toward vaccination are often examined to understand factors associated with the acceptability of vaccines and inform strategies for increasing vaccine uptake [20]. We utilize a multi-center prospective cohort of essential workers with the following objectives: 1) examine KAP as predictors of vaccine uptake ; 2) assess differences in KAP by vaccine intention, prior SARS-CoV-2 positivity, and occupation group; and 3) assess individual-level change in KAP over time.

2. Methods

2.1. Study design & population

The HEROES-RECOVER studies represent a multi-center network of prospective cohorts, including Arizona Healthcare, Emergency Response and Other Essential Workers Surveillance Study (HEROES) and Research on the Epidemiology of SARS-CoV-2 in Essential Response Personnel (RECOVER) funded by the CDC with sites in Phoenix, Tucson, and other areas in Arizona; Miami, Florida; Duluth, Minnesota; Portland, Oregon; Temple, Texas; and Salt Lake City, Utah. Details of the protocols of the studies have been previously published [21,22]. Ongoing enrollment began in July 2020 and included HCP, first responders, and FW who worked at least 20 hours per week and had routine occupational exposure to coworkers or the public.

Participants completed detailed epidemiologic surveys at enrollment and at approximately three-month intervals (Follow-up surveys 1 and 2). Text message-based surveys were completed weekly to monitor illness and potential COVID-19 contact in the past 7 days. The study is ongoing; for this analysis, only participants actively enrolled during the Follow-up 1 survey distribution were included. Data analyzed included SARS-CoV-2 infection, COVID-19 vaccination, and KAP data through May 19, 2021.

To identify SARS-CoV-2 infections, participants self-collected mid-turbinate nasal swabs weekly for SARS-CoV-2 RT-PCR testing and provided blood specimens at enrollment and three-month intervals (supplemental Figure 1 for study timing). Beginning in December 2020, participants were prompted to report uptake of the COVID-19 vaccine; vaccine survey distribution was based on vaccine availability data from state and county health departments. Vaccination was verified by participant-provided vaccination cards, electronic medical records, or State Immunization Information Systems. All protocols were reviewed and approved by each site's Institutional Review Boards; study participants provided informed consent for all study activities.

2.2. Primary outcomes

Vaccine intention and KAP questions were included in two follow-up surveys: Follow-up survey 1 (distributed late December 2020-February 2021) and Follow-up survey 2 (distributed late March-May 2021). Participants that joined the studies during the follow-up periods received the KAP questions at the time of enrollment.

Vaccine intention was derived using participants' first response to the question, "What are the chances that you will get a COVID-19 vaccination?" and vaccination status at the time of Follow-up survey 1. Participants were grouped into three intention categories: 1) reluctant as those who answered, "almost zero chance" or "very small chance" and were unvaccinated, 2) reachable as those who answered, "small chance", "do not know", or "moderate" and were unvaccinated, or 3) endorser as those who answered, "large chance", "very large chance", or "almost certain", or were vaccinated at Follow-up survey 1. Participants' vaccine intention group did not change based upon Follow-up survey 2 KAP responses or a change in vaccination status between surveys.

The surveys included six questions to assess the KAP constructs regarding COVID-19: knowledge of SARS-CoV-2 and COVID-19 vaccines; attitudes about safety, effectiveness, trust in the government; and perceived risk of becoming ill if they were not vaccinated (Table 1). Responses to each question were rated on a 5- or 7-level Likert scale indicating lowest to highest ranking.

2.3. Predictors and confounders

For models examining KAP differences and predictors of vaccination the following variables were included: socio-demographic (including gender, age, race, ethnicity, education, household income), study site, occupation and occupational setting, and participant health status (including SARS-CoV-2 infection status and medical history), and COVID-19 vaccination status. HCP were categorized into "HCP inpatient" for any individual that works in a

Table 1
Knowledge, Attitude, and Practice (KAP) Questions.

Topic	Question Text	Range
Vaccine Intention	What are the chances that you will get a COVID-19 vaccination?	8-point Likert (1 = Don't know, 8 = Almost certain)
Chance of getting sick if not vaccinated	If you are unable to or don't get a COVID-19 vaccination, what do you think your chance of getting sick with COVID-19 this year will be?	7-point Likert (1 = Almost zero, 8 = Almost certain)
Virus Knowledge	How much do you know about the SARS-CoV-2 (COVID-19) virus and the illness it causes?	5-point Likert (1 = Nothing at all, 5 = A great deal)
Vaccine Knowledge	How much do you know about the COVID-19 vaccine? Would you say…?	5-point Likert (1 = Nothing at all, 5 = A great deal)
Vaccine Safety	How safe do you think the COVID-19 vaccine is?	5-point Likert (1 = Not at all, 5 = Extremely safe)
Vaccine Effectiveness	How effective do you think the COVID-19 vaccine is in preventing you from getting sick with COVID-19?	5-point Likert (1 = Not at all, 5 = Extremely effective)
Trust in government	I trust what the government says about the COVID-19 vaccine	5-point Likert (1 = Strongly disagree, 5 = Strongly agree)

hospital, and "HCP other" for any individual that works in any outpatient healthcare facility or long-term care. First responders were grouped into either "firefighter" (firefighters/Emergency Medical Services) and "other first responders" (law enforcement, correctional officers, and border patrol). FW likewise had two categories: "FW public-facing" (educational settings, retail, food service, and hospitality) and "other FW" (infrastructure, manufacturing, warehouse, utility, and transportation). Participants were categorized as having had a SARS-CoV-2 infection prior to Follow-up survey 1 if they reported detection by antibody, antigen, or RT-PCR assay prior to enrollment, or if SARS-CoV-2 was detected by RT-PCR or an antibody test during the study.

