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RESEARCH ARTICLE

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Greater Covid-19 vaccine uptake among enrollees offered health and social needs case management: Results from a randomized trial

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Abstract

Objective: To investigate Covid-19 vaccination as a potential secondary public health benefit of case management for Medicaid beneficiaries with health and social needs.

Data Sources and Study Setting: The CommunityConnect case management program for Medicaid beneficiaries is run by Contra Costa Health, a county safety net health system in California. Program enrollment data were merged with comprehensive county vaccination records.

Study Design: Individuals with elevated risk of hospital and emergency department use were randomized each month to a case management intervention or usual care. Interdisciplinary case managers offered coaching, community referrals, healthcare connections, and other support based on enrollee interest and need. Using survival analysis with intent-to-treat assignment, we assessed rates of first-dose Covid-19 vaccination from December 2020 to September 2021. In exploratory sub-analyses we also examined effect heterogeneity by gender, race/ethnicity, age, and primary language.

Data Collection and Extraction Methods: Data were extracted from county and program records as of September 2021, totaling 12,866 interventions and 25,761 control enrollments.

Principal Findings: Approximately 58% of enrollees were female and 41% were under age 35. Enrollees were 23% White, 12% Asian/Pacific Islander, 20% Black/African American, and 36% Hispanic/Latino, and 10% other/unknown. Approximately 35% of the intervention group engaged with their case manager. Approximately 56% of all intervention and control enrollees were vaccinated after 9 months of analysis time. Intervention enrollees had a higher vaccination rate compared to control enrollees (adjusted hazard ratio [aHR]: 1.06; 95% confidence interval [CI]: 1.02–1.10). In sub-analyses, the intervention was associated with stronger likelihood of vaccination among males and individuals under age 35.

Conclusions: Case management infrastructure modestly improved Covid-19 vaccine uptake in a population of Medicaid beneficiaries that over-represents social groups with barriers to early Covid-19 vaccination. Amidst mixed evidence on

vaccination-specific incentives, leveraging trusted case managers and existing case management programs may be a valuable prevention strategy.

KEYWORDS
case management, complex care, Covid-19 vaccination, Medicaid, social needs, survival analysis, vaccine uptake

What is known on this topic

- There is increasing evidence that case management for health and social risks may decrease use of high-cost healthcare services like hospitalization.
- There is little evidence on other case management outcomes including vaccination as a spillover public health benefit.
- Studies of vaccine-specific incentives like lotteries and small monetary payments yield inconsistent results.

What this study adds

- Enrollees offered case management had a 5% greater hazard of vaccination compared to a randomly selected control group.
- The preexisting case management infrastructure may have enabled enrollees to uptake vaccination sooner, supported by trusting relationships and navigation assistance.

1 | INTRODUCTION

Health systems are increasingly deploying new case management programs to address health and social risks among patients with complex care needs.[1,2] While it is well established that social risks are associated with worse health and greater healthcare needs,[3–5] the effectiveness of social risk interventions is less clear.[6] Early studies have investigated impacts on hospitalizations, emergency department visits, and cost of care.[7,8] Potential spillover effects to public health measures and other prevention indicators are understudied.

During the Covid-19 pandemic, public health entities enacted unprecedented measures to curb virus spread. Existing health and social needs interventions may have provided valuable scaffolding for Covid-19 prevention efforts. Case managers were often on the front lines of educating patients,[9] and may have served as a preexisting trusted source of information.[10] In particular, case managers may have helped clarify vaccine eligibility, availability, and why vaccination is important amidst changing information and common misinformation.[11]

As in prior pandemics, minoritized and lower socioeconomic communities experienced greater challenges meeting basic needs,[12] more Covid-19 hospitalizations,[13,14] and less access to prevention[15,16] including less vaccination uptake.[17,18] Covid-19 outcomes are a reminder that long-standing structural vulnerabilities like economic opportunities, neighborhood environments, and racism continue to underlie health and healthcare inequities.[19,20] It is possible that interventions to support health and social needs may have helped improve outcomes for groups that have been historically marginalized. For example, case management programs may have provided tailored, responsive, and culturally sensitive support to mitigate health inequities.

Accordingly, we designed a study examining the CommunityConnect case management program in Contra Costa County, California. CommunityConnect is an established, large-scale program that supports adult Medicaid beneficiaries with complex health and social conditions.[8] Enrollees over-represent populations at greater risk of Covid-19 and who face greater obstacles to obtain vaccination. In prior analyses, beneficiaries offered the CommunityConnect case management program experienced significantly fewer hospitalizations within 12 months compared to the control group.[8]

In this analysis, we merged comprehensive county vaccination records with CommunityConnect enrollment records to examine whether the program influenced Covid-19 vaccination uptake. Data span March 2020 to September 2021, encompassing the Covid-19 pandemic onset through the "Delta variant" wave. We hypothesized that case managers may have helped enrollees seek and obtain Covid-19 vaccination. We also hypothesized that program enrollment may have stronger impacts among groups that have been historically marginalized including racially/ethnically minoritized groups and those with a primary language other than English.

2 | METHODS

2.1 | Study design

We matched case management enrollment records and comprehensive vaccination data from the Contra Costa County Public Health Department. Vaccination data included any vaccination that occurred in California for a Contra Costa County resident, including vaccinations administered through state vaccination sites, retail pharmacies, and other providers. Records contained the vaccination date and a designation for first dose or second dose.

