Title

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Journal

Vaccine, 40(47)

ISSN

0264-410X

Authors

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Publication Date

2022-11-01

DOI

10.1016/j.vaccine.2022.09.061

Vaccine xxx (xxxx) xxx

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Scarier than the flu shot? : The social determinants of shingles and influenza vaccinations among U.S. older adults

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ARTICLE INFO

Article history:
Received 25 April 2022
Received in revised form 26 August 2022
Accepted 19 September 2022
Available online xxxx

ABSTRACT

Background: Although more than half of older adults receive the annual influenza vaccine (flu shot), only about one-third have ever been vaccinated for shingles. With this in mind, our study examines how the associations between sociodemographic characteristics, health behaviors, and vaccine uptake differ between these two viruses. In doing so, it also investigates whether the social predictors of shingles vaccination changed after the rollout of a new vaccine in 2017.

Methods: Data come from the 2017 and 2020 waves of the Behavioral Risk Factor Surveillance System survey, using a subset of older adults aged 60-plus (N = 389,165). We use logistic regression models to test for associations between individual-level characteristics and vaccine uptake.

Results: One, when compared to Whites, Black respondents had approximately 30 % lower odds of having received the annual influenza vaccine (Odds Ratios [OR] = 0.72 [95 % CI 0.66–0.78] in 2017, and 0.66 [0.60–0.72] in 2020). For the shingles vaccine, these racial differences were starker (OR = 0.53 [0.48–0.59] in 2017, and OR = 0.55 [0.49–0.60] in 2020). Two, self-rated health was negatively associated with having received the influenza vaccine, but showed little relationship with shingles vaccination. Three, men were less likely than women to receive both vaccines in 2020 (OR = 0.88 [0.83–0.94] for influenza, and OR = 0.80 [0.75–0.85] for shingles). Four, older adults who abstained from alcohol were, generally, less likely to receive either vaccine, when compared to both moderate and heavy drinkers. Finally, we found that the release of a new shingles vaccine in 2017 (Shingrix) had little effect on vaccination prevalence or its social determinants.

Conclusion: The importance of social groups, health, and health behaviors on vaccination status may be disease-dependent. This study also provides possible guidance to health care providers and health organizations looking to increase vaccine uptake among older adults, which may have more urgency since the arrival of COVID-19.

1. Introduction

The COVID-19 pandemic has placed a renewed emphasis on unvaccinated vulnerable populations, including older adults [1]. That said, a vast majority of non-COVID socio-behavioral vaccination research continues to focus on adolescent and early childhood uptake; with an emphasis on parents, socioeconomic status, and race/ethnicity [2,3]. This is unfortunate, since older adults have higher mortality and morbidity rates from infectious diseases, and population aging exacerbates the stress these diseases place on healthcare systems [4].

The limited studies on older adult vaccine uptake have primarily concentrated on the *influenza* vaccine (flu shot), likely because older adults represent about 90 % of influenza-related deaths worldwide [5]. In addition, only about two-thirds of U.S. adults age 65 and older receive an annual flu shot [6], despite CDC recommendations for all adults to be vaccinated [7]. One downside of the emphasis on influenza vaccination is that the social determinants of other preventable diseases are given insufficient attention. In particular, only about one-third of older adults have received the *shingles* vaccine [8], contributing to approximately-one million shingles cases per year [9].

Understanding systematic differences in these "less than optimal" vaccination rates [10] could also guide intervention and health-promotion programs. While prior work has identified some ways in which influenza vaccination differs by social group [11], there has been little analogous research for shingles vaccination, nor any formal comparison between these two vaccines. Utilizing a large nationally representative survey of almost 390,000 responses across two time points, the present study examines

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https://doi.org/10.1016/j.vaccine.2022.09.061
0264-410X/

how the social predictors of older adult vaccine uptake may differ between influenza and shingles vaccines. In doing so, it also provides some insight into how a change in the recommended shingles vaccine in 2017 may have influenced vaccinations.