In models examining Objectives 1 and 2, COVID-19 contact data were reported as the number of hours spent at work (1) in any setting and in direct contact with individuals with suspected or confirmed COVID-19 and (2) the public in the past 7 days. They also indicated the percent of time protective equipment (PPE) was used during this contact. For Objectives 2 and 3, KAP responses (defined above) were used as the primary predictors of interest.

2.4. Statistical analysis

All participants who completed the Follow-up 1 survey were included in the analysis. Continuous measurements were expressed as means and standard deviations or median and interquartile range, as appropriate. Counts and percentages were used for categorical variables. Likert scores were dichotomized for each KAP question, using responses greater than midpoint as positive associations and midpoint and lower as neutral/negative associations (Table 1).

To test the effect of each KAP on vaccine uptake when including socio-demographics, occupation and occupational setting, vaccine intention, and prior positivity together (objective 1), adjusted ordinal logistic regression with robust standard errors were utilized. Bonferroni corrections adjusted for the multiple comparisons with statistical significance based on 95% confidence intervals.

Socio-demographics, occupation and occupational setting, previous positivity, KAP responses were stratified by vaccine intention and utilized chi-squared tests or one-way ANOVA tests to examine family-wise differences between the vaccine intention groups, with statistical significance based on p-values < 0.05 (objective 2).

Unadjusted ordinal logistic regression with robust standard errors were used to examine the relationship between each KAP question in the Follow-up 1 survey and vaccine intention, each occupation, and prior positivity. Bonferroni corrections adjusted for multiple comparisons and statistical significance based on 95% confidence intervals. Pair-wise differences in answers to KAP questions were evaluated with a difference in proportion test.

For KAP change (Objective 3), Chi-squared tests were used on a subset of participants who completed both surveys to determine statistically significant differences in each KAP question at Follow-up 2 compared to Follow-up 1, with significance based on p-values < 0.05. We descriptively examined vaccine uptake and KAPs over time for each vaccine intention group. To examine changes in vaccination status over time with changes in KAP scores, we utilized a first-differences analysis, controlling for the impact of time-invariant differences of predictors and confounders listed above. This analysis exploits participants' repeated responses to KAP questions in Follow-up survey 1 and 2 and changes in vaccination status during the period to assess the relationship between individuals' KAPs and vaccination status for the overall sample and by endorsers vs. the reluctant and reachable groups.

All statistical analyses were completed using R (version 4.0.4; R Foundation for Statistical Computing) and Stata (version 16; StataCorp).

3. Results

Overall Participants. From December 2020 to February 2021, 4,803 (87%) of 5,527 participants responded to Follow-up survey 1; 1,105 (23%) HCP inpatient, 1,323 (28%) other HCP, 729 (15%) firefighter, 255 (5%) other first responders, 990 (21%) FW public, and 285 (6%) other FW (Table 2). Most participants were female (62%) and aged < 45 years (58%). Additionally, 72% were non-Hispanic White and 14% Hispanic. Participants were highly educated, including 76% with at least a college degree. Participants were healthy, with only 24% reporting an underlying condition. At the time of the Follow-up 1 survey, 960 (20%) of participants had previously been infected with SARS-CoV-2 and 1720 (36%) had received a COVID-19 vaccination.

Vaccination Intention. Most participants were categorized as endorsers (70%), having either indicated a high likelihood to receive the COVID-19 vaccine (35%) or having already received it at the time of Follow-up 1 survey (36%); 16% of participants were considered reachable, and 14% reluctant. Prior SARS-CoV-2 infection was more common among reluctant (35%) and reachable participants (25%) compared with endorsers (16%). By May 19, 2021, 72% of participants had received at least one dose of a COVID-19 vaccine (Table 2); 86% of endorser, 53% of reachable, and 25% of reluctant groups having received at least one dose.

3.1. Objective 1: KAP as predictor for vaccine uptake

After adjusting for socio-demographic factors, health status, and hours of direct contact with the public, KAP responses strongly predicted vaccine uptake. Participants reporting more positive attitudes about COVID-19 vaccine safety were 5.5 times more likely to receive a COVID-19 vaccine compared with those reporting more negative attitudes (aOR = 5.46, 95% CI: 1.43–20.82). Those with a belief that the vaccine is effective were 5 times as likely to receive a COVID-19 vaccine (aOR = 4.98 95% CI: 1.30–19.14) (Table 3).

Table 2
Descriptive Statistics, Stratified by Vaccine Intent Group in a Survey of Essential Workers December 2020 through May 2021.