Our analyses leveraged CommunityConnect's randomized, Zelen-design clinical trial.[21] The Zelen design is a randomized controlled trial in which participants are enrolled based on existing records rather than via active recruitment. Individuals were randomly selected for the intervention or control arm if they were in the top 15% of predicted risk for avoidable hospital and emergency department visits. Predicted risk was calculated each month using a model that incorporated 91 variables including demographics, utilization history, clinical diagnoses, behavioral indicators, and social risk indicators, resulting in a population with heterogeneous health and social circumstances. Control patients remained eligible for random selection into the intervention in subsequent months if their predicted risk continued to be in the top 15%.

All intervention and control patients were observed for 12 months after their enrollment date except when control patients were selected into the intervention, ending follow-up as controls. The crossover design allowed each eligible individual an equal opportunity to receive services. It also produced an informative censoring process where higher risk controls were more likely to be selected and have their follow-up terminated. Therefore, we applied inverse probability of censoring weights to account for cases of cross over from control to intervention.[22,23] Additional details about the original trial design are described in Brown et al., 2022.[8]

Study procedures were approved by the Contra Costa Regional Medical Center and Health Centers Institutional Review Committee. The trial design was registered as ClinicalTrials.gov number NCT04000074; however, because trial registration occurred prior to the pandemic it did not anticipate analyzing Covid-19 outcomes. We report the study design, results, and discussion following the CONSORT statement and its extension for reporting of pragmatic trials.[24]

2.2 | Setting

Contra Costa Health Services is an integrated county safety net health system in California's San Francisco Bay Area. The system encompasses the county public health department, the county hospital, a network of primary care clinics, and the Medicaid managed care plan that insures 87% of Medicaid beneficiaries. In 2016, Contra Costa Health Services initiated CommunityConnect, a major ($200 million) investment through Medicaid's 1115 waiver pilot program. Medicaid 1115 waivers allow states to test state-specific policies to improve their Medicaid programs. For example, pilot programs may include healthcare payments healthcare payments for new services like housing subsidies and transportation.[25] In Contra Costa, the pilot program established new data infrastructure and case management services that deepened the county's alignment of public health, healthcare, and social services.

2.3 | Participants and eligibility

Eligibility for the CommunityConnect trial included: adults 18 years or older residing in Contra Costa County; enrollment in full-scope Medicaid; not enrolled in a duplicative case management program; not currently in detention for more than 30 days; and not in a vegetative state. For this analysis, inclusion was limited to individuals newly enrolled in the CommunityConnect trial between March 2020 when the pandemic began through April 2021 when new trial enrollments stopped. This analysis includes participants for up to 12 months, consistent with the trial design, or until the September 2021 data cut-off. We exclude individuals enrolled before March 2020 due to program changes induced by the pandemic (e.g., all in-person visits became telephonic). The March 2020 start also facilitates overlap between an enrollee's 12-month observation window and when vaccines became available in December 2020.

Sample size was pragmatically determined based on program capacity. CommunityConnect employed about 100 case managers who collectively served around 12,500 individuals at a given time. In most months the program had capacity to accept 800–1200 new individuals to the intervention depending on the number of existing enrollees that graduated or did not engage. For each intervention assignment, approximately two individuals were assigned to the control group from the same eligibility pool. The eligibility pool consisted of those in the top 15% of predicted risk for avoidable hospital or emergency department visit and numbered up to 25,000 individuals each month.

The Contra Costa Health Services business intelligence team identified eligible individuals, ran the predictive risk model, generated random assignments, and assigned new intervention patients to case managers via the electronic health record (EHR). Demographic characteristics including race and/or ethnicity were pre-defined from the electronic health record. Participants in the control arm received usual care from the health system. Blinding was not feasible. It was not possible for participants to decline enrollment in the study because study inclusion was conducted administratively, and outcomes were obtained from administrative records.

2.4 | Intervention

Individuals assigned to the intervention were paired with a case manager, who made at least three phone attempts and sent one letter to connect with enrollees. Approximately 35% of intervention enrollees responded to the case manager and identified one or more needs such as food, utilities, transportation, employment, or health to address together during the study period. All intervention enrollees were analyzed as part of the intervention group, including those who did not respond to the case manager.

Case managers represented a variety of disciplines including community health workers, nurses, social workers, and behavioral health specialists. While case managers were able to draw on their professional background to align their support with patients' needs and interests, all case managers were expected to follow similar process standards such as reaching out to assigned patients on at least a monthly basis. Case managers began their work with enrollees by screening for needs related to healthcare access, behavioral health, and social determinants of health. Many screening questions were open-ended, developed through iterative quality improvement cycles. Case managers then tailored their support based on conversations with enrollees. They provided coaching, referrals to community services, help with applying for public benefits, and assistance communicating

with healthcare providers. They also linked some enrollees to CommunityConnect-managed resources such as cell phones, emergency housing funds, and legal aid. For more information about the screening tool development, final screening questions, and case manager services, see supplementary materials published with Brown et al.[8]

In March 2020, in-person visits were curtailed following regional public health orders to shelter-in-place due to Covid 19. All visits shifted to telephone, text, and email communications. Staffing challenges also arose during the pandemic as case managers were reassigned to duties like Covid-19 testing and contact tracing. Nonetheless, over 90% of enrollees assigned to the intervention received at least one outreach call during the pandemic and the percent of enrollees engaging with case managers remained comparable to pre-pandemic levels.