2. Background

2.1. Older adults influenza vaccination

Influenza contributes to more than half a million hospitalizations and 30,000 deaths per year in the United States [12]. Unfortunately, although the U.S. is generally considered one of the global leaders in influenza vaccination [5], there is considerable uptake disparities across social groups. As one prominent example, a *meta*-analysis found that racial and ethnic minorities have approximately 30 % lower odds of having received the flu shot, when compared to (non-Hispanic) Whites. Focusing only on Black Americans, this difference is even greater [13], which can be partially attributable to medical mistrust, perceived negative healthcare experiences, and lack of routine vaccination recommendations from healthcare providers [14,15].

Prior analyses have also found vaccination differences by socioeconomic status. For example, having relatively higher educational attainment may increase the odds of older adult influenza vaccination by 20 % [11]. Explanations for this include (1) having a better understanding of how vaccinations work, and (2) social environments more amenable to healthy decisions [16]. Prior research also suggests that lower income individuals have approximately 10 % lower odds of receiving the flu shot than higher income individuals [11].

Other demographic characteristics likely play important roles in predicting influenza vaccine uptake. For example, women tend to engage more frequently in several healthy behaviors [17] and being married is associated with greater flu shot uptake [5]. Interestingly, older adults who work may be *less* likely to receive the flu shot, in part because they are more confident in their health [18]. Finally, age appears to be positively associated with receiving the flu vaccine [6]; which may be due to physician encouragement or patient understanding of increased mortality risks.

There are also reasons to believe that self-rated health (SRH) and health behaviors are predictive of influenza vaccination. For example, research has found that individuals with fair or poor SRH are more likely to have received the flu shot, when compared to those with more favorable health appraisals [19]. One explanation for this is that those who report fair or poor health (often due to chronic and/or serious health conditions) are more likely to be advised by their physician about the importance of regular vaccinations [11]. Conversely, it may be that some older individuals reporting good or excellent health believe vaccines could endanger their optimistic evaluations [20]. Flu vaccine uptake would also be associated with health *behaviors* if it were a proxy for a generally healthy lifestyle. For example, individuals who utilize preventive health services may be more likely to be vaccinated than those who do not, in part because of regular physician reminders. Identifying relationships between health behaviors and vaccinations may aid in targeted interventions that encourage uptake.

Historically, U.S. adult (65-plus) influenza vaccination rates have been relatively steady, averaging 65.6 % per year between 2010 and 2020 [6]. Despite this consistency, coverage peaked in 2020 (69.8 %), which may have been due to increased concern over communicable diseases during the COVID-19 pandemic. It is unclear, however, whether any *associations* between sociodemographic characteristics and influenza vaccine uptake also changed in 2020, when compared to prior years.

2.2. Shingles vaccination

Shingles (also known as "herpes zoster") is a painful rash caused by reactivation of the varicella-zoster virus that causes chickenpox. Shingles can occur at any age, but older adults have both the highest incidence rates and the highest rates of accompanying serious complications [21]. In particular, postherpetic neuralgia—a post-shingles burning pain that can last for months—affects one in three individuals who experience shingles after age 70 [22]. Although shingles vaccines have been readily available since 2006, only about one-third of those aged 60-plus have been vaccinated [8].

In 2006, *Zostavax* became the first shingles vaccine approved for use in the United States. At that time, the Centers for Disease Control (CDC) recommended it for non-immunocompromised Americans aged 60-plus [21]. Unfortunately, Zostavax provides waning protection over time and prevents only about half of all shingles reactivations. In 2017, a second shingles vaccine—*Shingrix*—was approved, which prevents about 90 % of shingles reactivations. Starting that year, the CDC recommended all individuals aged 50-plus receive the two-dose Shingrix vaccine sequence, and Zostavax was discontinued by the end of 2020 [23].

The limited social science research on shingles vaccination has focused on Zostavax [8,24]. Because of this, little is known about how the social determinants of vaccination may have been impacted by the introduction of Shingrix. On one hand, Shingrix's increased efficacy and earlier recommended age may encourage greater uptake [25]. Conversely, concerns over the side effects from a new vaccine, or its efficacy, may lead some to forgo their second dose or avoid it altogether.