	TOTAL N (%)	Reluctant N (%)	Reachable N (%)	Endorser[a] N (%)	P-value
Totals	**4803 (100%)**	**653 (13.6%)**	**770 (16.0%)**	**3380 (70.4%)**	
Socio-demographic Characteristics					
Gender*					0.03
Female	2960 (61.3%)	387 (59.3%)	513 (66.6%)	2060 (60.9%)	
Male	1827 (37.8%)	265 (40.6%)	255 (33.1%)	1307 (38.7%)	
Age (years)					<0.01
18–24	143 (3.0%)	24 (3.7%)	32 (4.2%)	87 (2.6%)	
25–44	2651 (54.9%)	358 (54.8%)	449 (58.3%)	1844 (54.6%)	
45–64	1908 (39.5%)	259 (39.7%)	265 (34.4%)	1384 (40.9%)	
65+	101 (2.1%)	12 (1.8%)	24 (3.1%)	65 (1.9%)	
Race/Ethnicity*					<0.001
Non-Hispanic-White	3449 (71.4%)	431 (66.0%)	525 (68.2%)	2493 (73.8%)	
African American	90 (1.9%)	18 (2.8%)	23 (3.0%)	49 (1.4%)	
Asian Am./Island Pacific	141 (2.9%)	14 (2.1%)	13 (1.7%)	114 (3.4%)	
Hispanic-White	694 (14.4%)	117 (17.9%)	121 (15.7%)	456 (13.5%)	
Multi-Racial/Other	429 (8.9%)	73 (11.2%)	88 (11.4%)	268 (7.9%)	
Education*					<0.001
Less than college	154 (3.2%)	35 (5.4%)	40 (5.2%)	79 (2.3%)	
Some college	856 (17.7%)	186 (28.5%)	201 (26.1%)	469 (13.9%)	
College degree or above	3685 (76.3%)	413 (63.2%)	513 (66.6%)	2759 (81.6%)	
Annual Income*					<0.001
< 50 k	702 (14.6%)	128 (19.6%)	152 (19.7%)	422 (12.5%)	
50 k-100 k	1955 (40.7%)	244 (37.4%)	280 (36.4%)	898 (26.6%)	
100 k+	2000 (41.6%)	261 (40.0%)	317 (41.2%)	1965 (58.1%)	
Occupation					<0.001
HCP inpatient	1105 (22.9%)	100 (15.3%)	115 (14.9%)	890 (26.3%)	
HCP other	1323 (27.4%)	148 (22.7%)	163 (21.2%)	1012 (29.9%)	
First responder firefighter	729 (15.1%)	119 (18.2%)	78 (10.1%)	532 (15.7%)	
First responder other	255 (5.3%)	54 (8.3%)	41 (5.3%)	160 (4.7%)	
FW public	990 (20.5%)	156 (23.9%)	261 (33.9%)	573 (17.0%)	
FW other	285 (5.9%)	57 (8.7%)	80 (10.4%)	148 (4.4%)	
Underlying Medical Conditions					
Asthma					0.990
No	4292 (88.9%)	578 (88.5%)	685 (89.0%)	3029 (89.6%)	
Yes	446 (9.2%)	59 (9.0%)	72 (9.4%)	315 (9.3%)	
Diabetes					0.920
No	4576 (94.7%)	615 (94.2%)	733 (95.2%)	3228 (95.5%)	
Yes	162 (3.4%)	22 (3.4%)	24 (3.1%)	116 (3.4%)	
Hypertension					0.710
No	4158 (86.1%)	556 (85.1%)	659 (85.6%)	2943 (87.1%)	
Yes	580 (12.0%)	81 (12.4%)	98 (12.7%)	401 (11.9%)	
Any above condition*					0.869
No	3176 (66.1%)	425 (65.1%)	502 (65.2%)	2249 (66.5%)	
Yes	1562 (32.5%)	212 (32.5%)	255 (33.1%)	1095 (32.4%)	
SARS-CoV-2 Infection Prior to Follow-Up 1 Survey					<0.001
No	3843 (79.6%)	424 (64.9%)	576 (74.8%)	2843 (84.1%)	
Yes	960 (19.9%)	229 (35.1%)	194 (25.2%)	537 (15.9%)	
COVID-19 Vaccine received during the study					
Received Covid-19 Vaccine, Follow-up 1					
No	3083 (64.2%)	653 (100%)	770 (100%)	1660 (49.1%)	
Yes	1720 (35.8%)	0 (0%)	0 (0%)	1720 (50.9%)	
Received Covid-19 Vaccine, Follow-up 2					<0.001
No	1332 (27.7%)	489 (74.9%)	366 (47.5%)	477 (14.1%)	
Yes	3471 (72.3%)	164 (25.1%)	404 (52.5%)	2903 (85.9%)	
Responses to KAP questions					
Chances of getting sick if not vaccinated					<0.001
Negative/Neutral	2693 (55.8%)	544 (83.3%)	515 (66.9%)	1634 (48.3%)	
Positive	1985 (41.1%)	109 (16.7%)	252 (32.7%)	1624 (48.0%)	
Virus Knowledge					<0.001
Negative/Neutral	1575 (32.8%)	282 (43.2%)	322 (41.8%)	971 (28.7%)	
Positive	3191 (66.4%)	371 (56.8%)	442 (57.4%)	2378 (70.4%)	
Vaccine Knowledge					<0.001
Negative/Neutral	2838 (58.8%)	505 (77.3%)	582 (75.6%)	1751 (51.8%)	
Positive	1935 (40.1%)	148 (22.7%)	187 (24.3%)	1600 (47.3%)	
Vaccine Safety					<0.001