Case managers supported vaccination efforts by answering standard questions about vaccine safety or potential side effects. For clinical questions, case managers referred enrollees to a physician or the county's Covid line, a dedicated 1-800 number. Case managers encouraged enrollees to advocate for themselves to get the vaccine. They also provided up-to-date information on where vaccines were available and how to schedule a vaccination online or by phone. For some enrollees, particularly those with less digital literacy, case managers scheduled vaccination appointments on the enrollee's behalf.

2.5 | Usual care

Patients assigned to usual care could continue to access county health services but received no additional services. Control group patients did not receive communication from the health system about the trial as all data collection was based on administrative records. As previously described, control group patients who remained at high risk for avoidable hospitalization and utilization could be selected for the intervention in future months.

2.6 | Outcomes

The primary outcome was the rate of Covid-19 vaccination between intervention and control patients based on the date of the first vaccine dose. We also examined the date of the second vaccine dose as a sensitivity analysis. Covid-19 booster shots were not examined as they became available after the end of our vaccine data window.

2.7 | Statistical analysis

We compared baseline demographic and health characteristics of individuals selected into the intervention and control groups using standardized mean differences. We examined Covid-19 vaccination uptake using Cox proportional hazards regression estimates. First-dose vaccination uptake between the intervention and control group was calculated using a risk period beginning December 1, 2020, the earliest date vaccinations became available. For individuals enrolled after December 1, 2020 and not yet vaccinated, the risk period began at their enrollment start. The risk period ended at the earliest occasion of one of the following events: when vaccination was received, at 12 months of enrollment, upon crossover among controls selected for the intervention, or on September 30, 2021, the last month of data availability based on when data was cut for analysis. We excluded any enrollee who received a vaccine dose before his or her enrollment period start, based on standard survival analysis methods.[26]

The inverse probability of censoring weighting was used in all models. The weights correct for the likelihood that controls with higher risk scores would be more likely to crossover to the intervention in a future month, while controls with lower risk scores would more easily fall below enrollment risk score thresholds. Overall, approximately 45% of control enrollments crossed over to the intervention group before the end of their 12-month observation window. Thus, the inverse probability of censoring weighting maintain the risk balance between study arms over time by upweighting higher-risk controls who remained in the control group. Survival models used the mean of an enrollee's time-varying weights. The intent-to-treat analysis maintains intervention and control group comparability.

Cluster robust standard errors were used to account for patients with multiple enrollments. We present unadjusted and adjusted main analyses. Adjustments account for pre-specified demographic characteristics (gender, age, race, and primary language); health conditions (arthritis, back disorder, COPD, CHF, diabetes, anxiety, depression, and smoking status); behavioral health acuity; social conditions (employment, and homeless status); and time enrolled. These adjustments correct for possible imbalances despite randomization and potentially increase statistical power.[27] In exploratory sub-analyses, we stratified by gender, race/ethnicity, age, and language to examine whether the intervention differentially impacted key subpopulations, particularly those where case management support may have stronger influence due to lower vaccination uptake and greater structural obstacles to vaccination.[18,28] As a sensitivity check, we also examined a model with interaction effects between the same subpopulations in the stratified analysis and assignment to the intervention group. All analyses were performed using *Stata* version 17 BE.[29]

3 | RESULTS

3.1 | Sample characteristics

The sample includes 12,866 out of 13,019 intervention enrollments and 25,761 out of 26,047 enrollments. A total of 133 intervention enrollments and 286 control enrollments were excluded because they received the Covid-19 vaccination before their enrollment start (Figure 1). Analysis was intent-to-treat, with all enrollees assigned to the intervention analyzed in the intervention group. Approximately 35% of intervention enrollments engaged with a case manager, which was defined as case manager documentation of at least one patient