We are not aware of any U.S. studies that have formally considered how the social determinants of older adult vaccination may differ between shingles and influenza, even though there are clues that this may be the case. For instance, Vogelsang and Polonijo [24] found that Hispanic and Black older adults have 50 % lower odds of shingles vaccination, which is greater in magnitude than racial and ethnic differences found in similar flu vaccine studies [13]. In addition, a U.K. study found that "knowledge and awareness" is a primary factor in predicting uptake differences among different vaccines [25]. If so, the comparatively lower awareness of the shingles vaccine could lead to stronger associations between education and vaccination. It could also explain why some health behaviors—such as physician visits—may be a particularly important predictor for shingles vaccine uptake [26].

Despite possible differences in social determinants between the two vaccines, there are likely to be many similarities. For example, being married in older ages tends to amplify health conscientiousness and healthy behaviors for both partners [27]. Along the same lines, individuals report that a desire to maintain a healthy and disease-free lifestyle is one of the strongest influences of vaccination decisions [25]. Finally, there appears to be similar regional and state patterns to older adult flu [6] and shingles [28] vaccine uptake.

Motivated by these possible differences and a relative lack of research on shingles vaccination uptake, the present study investigates two research questions:

RQ1: How do the social determinants of shingles vaccination differ from that of influenza vaccination?; and.

RQ2: How did the social determinants of these vaccines change between 2017 and 2020, coinciding with Shingrix approval?

3. Data and methods

Data come from the BRFSS (Behavioral Risk Factor Surveillance System), an annual state-based telephone survey initiated and administered by the CDC [29]. The BRFSS focuses on health-related risk behaviors, health conditions, and the use of preventive

services, making it ideal for answering our research questions. On average, the BRFSS interviews more than 400,000 adults annually, of which approximately half are aged 60-plus. Individuals are randomly selected using a multistage cluster design, and data are weighted by age, sex, and race/ethnicity to represent adult populations at the state and local level [29].

Our analytical sample uses the 2017 and 2020 BRFSS waves, since these were the only surveys that contained questions about shingles vaccination and health behaviors. To focus on older-adults and ensure consistency between waves, we restrict our analysis to adults aged 60-plus (n = 209,025 and 181,415 in 2017 and 2020, respectively), the CDC-recommended age range for shingles vaccination in 2017. Fortuitously, the release of *Shingrix* (October 2017) approximately coincided with the end of the 2017 wave data collection, allowing us to note how this new vaccine may have influenced uptake between 2017 and 2020. Respondents were dropped from the survey if they were missing SRH data (n = 725 [0.35 %] in 2017, and n = 551 [0.30 %] in 2020), resulting in a final analytical sample of 208,301 in 2017 and 180,864 in 2020.

3.1. Variables

Completed influenza and shingles vaccinations were determined by the questions "During the last 12 months, have you had either the flu shot or a flu vaccine spray (in your nose)?"; and "Have you ever had the shingles or zoster vaccine?", respectively. Our analyses also include several sociodemographic variables (age, gender, race/ethnicity, income, education, marital status, veteran status, work status, residential region, and whether or not the respondent lives with a child) that may be associated with vaccine uptake. Since age was top coded as "80-plus" in the BRFSS, we employ-three age categories (60–69, 70–79, 80-plus). Respondent sex (male/female) is used as a proxy for gender. Whites refer to (non-Hispanic) Whites, while categories for other sociodemographic variables were guided by the BRFSS codebooks. Residential categories (U.S. census regions) align with CDC's vaccine research [28] and are detailed in the online supplement (Table S1).

Matching prior similar vaccine research [5,24], we also control for SRH and other health behaviors. SRH is measured using the standard five-category scale, ranging from "excellent" to "poor". The five health behaviors we use in our analyses are those asked consistently in both waves: cigarette use, alcohol use, exercise, seat belt use, and routine checkup behavior. Cigarette smoking was coded as a "1" for respondents who smoke cigarettes in any capacity. Alcohol use describes whether the respondent, over the past 30 days, (a) did not drink alcohol, (b) drank only in moderation, or (c) binge drank at least once (≥5 drinks for men, ≥4 for women). A respondent was considered to have "some" exercise if, during the past month, they participated in physical activity outside of work. An annual checkup was coded as a "1" if respondents reporting having one within the past 12 months.