(*continued on next page*)

Table 2 (*continued*)

	TOTAL N (%)	Reluctant N (%)	Reachable N (%)	Endorser[a] N (%)	P-value
Negative/Neutral	1825 (37.8%)	535 (81.9%)	427 (55.5%)	863 (25.5%)	
Positive	2945 (61.0%)	114 (17.5%)	343 (44.5%)	2488 (73.6%)	
Vaccine Effectiveness					<0.001
Negative/Neutral	1825 (37.8%)	498 (76.3%)	392 (50.9%)	935 (27.7%)	
Positive	2944 (61.0%)	152 (23.3%)	375 (48.7%)	2417 (71.5%)	
Trust in the Government					<0.001
Negative/Neutral	2371 (49.1%)	513 (78.6%)	443 (57.5%)	1415 (41.9%)	
Positive	2404 (49.8%)	140 (21.4%)	327 (42.5%)	1937 (57.3%)	

Reluctant participants indicated low likelihood of being vaccinated, Reachable participants mentioned a moderate likelihood of being unvaccinated, and Endorser participants indicated a high likelihood of being vaccinated or were already vaccinated; [a] People who answered the KAP questions after being vaccinated were considered endorsers to get vaccinated; [b] Only asked to unvaccinated participants in non-AZ sites; Likert responses were condensed from 5 to 8 categories (depending on the question) to negative/neutral and positive.

* Proportions may differ due to missing data not shown or small numbers sequestered.

3.2. Objective 2: KAP responses by intention group, prior SARS-CoV-2 infection and occupation

Vaccine Intention Groups. Reluctant and reachable participants were more likely to report negative attitudes about vaccine safety (82% and 56%, respectively), vaccine effectiveness (76% and 51%, respectively), and trust in the government (79% and 58%, respectively). Additionally, reluctant participants were substantially less likely to perceive the COVID-19 vaccines as safe compared to endorsers (aOR = 0.33, 95% CI: 0.28–0.38) (Table 3), or as effective (aOR = 0.32, 95% CI: 0.22–0.48). Reachable participants were less likely to report knowledge about the COVID-19 vaccine than reluctant participants (aOR = 0.53, 95% CI: 0.30–0.96 and aOR = 0.49 95% CI: 0.34–0.75, respectively).

Prior SARS-CoV-2 Infection. Among 960 (20%) participants who reported SARS-CoV-2 infection prior to enrollment, 24% (n = 229) were categorized as reluctant, 20% as reachable (n = 194), and 56% (n = 537) as endorsers (Table 2). In the adjusted models, participants with prior infection were 32% less likely to be concerned about getting sick if not vaccinated (aOR 0.68, 95% CI: 0.56–0.84) and 22% less likely to believe the COVID-19 vaccine was effective (aOR 0.78, 95 %CI: 0.64–0.96) compared with uninfected participants. There were no significant differences in perceived virus knowledge, vaccine safety, or trust in government by infection status in the adjusted models (Table 3).

Occupation. There was little difference between occupational subcategories of HCP or first responders in the adjusted models (Table 3). Firefighters and other first responder were each approximately 40% less likely than inpatient HCP to believe the COVID-19 vaccine was effective (aOR = 0.58, 95% CI 0.40–0.84 and aOR = 0.61, 95% CI 0.49–0.76, respectively). The other FW category was 51% more likely to believe the COVID-19 vaccine was effective compared to inpatient HCP (aOR = 1.49, 95% CI 1.26–1.77), followed by public-facing FW (aOR = 1.25, 95% CI 1.02–1.53) (Table 3).

3.3. Objective 3. KAP change over time

To evaluate change in KAP over time, 2017 (49%) participants that completed both Follow-up 1 and 2 surveys were included in analysis. Between administration of the two surveys, 25% of reluctant, 56% reachable, and 83% of endorser groups received the COVID-19 vaccine. Unvaccinated endorsers were more likely to be male (p = 0.017), younger (p = 0.014), and firefighters (p < 0.001) than vaccinated endorsers (Table 4). Unvaccinated reluctant participants had a 9% decrease in positive responses to questions about their knowledge of the virus (Table 5). Vaccinated participants had a higher increase in positive response toward vaccine effectiveness (31% increase) than those that remained unvaccinated (7% increase).

Participants in the reachable and endorser groups showed decreases in positive responses for knowledge about the virus between the two time points (-19% and –22%, respectively) (Table 5). The reachable group had large increases in positive responses for questions about vaccine knowledge (25% of vaccinated, 25% of unvaccinated), vaccine safety (10% of vaccinated, 34% of unvaccinated), and vaccine effectiveness (12% of vaccinated, 27% of unvaccinated).