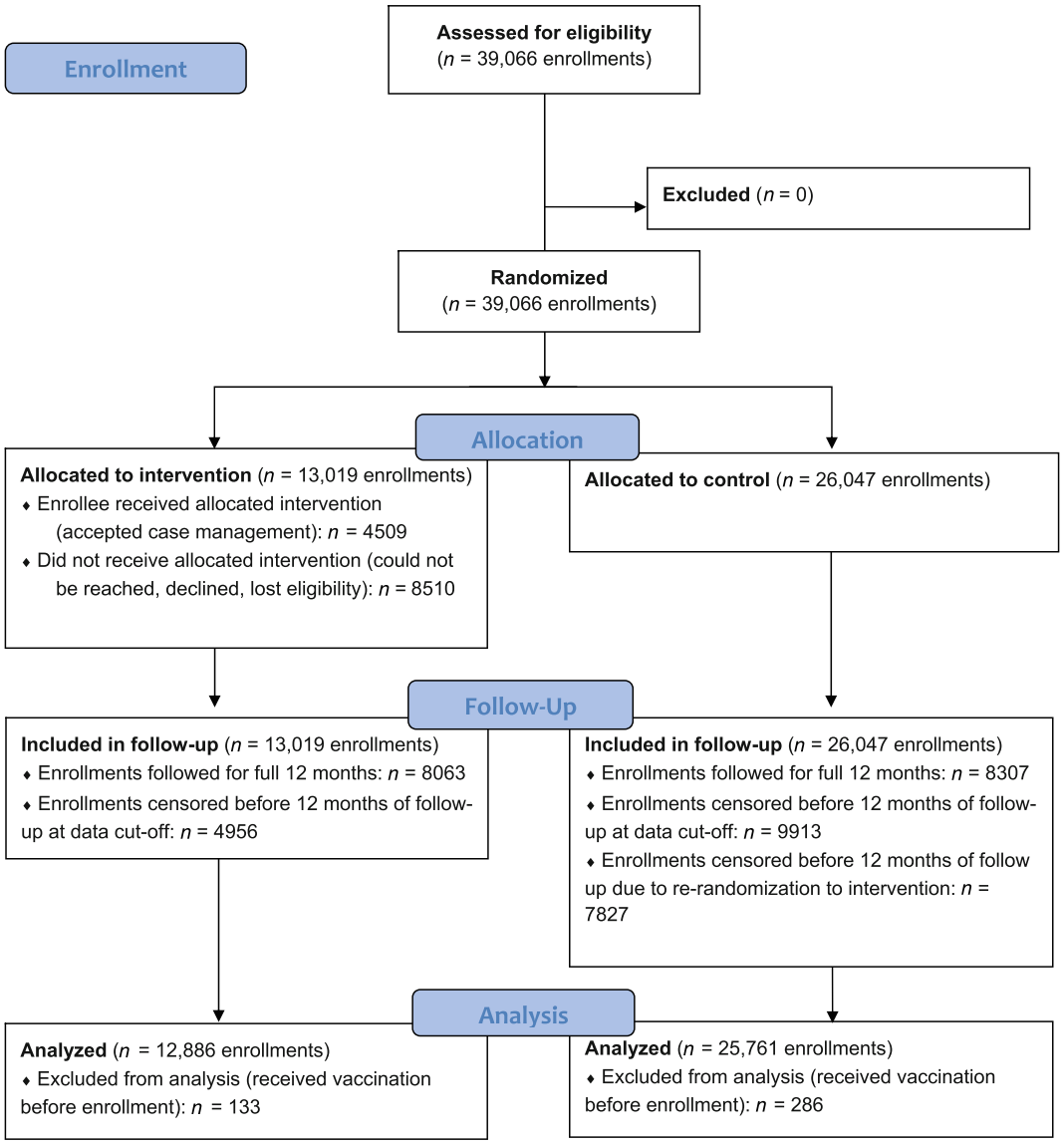

FIGURE 1 CONSORT flow diagram of enrollments analyzed.

goal. Enrollees were predominantly female (58% intervention vs. 59% control), under age 35 (40% intervention vs. 41% control), and represented diverse racial/ethnic backgrounds (e.g., 19% Black or African American/37% Hispanic or Latino/23% White in the intervention group vs. 20% Black or African American/36% Hispanic or Latino/23% White in the control group). Common chronic conditions include back disorder (30% intervention vs. 30% control), anxiety (26% intervention vs. 25% control), and diabetes (16% intervention vs. 16% control). The absolute values of the standardized mean differences were 0.03 or less for all demographic characteristics, indicating that the intervention and control groups were well balanced (Table 1).

3.2 | Immunization outcomes

In weighted analyses, we observed a total of 12,026 first-dose vaccinations. The percent of all enrollees with a first-dose vaccination was 10.3% at 3 months, 47.3% at 6 months, and 56.2% at 9 months. The overall incidence was 3.2 vaccinations per 1000 person-months. In the intervention group, we observed 6307 first-dose vaccinations, with 10.7% vaccinated at 3 months, 49.0% vaccinated at 6 months, and 57.7% vaccinated at 9 months. The intervention group incidence was 3.3 vaccinations per 1000 person-months. In the control group we observed 5719 first-dose vaccinations, with 9.9% vaccinated at 3 months, 45.5% vaccinated at 6 months, and 54.5% vaccinated at 9 months. The control group incidence was 3.1 vaccinations per 1000 person-months.

Results indicate there was a statistically significant greater likelihood of vaccination from December 1, 2020 to September 30, 2021 among enrollees offered case management. The unadjusted hazard ratio was 1.09 (95% confidence interval [CI]: 1.05–1.13). The adjusted hazard ratio (aHR) was 1.05 (95% CI: 1.02–1.10). Results were similar for analyses based on the date of second-dose vaccination (Tables 2 and A1).

TABLE 1 Intervention and control group demographics.