3.2. Analytic strategy

Our analytic strategy involved estimating two logistic regression models for each survey wave (M1 and M2 for 2017, M3 and M4 for 2020). In all models, the dependent variable is a dichotomous variable representing a completed vaccination (influenza for M1 and M3, shingles for M2 and M4). For RQ1, we compare and contrast results from M1 to M2 (for 2017) and M3 to M4 (for 2020). For RQ2, we compare and contrast results from M1 to M3, and M2 to M4.

4. Results

Table 1 reports sample descriptive statistics, by wave and for the total sample. The weighted percentage of older adults who received their annual influenza vaccine was 50.9 % in 2017, which increased to 58.8 % in 2020 (an increase of 7.9 percentage points). For the shingles vaccine, 36.7 % had received it by 2020, up from 34.5 % in 2017 (an increase of 2.2 percentage points). Slightly more than half of the combined sample identified as female (54.5 %), were between ages 60 and 69 (51.6 %), were married (56.9 %), and reported no alcohol use (58.3 %). The majority of respondents identified as non-Hispanic White (75.3 %) and reported meeting with their physician within the past 12 months (85.9 %). The modal educational and self-rated health categories were "high school graduate (or less)" (42.9 %) and "good" (33.2 %), respectively.

4.1. Social determinants of vaccination in 2017

Table 2 displays logistic regression results, presented as odds ratios, using the BRFSS 2017 wave. For five covariates, associations were remarkably different between the shingles and influenza vaccines. One, we found that men were less likely than women (Odds Ratio [OR] = 0.76) to receive the shingles vaccine, even though there were no gender differences in influenza vaccine uptake. Two, Hispanics, when compared to Whites, had lower odds of receiving the shingles vaccine (OR = 0.56), but similar odds of influenza vaccination. Three, SRH had a negative relationship with influenza vaccination. That is, when compared to those reporting good health, those with fair and poor health had greater odds of uptake (OR = 1.22–1.23), while those with excellent or very good SRH had lower odds (OR = 0.75–0.87). For the shingles vaccine, however, those in poor health had slightly *lower* odds of being vaccinated (OR = 0.91), while those in very good health had slightly greater odds (OR = 1.10). Four, when compared to excessive drinkers, those who did not drink alcohol were less likely to receive the shingles vaccine (OR = 0.84) but had no difference in influenza vaccine uptake. Five, living with a child was associated with 28 % lower odds of receiving the shingles vaccine, but had no relationship with the influenza vaccine.

For two other covariates, their negative association with being vaccinated was greater in magnitude for shingles than for influenza. For one, Black older adults (when compared to Whites) had 28 % lower odds of receiving the influenza vaccine, but almost 50 % lower odds (OR = 0.53) of receiving the shingles vaccine. Two, when compared to those making at least $75,000 per year, individuals with lower incomes were estimated to have 8–15 % lower odds of being vaccinated for influenza, but 14–44 % lower odds for shingles.

4.2. Social determinants of vaccination in 2020

Table 3 displays results using the BRFSS 2020 wave. With respect to RQ2, we found only two substantive differences when comparing the social determinants of shingles vaccination between 2017 (M2) and 2020 (M4), coinciding with Shingrix's approval. One, being widowed (OR = 0.88) or never married (OR = 0.83) were each associated with lower odds of shingles vaccine uptake in 2020, contrasting with no marital status differences in 2017. Two, those with poor SRH had lower odds of being vaccinated for shingles in 2017 (OR = 0.91), but not in 2020.

We also compared the social determinants of influenza vaccination between 2017 (M1) and 2020 (M3). Results from these estimates were generally similar, with three notable exceptions. One, men had lower odds of flu vaccination in 2020 (OR = 0.88), compared to no gender differences in 2017. Two, although we found

Table 1
Descriptive Statistics (Weighted Percentages and Unweighted N's), 2017 (N = 208,301) and 2020 (N = 180,864), Behavioral Risk Factor Surveillance System Survey.