Change in vaccination status with change in KAP. Amongst the overall sample, an increase of one point in response to the vaccine safety KAP corresponded with a 19 percent increase in the likelihood of becoming vaccinated. Each point-increase in belief in vaccine effectiveness resulted in a similarly strong increase in likelihood of vaccination (17% increase), with vaccine knowledge and trust in government showing moderate increases (11 % and 9% respectively), and general knowledge of COVID-19 showing the smallest increase (2%). For all five, the effect was more pronounced in the endorser group than in the reluctant and reachable groups (Table 6).

4. Discussion

The HEROES-RECOVER prospective cohort provided a unique opportunity to examine COVID-19 vaccine knowledge, attitudes, and practices longitudinally in a large population of essential workers with high occupational COVID-19 exposure. The prospective design captured how vaccination intention, KAP, and vaccine uptake changed between December 2020 to May 2021, a critical time in COVID-19 vaccine roll-out in the United States.

First responders and participants with prior SARS-CoV-2 infection were more likely to be reluctant to receive the COVID-19 vaccine than other groups. First responders had the highest percentage of vaccine reluctant participants, especially the non-firefighter subcategory. Additionally, even first responders that were endorsers had low rates of vaccination.

Participants with prior SARS-CoV-2 infection were less likely to receive the COVID-19 vaccine and make up more than one-third of the vaccine reluctant group and one-quarter of the reachable group. Other studies have reported similar findings where previously infected were less concerned about reinfection and/or interest in vaccination [23], but better understanding why they report fewer positive attitudes toward vaccine effectiveness will be important in persuading them to get vaccinated. Additional studies highlighting the benefits of vaccination for those with prior infection may help to stress the importance of vaccination among this group [24].

Across vaccination intent, demographics, occupational, and prior SARS-CoV-2 infection groups, three KAP domains were con-

Table 3
Difference in Knowledge, Attitude, and Practice (KAP) Questions Stratified by Vaccination Status, Intention Group, Occupation, and Prior SARS-CoV-2 Positivity in a Cohort of Essential Workers (N = 4803)[a].

	Unadjusted		Adjusted[b]	
	OR	95% CI	OR	95% CI
Vaccinated during the study (not vaccinated is the reference group)				
Virus Knowledge	1.58	1.40 – 1.79		
Vaccine Knowledge	2.49	2.17 – 2.87		
Vaccine Safety	9.81	8.42 – 11.44	5.46	1.43 – 20.82
Vaccine Effectiveness	8.29	7.10 – 9.67	4.98	1.30 – 19.14
Trust in government	4.40	3.87 – 5.00		
Chances of getting sick	4.15	3.58 – 4.81		
By Intention Group (Endorser is the reference Group)				
Reluctant				
Virus Knowledge	0.53	0.45 – 0.62		
Vaccine Knowledge	0.30	0.26 – 0.35	0.49	0.34 – 0.72
Vaccine Safety	0.08	0.06 – 0.09	0.23	0.15 – 0.33
Vaccine Effectiveness	0.12	0.10 – 0.14	0.32	0.22 – 0.48
Trust in government	0.20	0.17 – 0.23	0.43	0.30 – 0.61
Chances of getting sick	0.23	0.20 – 0.27	0.48	0.32 – 0.74
Reachable				
Virus Knowledge	0.52	0.45 – 0.60		
Vaccine Knowledge	0.34	0.30 – 0.40	0.53	0.30 – 0.96
Vaccine Safety	0.33	0.28 – 0.38	0.56	0.31 – 1.00
Vaccine Effectiveness	0.40	0.35 – 0.47		
Trust in government	0.58	0.51 – 0.67		
Chances of getting sick	0.59	0.51 – 0.68		
Occupation (HCP inpatient is the reference group)				
HCP other				
Virus Knowledge	0.81	0.70 – 0.94		
Vaccine Knowledge	0.97	0.84 – 1.12		
Vaccine Safety	0.91	0.79 – 1.06		
Vaccine Effectiveness	1.02	0.87 – 1.18		
Trust in government	0.98	0.85 – 1.13		
Chances of getting sick	0.89	0.77 – 1.03		
First responder firefighter				
Virus Knowledge	0.37	0.31 – 0.44	0.48	0.39 – 0.59
Vaccine Knowledge	0.43	0.36 – 0.51	0.57	0.46 – 0.71
Vaccine Safety	0.43	0.36 – 0.51	0.60	0.48 – 0.74
Vaccine Effectiveness	0.41	0.34 – 0.49	0.61	0.49 – 0.76
Trust in government	0.62	0.52 – 0.73		
Chances of getting sick	0.72	0.61 – 0.85		
First responder other				
Virus Knowledge	0.20	0.15 – 0.25	0.25	0.18 – 0.36
Vaccine Knowledge	0.19	0.15 – 0.25	0.34	0.24 – 0.49
Vaccine Safety	0.34	0.26 – 0.43	0.46	0.32 – 0.67
Vaccine Effectiveness	0.41	0.32 – 0.53	0.58	0.40 – 0.84
Trust in government	0.48	0.37 – 0.60	0.67	0.47 – 0.95
Chances of getting sick	0.71	0.56 – 0.91		
FW Public				
Virus Knowledge	0.30	0.26 – 0.36	0.41	0.34 – 0.50
Vaccine Knowledge	0.30	0.25 – 0.35	0.41	0.33 – 0.50
Vaccine Safety	0.65	0.55 – 0.76		
Vaccine Effectiveness	0.75	0.64 – 0.88	1.25	1.02 – 1.53
Trust in government	0.95	0.82 – 1.11	1.38	1.14 – 1.68
Chances of getting sick	0.94	0.81 – 1.10	1.33	1.13 – 1.56
FW other				
Virus Knowledge	0.28	0.22 – 0.35	0.41	0.35 – 0.49
Vaccine Knowledge	0.36	0.28 – 0.45	0.49	0.41 – 0.57
Vaccine Safety	0.59	0.47 – 0.75		
Vaccine Effectiveness	0.72	0.56 – 0.91	1.49	1.26 – 1.77
Trust in government	0.86	0.68 – 1.08		
Chances of getting sick	0.52	0.41 – 0.65		
Prior SARS-CoV-2 Infection (No known prior infection as the reference group)				
Virus Knowledge	0.91	0.85 – 0.98		
Vaccine Knowledge	0.62	0.57 – 0.68	0.78	0.64 – 0.95
Vaccine Safety	0.51	0.47 – 0.55		
Vaccine Effectiveness	0.48	0.44 – 0.52	0.78	0.64 – 0.96
Trust in government	0.62	0.58 – 0.67		
Chances of getting sick	0.46	0.42 – 0.51	0.68	0.56 – 0.84