	Intervention ($n = 12,886$ enrollees)		Control ($n = 25,761$ enrollees)		Standardized mean difference
	n	%	*n*	%	
Sex					
Male	5403	42%	10,605	41%	0.01
Female	7481	58%	15,154	59%	−0.01
Age category					
Under 35	5177	40%	10,738	42%	−0.03
35 to under 50	3217	25%	6299	25%	0.01
50 to under 65	2735	21%	5299	21%	0.02
65 and above	1757	14%	3425	13%	0.01
Race/ethnicity					
White	2971	23%	5929	23%	0.00
Asian or Pacific Islander	1463	11%	3008	12%	−0.01
Black or African American	2432	19%	5196	20%	−0.03
Hispanic or Latino	4741	37%	9155	36%	0.03
Other/unknown	1279	10%	2473	10%	0.01
Preferred language					
English	9629	75%	19,269	75%	0.00
Spanish	2333	18%	4559	18%	0.01
Other language	924	7%	1933	8%	−0.01
Behavioral health acuity					
None	10,154	79%	20,333	79%	0.00
Mild-Moderate	1744	14%	3513	14%	0.00
Moderate-Severe	988	8%	1915	7%	0.01
Smoking status					
Never	7379	57%	14,730	57%	0.00
Current	2228	17%	4385	17%	0.01
Former	2079	16%	4079	16%	0.01
Unknown	1184	9%	2547	10%	−0.03
Region					
Central	3106	24%	6214	24%	0.00
East	4877	38%	9669	37%	0.01
Far East	1217	9%	2507	10%	−0.01
West	3569	28%	7094	28%	0.00
History of chronic disease					
Arthritis	2155	17%	4131	16%	0.01
Back disorder	3861	30%	7763	30%	0.00
COPD	490	4%	957	4%	0.01
CHF	287	2%	644	3%	−0.02
CAD	400	3%	778	3%	0.00
Diabetes	1981	15%	3958	15%	0.00
Anxiety disorder	3341	26%	6529	25%	0.02
Depressive disorder	3431	27%	6634	26%	0.02
Social factors					
Homeless	369	3%	692	3%	0.01
Employed	9698	75%	19,317	75%	0.01

TABLE 1 (Continued)

	Intervention ($n = 12,886$ enrollees)		Control ($n = 25,761$ enrollees)		Standardized mean difference
	n	%	*n*	%	
Enrollment start					
March–June 2020	4578	36%	9164	36%	0.00
July 2020–December 2020	5315	41%	10,631	41%	0.00
January–April 2021	2993	23%	5966	23%	0.00

In exploratory analyses stratified by subpopulation, males in the intervention group were significantly more likely to be vaccinated compared to males in the control group (aHR: 1.10, 95% CI: 1.04–1.18). There was no difference among females (aHR: 1.03, 95% CI: 0.98–1.09). Intervention group enrollees under age 35 were also more likely to be vaccinated compared to control group enrollees under age 35 (aHR: 1.10, 95% CI: 1.02–1.18). There were no differences among other age groups (age 35-under 50 aHR: 1.06, 95% CI: 0.98–1.15; age 50 to under 65 aHR: 1.02, 95% CI: 0.95–1.10; age 65+ aHR: 1.01, 95% CI: 0.94–1.10). In addition, intervention group enrollees whose primary language was English were more likely to be vaccinated compared to control group enrollees whose primary language was English (aHR: 1.08, 95% CI: 1.03–1.13). There were no differences among those who primarily spoke Spanish (aHR: 1.01, 95% CI: 0.93–1.10) or other languages (aHR 1.00, 95% CI: 0.90–1.13). Hazard ratios for Black or African American and Hispanic or Latino enrollees in the intervention group compared to those in the control group trended positive but were not statistically significant (Figure 2). In a model that included interaction terms for the same subpopulations examined in stratified analysis, patterns for male enrollees and those under age 35 were similar but interaction terms were not statistically significant at a p-value threshold of $p < 0.05$. There was no interaction between the intervention and the English-language subpopulation ($p = 0.66$) (Table A1).

4 | DISCUSSION

In support of our main hypothesis, case management enrollees had a 5% increased hazard of Covid-19 vaccination compared to similar individuals who were not offered case management. Further, the enrolled Medicaid beneficiaries over-represent social groups with barriers to early Covid-19 vaccination. Vaccination in the case management group particularly diverged from the control group at around 6 months (49.0% vs. 45.4%), which corresponds to May 2021 for those enrolled around the time vaccine roll-out started. During this time vaccines became more available to the general public, but there was still uncertainty about how and where to get vaccinated. One potential mechanism for greater vaccination in the intervention group is that some case managers helped enrollees navigate online scheduling platforms to sign up for vaccination appointments, a commonly cited hurdle during early Covid-19 vaccination efforts.[30] It is also possible that case managers built trust when helping enrollees access resources for health and social needs[31] so that case managers were also trusted as a source of current and accurate Covid-19 information.

In sub-analyses, the case management intervention may have stronger benefits for male enrollees and enrollees under age 35, cohorts that typically access fewer preventive healthcare services.[32,33] These results support the idea that case managers could be a valuable bridge to underutilized services. In addition, similar results for second-dose vaccinations suggest that case management infrastructure could also bolster subsequent vaccination efforts.

The case management intervention did not have statistically significant impacts on vaccine uptake for minoritized racial/ethnic groups. On the one hand, it is possible that our study was not adequately powered to detect statistically significant effects by race/ethnicity. For example, given the number of vaccinations observed, we estimate that an effect size (aHR) of 1.14 or greater would be needed among Black or African American intervention group enrollees compared to Black or African American control group enrollees to reach statistical significance. On the other hand, the CommunityConnect case management intervention was relatively light touch. It is possible that deeper community engagement was needed to build trust and overcome barriers faced by minoritized populations.[34,35]

Minoritized racial/ethnic groups also faced barriers such as less vaccine supply in their communities[36] and disproportionate exposure to economic hindrances, such as having to take unpaid time off work to get vaccinated.[37] These structural barriers may have inhibited case managers' ability to influence vaccine uptake. The lagging vaccine uptake among minoritized populations both nationally[18] and in Contra Costa County[38] suggests more work is needed to close vaccination disparities.