	Weighted % (2017)	N (2017)	Weighted % (2020)	N (2020)	Weighted % (Total)
Received Influenza Vaccine	50.9 %	111,634	58.8 %	112,099	55.0 %
Received Shingles Vaccine	34.5 %	80,982	36.7 %	74,776	35.7 %
Age:					
60–69	52.5 %	102,242	50.8 %	84,735	51.6 %
70–79	32.1 %	70,486	33.8 %	64,826	33.0 %
80-plus	15.4 %	35,373	15.4 %	31,303	15.4 %
Women	54.9 %	122,934	54.2 %	103,243	54.5 %
Race/Ethnicity:					
Non-Hispanic White	75.9 %	175,508	74.7 %	151,770	75.3 %
Black	9.8 %	14,345	10.2 %	11,914	10.0 %
Hispanic	9.1 %	8,534	9.7 %	7,882	9.4 %
Asian	2.7 %	2,378	2.8 %	2,382	2.8 %
Native American	0.9 %	2,990	0.9 %	2,418	0.9 %
Other	1.6 %	4,546	1.7 %	4,558	1.6 %
Annual Income:					
$0–$19,999	16.0 %	30,454	13.8 %	22,100	14.9 %
$20,000–$34,999	18.2 %	38,573	16.0 %	30,556	17.1 %
$35,000–$49,999	12.2 %	27,024	11.3 %	22,030	11.7 %
$50,000–$74,999	12.3 %	27,399	12.3 %	23,925	12.3 %
≥$75,000	21.8 %	43,997	22.9 %	41,061	22.4 %
Missing	19.5 %	40,854	23.7 %	41,192	21.6 %
Education:					
≤ High School	43.7 %	75,169	42.2 %	62,454	42.9 %
Some College	30.4 %	56,777	30.6 %	50,482	30.5 %
College Graduate	25.9 %	76,355	27.2 %	67,928	26.6 %
Marital Status:					
Married	56.7 %	108,202	57.2 %	96,510	56.9 %
Widowed	20.0 %	49,336	19.0 %	39,491	19.5 %
Divorced	16.0 %	34,488	15.9 %	29,271	15.9 %
Never married	7.3 %	16,275	7.9 %	15,592	7.7 %
Live w/ Child	7.0 %	10,102	6.9 %	8,951	6.9 %
Veteran	18.4 %	38,660	16.5 %	31,173	17.4 %
Currently Working	25.2 %	51,247	25.0 %	44,397	25.1 %
Self-Rated Health:					
Excellent	12.9 %	27,605	14.0 %	26,626	13.5 %
Very Good	28.7 %	64,416	30.7 %	59,830	29.7 %
Good	33.0 %	68,268	33.3 %	58,266	33.2 %
Fair	17.9 %	33,854	15.8 %	26,415	16.8 %
Poor	7.5 %	14,158	6.2 %	9,727	6.8 %
Does Not Smoke Cigarettes	89.4 %	187,912	89.7 %	163,176	89.6 %
Alcohol Use:					
None	57.2 %	117,911	59.4 %	105,367	58.3 %
Moderate	36.7 %	78,898	34.8 %	65,481	35.7 %
Excessive	6.1 %	11,492	5.8 %	10,016	6.0 %
Some Exercise	63.1 %	134,956	70.2 %	129,537	66.8 %
Wears Seat Belts	83.1 %	173,577	85.1 %	152,530	84.2 %
Annual Checkup	84.9 %	175,285	86.9 %	157,437	85.9 %

no flu vaccine differences between Hispanics and Whites in 2017, Hispanics had 26 % lower odds of flu vaccination in 2020. Last, alcohol abstainers and excessive drinkers had similar odds of receiving the flu shot in 2017. However, in 2020, abstainers had lower odds (OR = 0.88) of receiving the flu shot.

Fig. 1 displays the estimated marginal trajectories of being vaccinated for the entire sample, stratified by race/ethnicity and income. That is, each line represents the predicted probability of being vaccinated for somneone in that race/ethnicity category; given their annual income. The left and right sides of the figure predict influenza and shingles vaccination, respectively, and highlights three results from our analyses: (1) racial/ethnic differences, (2) the income gradient, and (3) aggregate differences between these two vaccines. For example, (1) the estimated probability of influenza vaccination (left side) for low-income individuals is similar between racial/ethnic categories—approximately 45 %, 49 %, and 54 % for Blacks, Hispanics, and Whites, respectively. For shingles (right side), however, only 20 % of low-income Black and Hispanic older adults are estimated to have been vaccinated, compared to 30 % of low-income Whites. Next, (2) the gradient between income and vaccination is more pronounced for the shingles vaccine. For example, the predicted vaccination disparities between low- and high-income Whites (29 % and 43 %, respectively) is much greater for shingles than for influenza vaccination (54 % and 61 %, respectively). Finally, this figure underscores (3) stark uptake differences between shingles and influenza vaccination. That is, the predicted probability for *ever* receiving the shingles vaccine for a high-income White older adult (43 %) is less than that of a low-income Black older adult receiving the influenza vaccine within the past twelve months (45 %).