[a] P-values not reported due to inconsistencies that occur with multi-level categorical variables. Statistical significance based on 95% confidence intervals.
[b] Non-significant adjusted point estimates and confidence intervals not reported. Bonferroni corrections were used for each of vaccination status, intention group, occupation, and prior positivity. The model was adjusted for socio-demographics, occupation and occupational setting, vaccine intention, and prior positivity for SARS-CoV-2 infection.

sistently correlated with intent to vaccinate and vaccine uptake: safety, effectiveness, and the chance of getting sick if not vaccinated. These indicators of vaccination continued to predict vaccination over time, with more favorable attitudes about vaccine safety and effectiveness substantially increasing the likelihood of vaccination.

Table 4
Demographics of Vaccine Intention Groups, Stratified by Vaccination Status at Time of Follow-up Survey 2 in a Co**hort of Essential Workers.**

	Reluctant			Reachable			Endorser		
	Not Vaccinated (N = 289)	Vaccinated (N = 94)	p-value	Not Vaccinated (N = 152)	Vaccinated (N = 195)	p-value	Not Vaccinated (N = 246)	Vaccinated (N = 1232)	p-value
Gender			0.624			0.475			0.017
Female	168 (58.1%)	58 (61.7%)		104 (68.4%)	138 (70.8%)		133 (54.1%)	783 (63.6%)	
Male	121 (41.9%)	36 (38.3%)		47 (30.9%)	56 (28.7%)		112 (45.5%)	445 (36.1%)	
Age (years)			0.439			0.372			
18–24	11 (3.8%)	3 (3.2%)		9 (5.9%)	11 (5.6%)		10 (4.1%)	19 (1.5%)	0.014
25–44	158 (54.7%)	44 (46.8%)		89 (58.6%)	100 (51.3%)		132 (53.7%)	596 (48.4%)	
45–64	111 (38.4%)	45 (47.9%)		50 (32.9%)	73 (37.4%)		99 (40.2%)	579 (47.0%)	
65+	9 (3.1%)	2 (2.1%)		4 (2.6%)	11 (5.6%)		5 (2.0%)	38 (3.1%)	
Race/Ethnicity			0.975			0.310			0.241
Non-Hispanic-White	188 (65.1%)	60 (63.8%)		99 (65.1%)	125 (64.1%)		169 (68.7%)	883 (71.7%)	
African American	8 (2.8%)	3 (3.2%)		7 (4.6%)	2 (1.0%)		4 (1.6%)	13 (1.1%)	
Asian American	6 (2.1%)	2 (2.1%)		2 (1.3%)	3 (1.5%)		4 (1.6%)	30 (2.4%)	
Hispanic-White	54 (18.7%)	16 (17.0%)		26 (17.1%)	34 (17.4%)		48 (19.5%)	186 (15.1%)	
Multi-Racial	13 (4.5%)	4 (4.3%)		7 (4.6%)	16 (8.2%)		8 (3.3%)	69 (5.6%)	
Other	20 (6.9%)	9 (9.6%)		11 (7.2%)	15 (7.7%)		13 (5.3%)	51 (4.1%)	
Education			0.906			0.313			<0.001
Less than High school	0 (0%)	0 (0%)		2 (1.3%)	0 (0%)		0 (0%)	1 (0.1%)	
HS diploma/GED	15 (5.2%)	6 (6.4%)		8 (5.3%)	8 (4.1%)		11 (4.5%)	26 (2.1%)	
Some college	78 (27.0%)	25 (26.6%)		45 (29.6%)	50 (25.6%)		59 (24.0%)	140 (11.4%)	
College degree/above	187 (64.7%)	60 (63.8%)		95 (62.5%)	131 (67.2%)		172 (69.9%)	1041 (84.5%)	
Annual Income			0.177			0.308			<0.001
< 50 k	63 (21.8%)	10 (10.6%)		33 (21.7%)	32 (16.4%)		46 (18.7%)	108 (8.8%)	
50 k-100 k	104 (36.0%)	40 (42.6%)		47 (30.9%)	78 (40.0%)		74 (30.1%)	389 (31.6%)	
100 k-150 k	62 (21.5%)	22 (23.4%)		45 (29.6%)	46 (23.6%)		62 (25.2%)	328 (26.6%)	
150 k-200 k	27 (9.3%)	8 (8.5%)		16 (10.5%)	20 (10.3%)		35 (14.2%)	173 (14.0%)	
200 k+	20 (6.9%)	9 (9.6%)		9 (5.9%)	8 (4.1%)		23 (9.3%)	194 (15.7%)	