Other efforts to increase Covid-19 vaccination have yielded ambiguous evidence. Estimates from Ohio's Vax-a-Million lottery, which offered a total of $5 million to vaccinated Ohioans, attribute between 0.3 to 1 percentage points increased vaccination to the lottery incentive.[39,40] Estimates are even higher among lower income counties.[41] However, results were inconsistent across state lottery programs.[42,43] Other reports indicate that small monetary incentives ($25) were influential to promote vaccination.[44,45] Yet, a review of incentive programs nationwide found that overall neither lotteries nor guaranteed rewards were associated with significant changes in vaccination rates.[46]

Our study is the first to our knowledge to empirically study how an existing, cross-sector public health workforce influenced vaccination uptake. Our findings suggest that CommunityConnect and other social needs case management programs may be part of an ecosystem of care[47] that can be flexibly adapted for new purposes. This flexibility

TABLE 2 Increased vaccination among intervention patients.

	Vaccinations (weighted)			% Vaccinated (based on the survivor function)			Unadjusted model			Adjusted model		
	Events observed	Events expected	Incidence rate (per 1000 enrollee-months)	3 month (Begins February 2021)	6 month (Begins May 2021)	9 month (Begins August 2021)	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value
Dose 1												
Control	5719.2	5980.2	3.1	9.9%	45.4%	54.5%	1.09	1.05–1.13	<0.001	1.06	1.02–1.10	0.02
Intervention	6307	6046.1	3.3	10.7%	49.0%	57.7%						
Dose 2												
Control	4879.3	5106.0	2.4	6.0%	39.7%	49.3%	1.09	1.05–1.14	<0.001	1.06	1.02–1.10	0.006
Intervention	5505	5278.2	2.7	9.3%	42.8%	52.7%						

Abbreviation: CI, confidence interval.

may have been especially valuable in a crisis like the Covid-19 pandemic where guidelines on how to access vaccinations were unclear and frequently changed. CommunityConnect infrastructure may have served as a chassis for connecting community members at increased risk of Covid-19 with critical information and prevention resources.

4.1 | Limitations

Our study's strengths include the ability to adapt a pragmatic randomized trial design to understand alternative, unanticipated impacts of a large social needs case management program. Specifically, we link case management and county-wide Covid-19 vaccination records. While the vaccination records are comprehensive, they do not include vaccinations that took place outside California or without a Contra Costa County address.

An additional strength is that our study includes individuals who might not participate in recruitment-based trials. A limitation of this study design, however, is that only intent-to-treat analyses are valid. Though we anticipate a greater effect among enrollees who engaged with a case manager, we lack a valid comparison group. Nevertheless, the 35% engagement with case management services is in line with acceptance rates for other social needs assistance programs in health-care settings.[48] The intent-to-treat estimate is also more relevant for policy decision-makers who want to understand population impacts.

In addition, the external validity of our study may be limited since data reflect only one county which has an integrated public health system and robust public health functioning. Contra Costa County had one of the highest vaccination rates for a mid-size county in the United States, suggesting those in the usual care group also received substantial vaccination outreach. Programs like CommunityConnect may have different impacts in other settings.

Future research may benefit from data on outcomes such as stress/anxiety, quality of life, social connectedness, or other Covid-19 related experiences to holistically evaluate case management impacts. In addition, more granular information on characteristics such as neighborhoods or social networks could also provide valuable understanding of case management functioning and potentially related levers to improve vaccination.

4.2 | Implications

Our study builds on greatly needed social needs case management research and is among the first to examine impacts on vaccination, a public health outcome. Amidst mixed evidence on whether vaccine-specific incentives effectively influence vaccine uptake, we found a modest increase in the rate of Covid-19 vaccination among enrollees offered case management compared to a usual care control group. The Covid-19 pandemic highlighted critical structural barriers to care. Leveraging social needs case management may be an important strategy to mitigate structural barriers and advance population health and prevention, especially in times of crisis.