4.3. Supplemental analyses

We conducted four subsequent analyses. One, we considered the implications of missing data. With the exception of SRH (0.3 % of the sample in both waves) and income (treated as a separate category), only the dependent variables had more than a few cases of missing data (on average, 6.7 % of respondents did not answer the vaccination questions). In our primary analyses, missing responses were coded "0" (i.e., not vaccinated). For the sensitivity analyses, these observations were dropped, which resulted in no material impact on the results presented in this manuscript.

Table 2
Logistic Regression Results for Ever Receiving a Shingles or Influenza Vaccine, 2017 Behavioral Risk Factor Surveillance System Survey (N = 208,301).

	M1 (Influenza)		M2 (Shingles)	
OR	95 % CI	OR	95 % CI	
Age: (ref: 60–69)				
70–79	1.43***	[1.36, 1.50]	1.54***	[1.46, 1.62]
80-plus	1.64***	[1.53, 1.76]	1.28***	[1.19, 1.37]
Men (ref: Women)	0.95	[0.90, 1.00]	0.76***	[0.72, 0.80]
Race: (ref: Non-Hispanic White)				
Black	0.72***	[0.66, 0.78]	0.53***	[0.48, 0.59]
Hispanic	0.96	[0.86, 1.08]	0.56***	[0.49, 0.63]
Native American	0.91	[0.75, 1.11]	0.90	[0.72, 1.12]
Asian	0.99	[0.77, 1.26]	1.12	[0.88, 1.42]
Other	0.85*	[0.72, 0.99]	0.80*	[0.67, 0.95]
Income: (ref: ≥$75,000)				
$0–$19,999	0.85**	[0.77, 0.93]	0.56***	[0.51, 0.62]
$20,000–$34,999	0.84***	[0.78, 0.90]	0.68***	[0.63, 0.74]
$35,000–$49,999	0.91*	[0.84, 0.99]	0.82***	[0.75, 0.89]
$50,000–$74,999	0.92*	[0.85, 0.99]	0.86***	[0.80, 0.92]
Missing	0.76***	[0.70, 0.81]	0.65***	[0.61, 0.70]
Education (ref: College Degree)				
≤ High School	0.76***	[0.72, 0.81]	0.65***	[0.61, 0.69]
Some College	0.80***	[0.76, 0.85]	0.79***	[0.75, 0.84]
Marital Status: (ref: Married)				
Widowed	0.98	[0.92, 1.04]	0.98	[0.92, 1.04]
Divorced	0.92*	[0.86, 0.97]	0.93*	[0.87, 1.00]
Never Married	1.00	[0.92, 1.09]	0.99	[0.90, 1.08]
Live with Child	0.92	[0.83, 1.01]	0.72***	[0.65, 0.80]
Veteran	1.13***	[1.06, 1.20]	1.22***	[1.15, 1.31]
Currently Working	0.82***	[0.78, 0.87]	0.67***	[0.64, 0.71]
Region (ref: North [West Central])				
Pacific	0.68***	[0.62, 0.74]	0.87***	[0.79, 0.94]
Mountain	0.72***	[0.69, 0.76]	0.85***	[0.80, 0.89]
North (East Central)	0.75***	[0.71, 0.79]	0.75***	[0.71, 0.79]
South (West Central)	0.75***	[0.67, 0.83]	0.76***	[0.68, 0.84]
South (East Central)	0.78***	[0.72, 0.83]	0.68***	[0.64, 0.73]
South-Atlantic	0.86***	[0.81, 0.91]	0.71***	[0.67, 0.76]
Mid-Atlantic	0.86***	[0.81, 0.92]	0.68***	[0.64, 0.72]
New England	0.81***	[0.74, 0.86]	0.89**	[0.82, 0.96]
Territories	0.32***	[0.28, 0.39]	0.36***	[0.29, 0.45]
Self-Rated Health: (ref: Good)				
Excellent	0.75***	[0.70, 0.80]	0.98	[0.91, 1.05]
Very Good	0.87***	[0.83, 0.92]	1.10***	[1.04, 1.17]
Fair	1.23***	[1.15, 1.32]	1.04	[0.97, 1.12]
Poor	1.22***	[1.13, 1.34]	0.91*	[0.82, 0.99]
Does Not Smoke Cigarettes	1.31***	[1.22, 1.41]	1.52***	[1.40, 1.64]
Alcohol Use (ref: Excessive)				
Moderate	1.22***	[1.11, 1.34]	1.10	[0.99, 1.21]
None	1.03	[0.94, 1.13]	0.84***	[0.76, 0.93]
Some Exercise	1.42***	[1.35, 1.49]	1.27***	[1.21, 1.34]
Wears Seat Belts	4.23***	[3.96, 4.52]	3.33***	[3.06, 3.62]
Annual Checkup	2.04***	[1.92, 2.17]	1.89***	[1.77, 2.03]
F (df)	124.64*** (40, 208261)		126.44*** (40, 208261)	