Previously Tested Positive			0.405			0.003			<0.001
No	181 (62.6%)	64 (68.1%)		96 (63.2%)	153 (78.5%)		166 (67.5%)	1046 (84.9%)	
Yes	108 (37.4%)	30 (31.9%)		56 (36.8%)	42 (21.5%)		80 (32.5%)	186 (15.1%)	
Occupation			0.749			<0.001			<0.001
HCP Inpatient	45 (15.6%)	17 (18.1%)		30 (19.7%)	22 (11.3%)		50 (20.3%)	268 (21.8%)	
HCP Other	63 (21.8%)	16 (17.0%)		46 (30.3%)	28 (14.4%)		42 (17.1%)	321 (26.1%)	
First responder firefighter	55 (19.0%)	15 (16.0%)		20 (13.2%)	16 (8.2%)		62 (25.2%)	121 (9.8%)	
First responder other	29 (10.0%)	9 (9.6%)		5 (3.3%)	19 (9.7%)		16 (6.5%)	89 (7.2%)	
FW Public	67 (23.2%)	28 (29.8%)		36 (23.7%)	90 (46.2%)		40 (16.3%)	365 (29.6%)	
FW other	22 (7.6%)	7 (7.4%)		10 (6.6%)	17 (8.7%)		27 (11.0%)	68 (5.5%)	
Asthma			0.873			0.418			0.718
No	259 (89.6%)	85 (90.4%)		141 (92.8%)	173 (88.7%)		221 (89.8%)	1091 (88.6%)	
Yes	22 (7.6%)	6 (6.4%)		9 (5.9%)	17 (8.7%)		22 (8.9%)	122 (9.9%)	
Diabetes			0.565			0.217			0.409
No	274 (94.8%)	87 (92.6%)		148 (97.4%)	182 (93.3%)		237 (96.3%)	1167 (94.7%)	
Yes	7 (2.4%)	4 (4.3%)		2 (1.3%)	8 (4.1%)		6 (2.4%)	46 (3.7%)	
Hypertension			0.571			0.835			0.541
No	252 (87.2%)	79 (84.0%)		129 (84.9%)	166 (85.1%)		216 (87.8%)	1058 (85.9%)	
Yes	29 (10.0%)	12 (12.8%)		21 (13.8%)	24 (12.3%)		27 (11.0%)	155 (12.6%)	

Table 5
Change in Positive Response to Knowledge, Attitude, and Practice (KAP) Questions by Intention and Actual Vaccination from Follow-up Survey 1 to Follow-up Survey 2.

	Virus Knowledge		Vaccine Knowledge		Vaccine Safety		Vaccine Effectiveness		Trust in government	
	n(%)	p-value	n(%)	p-value	n(%)	p-value	n(%)	p-value	n(%)	p-value
Reluctant										
Never Vaccinated	−26 (-9.0%)	0.044	58 (20.0%)	<0.001	13 (4.5%)	0.170	21 (7.2%)	0.032	−5 (-1.7%)	0.635
Vaccinated	−8 (-8.5%)	0.305	20 (21.2%)	0.002	25 (26.6%)	<0.001	29 (30.9%)	<0.001	13 (13.8%)	0.049
Reachable										
Never Vaccinated	−29 (-19.0%)	0.001	38 (25.0%)	<0.001	15 (9.9%)	0.044	18 (11.9%)	0.035	0 (0.0%)	1.000
Vaccinated	2 (1.0%)	0.876	49 (25.2%)	<0.001	67 (34.4%)	<0.001	52 (26.6%)	<0.001	26 (13.3%)	0.011
Endorser										
Never Vaccinated	−53 (-21.5%)	<0.001	53 (21.5%)	<0.001	8 (3.2%)	0.476	6 (2.4%)	0.585	11 (4.4%)	0.303
Vaccinated	13 (1.1%)	0.596	235 (19.1%)	<0.001	147 (11.9%)	<0.001	136 (11.1%)	<0.001	117 (9.5%)	<0.001

We found knowledge about the SARS-CoV-2 virus, or the COVID-19 vaccine had no association with vaccine uptake. It is difficult to ascertain whether participants who perceive themselves to be knowledgeable are truly informed, but attitudes about vaccine safety and effectiveness appear to be more informative of individual intentions to vaccinate. Vaccination efforts that highlight vaccine safety and effectiveness may have a stronger influence on vaccination uptake than general or historical information. Utilizing KAP assessments to gauge a population's intentions or concerns in advance of vaccination campaigns is critical to not only gauge intention to vaccinate, but also to guide the development of vaccination messaging.