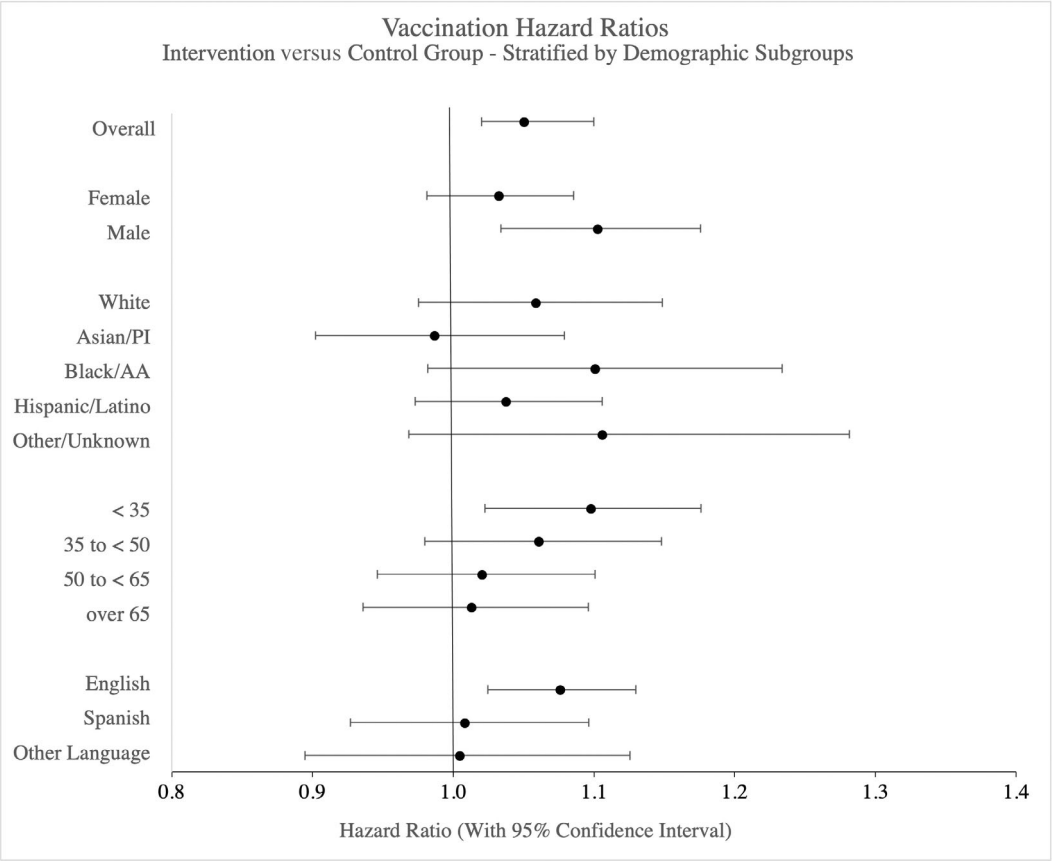

FIGURE 2 Vaccination hazard ratios stratified by gender, race/ethnicity, age, and language.

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APPENDIX A

TABLE A1 Adjusted hazard ratio of vaccination models.

	Dose 1—main model			Dose 1—with interactions			Dose 2—main model			Dose 2—with interactions		
	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value
Intervention	1.057	[1.02,1.10]	0.006**	1.075	[0.87,1.32]	0.496	1.06	[1.02,1.11]	0.007**	1.069	[0.95,1.20]	0.27
Female	0.935	[0.90,0.98]	0.002**				0.946	[0.90,0.99]	0.017*			
White	1	[1.00,1.00]	–				1	[1.00,1.00]	–			
Asian/Pacific Islander	1.617	[1.50,1.74]	0.000***				1.6	[1.48,1.73]	0.000***			
Black/African American	0.661	[0.61,0.71]	0.000***				0.64	[0.59,0.69]	0.000***			
Hispanic/Latino	1.01	[0.95,1.08]	0.774				1.001	[0.93,1.07]	0.972			
Other/unknown	1.043	[0.96,1.13]	0.329				1.037	[0.95,1.13]	0.408			
Age <35	1	[1.00,1.00]					1	[1.00,1.00]				
Age 35 to <50	1.287	[1.22,1.36]	0.000***				1.312	[1.24,1.39]	0.000***			
Age 50 to <65	1.681	[1.58,1.78]	0.000***				1.738	[1.63,1.85]	0.000***			
Age over 65	2.037	[1.91,2.17]	0.000***				2.214	[2.07,2.37]	0.000***			
English	1	[1.00,1.00]					1	[1.00,1.00]				
Spanish	1.226	[1.15,1.31]	0.000***				1.192	[1.12,1.27]	0.000***			
Other language	1.163	[1.08,1.26]	0.000***				1.15	[1.06,1.25]	0.001***			
Has history Arthritis	1.209	[1.14,1.28]	0.000***	1.21	[1.14,1.28]	0.000***	1.216	[1.15,1.29]	0.000***	1.217	[1.15,1.29]	0.000***
Has history Back Disorder	1.092	[1.05,1.14]	0.000***	1.093	[1.05,1.14]	0.000***	1.109	[1.06,1.16]	0.000***	1.11	[1.06,1.16]	0.000***
Has history Copd	1.143	[1.02,1.28]	0.018*	1.139	[1.02,1.27]	0.020*	1.154	[1.03,1.29]	0.012*	1.152	[1.03,1.29]	0.013*
Has history Chf	1.084	[0.95,1.24]	0.237	1.085	[0.95,1.24]	0.231	1.133	[0.99,1.30]	0.072	1.133	[0.99,1.30]	0.071
Has history Diabetes	1.176	[1.11,1.24]	0.000***	1.174	[1.11,1.24]	0.000***	1.161	[1.10,1.23]	0.000***	1.16	[1.09,1.23]	0.000***
Has history Anxiety Disorder	1.04	[0.99,1.10]	0.141	1.039	[0.99,1.09]	0.155	1.048	[0.99,1.11]	0.098	1.046	[0.99,1.11]	0.108
Has history Depressive Disorder	1.085	[1.03,1.14]	0.002**	1.086	[1.03,1.14]	0.002**	1.077	[1.02,1.14]	0.007**	1.079	[1.02,1.14]	0.006**
Behavioral health acuity: none	1	[1.00,1.00]	–	1	[1.00,1.00]	–	1	[1.00,1.00]	–	1	[1.00,1.00]	–
Behavioral health acuity: mild-moderate	1.105	[1.04,1.17]	0.001**	1.105	[1.04,1.17]	0.001**	1.14	[1.07,1.21]	0.000***	1.141	[1.07,1.22]	0.000***
Behavioral health acuity: moderate-severe	0.981	[0.90,1.06]	0.635	0.983	[0.91,1.07]	0.685	0.993	[0.91,1.08]	0.865	0.995	[0.91,1.08]	0.905
Is employed	0.875	[0.84,0.92]	0.000***	0.875	[0.84,0.92]	0.000***	0.877	[0.84,0.92]	0.000***	0.878	[0.84,0.92]	0.000***
Is homeless	0.764	[0.67,0.86]	0.000***	0.762	[0.67,0.86]	0.000***	0.737	[0.64,0.85]	0.000***	0.736	[0.64,0.85]	0.000***
Smoking status: never	1	[1.00,1.00]	–	1	[1.00,1.00]	–	1	[1.00,1.00]	–	1	[1.00,1.00]	–
Smoking status: current	0.691	[0.65,0.74]	0.000***	0.69	[0.65,0.74]	0.000***	0.682	[0.64,0.73]	0.000***	0.682	[0.64,0.73]	0.000***