Utilizing the prospective cohort, we were able to examine shifts in KAP over time, subgrouping vaccinated versus unvaccinated par-

Table 6
Change in Likelihood of Vaccination Status at Follow-up Survey 2 Compared to Follow-up Survey 1, by Change in Knowledge, Attitude, and Practice Questions in a Cohort of Essential Workers.

	Overall		Endorser		Reluctant & Reachable	
	(n = 1983)		(n = 1262)		(n = 721)	
	% increase	(SE)	% increase	(SE)	% increase	(SE)
Virus Knowledge	2.2***	(0.00839)	1.5	(0.0115)	−0.2	(0.0107)
Vaccine Knowledge	11.2***	(0.00782)	11.2***	(0.0108)	5.6***	(0.0105)
Vaccine Safety	18.7***	(0.00720)	18.0***	(0.0105)	13.6***	(0.0108)
Vaccine Effectiveness	17.2***	(0.00779)	16.1***	(0.0113)	11.7***	(0.0111)
Trust in government	9.4***	(0.00546)	8.1***	(0.00748)	6.3***	(0.00815)

*** p < 0.01, ** p < 0.05, * p < 0.1.

ticipants. The KAP factors that were most connected to vaccination remained influential over time. Our findings indicate that positive changes in individuals' perceptions of vaccine safety and efficacy were associated with the receipt of vaccination. These findings indicate that these KAPs are important for understanding differences in vaccination status not only across individuals, but also for understanding correlates with within-person changes in vaccination status.

Our findings are consistent with other studies conducted prior to COVID-19 vaccine authorization and availability [13,15]. While vaccine intent was assessed in our study after the FDA granted EUA, our findings capture an initial uncertainty that was seemingly overcome with time and positive findings for vaccine safety and effectiveness [11].

5. Limitations

This study is subject to several limitations. First, the follow-up surveys were spread out over about six weeks due to site's individual IRB timelines. As the level of information available evolved quickly during the study period, participants at sites where the follow-up surveys were administered later may have had access to a meaningfully different amount, or quality, of information. Secondly, all KAPs are self-reported and there may be a disconnect between perceived knowledge and actual level of knowledge. Next, while we are confident KAPs are successfully captured in our cohorts at the time of administration, due to the novelty of the COVID-19 vaccine, KAPs will likely continue to change and evolve past this analysis period. Finally, the mechanism prompting change in KAPs is not captured, so it is difficult to know why certain KAPs changed as they did over time; e.g., the change in certain KAPs between the two follow-up surveys may have been due to increased numbers of participants receiving the vaccine with few documented serious adverse event rates, increased access to information leading to more disease/vaccine literacy, changes in national and local COVID-19 incidence, etc. The demographic characteristics of the group that answered Follow-up 2 differed slightly from those that completed Follow-up 1, as there were more female participants (64% vs 60%), older participants (45% 40–65 years of age compared to 36%), and a different breakdown of occupations (FW 36% vs 20% and HCP 44% vs 58%). Race/ethnicity, education, and income were similar between the two groups. Finally, we did not differentiate between individual COVID-19 vaccine products in this analysis. In the first-differences analyses, other time-varying factors that may impact KAPs and vaccination status, such as changes in local policies, were unable to be accounted for in the model.

6. Public health implication

The HEROES-RECOVER cohort provides valuable insight into the perceptions and intentions of essential workers receiving the COVID-19 vaccine. With the current increase in cases, encouraging high-risk occupational groups to receive the COVID-19 vaccine is a critical next step. Our findings indicate that perceptions of the COVID-19 vaccine can shift over time and suggest that focusing on clear messages about the vaccine's safety and effectiveness in reducing SARS-CoV-2 virus infection and illness severity may increase vaccine uptake for reluctant and reachable participants. Targeted messaging by key stakeholders and healthcare providers for participants with prior infection and in occupations with low vaccine coverage and low trust in the government (like first responders) would be especially useful.

7. Disclosures

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

8. Statement of Contributions

K Lutrick, H Groom, A Fowlkes, K Groover, P Rivers, K Nguyen, M Herring, J Mayo Lamberte, K Prather, and S Yoon conceptualized the study and drafted the manuscript with the help of Z Baccam. J Parker, P Rivers, and K Groover conducted the statistical analysis. M Gaglani, A Naleway, K Dunnigan, A Phillips, M Thiese, and H Tyner were responsible for review and revision of the manuscript. All authors read and approved of the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Allison L. Naleway reported funding from Pfizer for a meningococcal B vaccine study unrelated to the submitted work.

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