(Continues)

TABLE A1 (Continued)

	Dose 1—main model			Dose 1—with interactions			Dose 2—main model			Dose 2—with interactions		
	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value
Smoking status: former	0.946	[0.89,1.00]	0.059	0.946	[0.89,1.00]	0.057	0.926	[0.87,0.98]	0.013*	0.925	[0.87,0.98]	0.012*
Smoking status: unknown	0.443	[0.40,0.49]	0.000***	0.443	[0.40,0.49]	0.000***	0.424	[0.38,0.47]	0.000***	0.424	[0.38,0.47]	0.000***
Central	1	[1.00,1.00]	–	1	[1.00,1.00]	–	1	[1.00,1.00]	–	1	[1.00,1.00]	–
East	0.797	[0.76,0.84]	0.000***	0.797	[0.76,0.84]	0.000***	0.795	[0.75,0.84]	0.000***	0.795	[0.75,0.84]	0.000***
Far East	0.787	[0.73,0.85]	0.000***	0.788	[0.73,0.85]	0.000***	0.799	[0.74,0.87]	0.000***	0.8	[0.74,0.87]	0.000***
West	0.863	[0.82,0.91]	0.000***	0.864	[0.82,0.91]	0.000***	0.881	[0.83,0.93]	0.000***	0.882	[0.83,0.94]	0.000***
Enrollment age (months)	1.022	[1.02,1.03]	0.000***	1.022	[1.02,1.03]	0.000***	1.025	[1.02,1.03]	0.000***	1.025	[1.02,1.03]	0.000***
Interaction effects												
Male				0.903	[0.84,0.97]	0.004**				0.917	[0.85,0.99]	0.022*
Intervention × Male				1.067	[0.98,1.16]	0.12				1.059	[0.97,1.16]	0.205
White				0.982	[0.85,1.13]	0.791				1.657	[1.47,1.87]	0.000***
Intervention × White				0.961	[0.81,1.13]	0.637				0.936	[0.81,1.08]	0.377
Asian/Pacific Islander				1.657	[1.43,1.92]	0.000***				0.627	[0.55,0.71]	0.000***
Intervention × Asian/Pacific Islander				0.884	[0.74,1.06]	0.173				1.042	[0.89,1.21]	0.601
Black/African American				0.625	[0.54,0.73]	0.000***				1.008	[0.90,1.13]	0.895
Intervention × Black/African American				1.032	[0.86,1.24]	0.73				0.987	[0.86,1.13]	0.853
Hispanic/Latino				0.991	[0.86,1.14]	0.895				1.027	[0.89,1.19]	0.716
Intervention × Hispanic/Latino				0.959	[0.81,1.13]	0.618				1.016	[0.85,1.21]	0.859
Other/unknown				1	[1.00,1.00]	–				1	[1.00,1.00]	–
Intervention × Other/Unknown				1	[1.00,1.00]	–				1	[1.00,1.00]	–
Age <35				0.469	[0.43,0.51]	0.000***				1.303	[1.19,1.43]	0.000***
Intervention × Age <35				1.09	[0.97,1.22]	0.131				1.013	[0.90,1.13]	0.826
Age 35 to <50				0.615	[0.56,0.68]	0.000***				1.801	[1.63,1.99]	0.000***
Intervention × Age 35 to <50				1.052	[0.93,1.18]	0.402				0.936	[0.83,1.05]	0.264
Age 50 to <65				0.827	[0.75,0.91]	0.000***				2.288	[2.08,2.52]	0.000***
Intervention × Age 50 to <65				0.996	[0.88,1.12]	0.942				0.939	[0.83,1.06]	0.302
Age over 65				1	[1.00,1.00]	–				1	[1.00,1.00]	–
Intervention × Age over 65				1	[1.00,1.00]	–				1	[1.00,1.00]	–
English				0.875	[0.77,0.99]	0.033*				1.193	[1.07,1.33]	0.002**
Intervention × English				0.967	[0.83,1.12]	0.663				0.999	[0.88,1.14]	0.991
Spanish				1.094	[0.94,1.28]	0.257				1.113	[0.98,1.26]	0.099

TABLE A1 (Continued)

	Dose 1—main model			Dose 1—with interactions			Dose 2—main model			Dose 2—with interactions		
	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value	Hazard ratio	95% CI	*p*-value
Intervention × Spanish				0.936	[0.78,1.13]	0.492				1.065	[0.91,1.24]	0.429
Other language				1	[1.00,1.00]	–				1	[1.00,1.00]	–
Intervention × Other language				1	[1.00,1.00]	–				1	[1.00,1.00]	–

Abbreviations: CHF = congestive heart failure; COPD = chronic obstructive pulmonary disorder. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.