Note: OR = odds ratio; CI = Confidence Interval; * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

Two, since serious health conditions have been linked to increased vaccine uptake [11] we estimated a set of models adding an index of seven health conditions (heart disease, asthma, kidney disease, diabetes, stroke, cancer, lung disease). Doing this, not surprisingly, eliminated the relationships between poor/fair SRH and influenza vaccination. It also strengthened the relationship between being in the lowest income category and not having received the influenza vaccine. It had no other material effect on any results.

For our third supplemental analysis (related to RQ2), we examined whether there were any systematic patterns in the modest shingles vaccination increase. From this, we noted a greater increase in those with fair or poor SRH (from 27.8 % to 31.6 %), when compared to other health ratings (36.9 % to 38.2 %). Last, we estimated a set of hierarchical linear models, nesting observations within regions, to account for unobserved dependence between individuals within the same region. Results from this set of models essentially mirrored those displayed in Tables 2 and 3, with the following exceptions: One, for the shingles vaccine, having excellent or poor SRH were each associated with approximately 10 % lower odds of vaccination in both 2017 and 2020 (compared to only one association found in the original estimates). Two, we found that moderate drinking was associated with greater odds of vaccination (OR = 1.10–1.20 [1.07–1.28]) in all four models (only one model in the original estimates). Three, men had lower odds of receiving the flu shot in 2017 (OR = 0.94 [0.92–0.96]) in the supplemental models, but not the original models.

5. Discussion

Although older adult vaccinations can be an effective tool to reduce morbidity and mortality, there are significant uptake gaps between and among social groups. The present manuscript not only identifies social determinants of vaccinations, but also finds that some of them—including race/ethnicity and gender—differ-

Table 3
Logistic Regression Results for Ever Receiving a Shingles or Influenza Vaccine, 2020 Behavioral Risk Factor Surveillance System Survey (N = 180,864).

	M3 (Influenza)		M4 (Shingles)	
	OR	95 % CI	OR	95 % CI
Age: (ref: 60–69)				
70–79	1.46***	[1.37, 1.55]	1.63***	[1.54, 1.73]
80-plus	1.52***	[1.40, 1.65]	1.35***	[1.25, 1.47]
Men (ref: Women)	0.88***	[0.83, 0.94]	0.80***	[0.75, 0.85]
Race: (ref: Non-Hispanic White)				
Black	0.66***	[0.60, 0.72]	0.55***	[0.49, 0.60]
Hispanic	0.74***	[0.64, 0.85]	0.63***	[0.54, 0.74]
Native American	0.73**	[0.58, 0.91]	0.68**	[0.52, 0.89]
Asian	0.94	[0.73, 1.20]	1.12	[0.88, 1.42]
Other	0.68***	[0.58, 0.80]	0.70***	[0.58, 0.83]
Income: (ref: ≥$75,000)				
$0–$19,999	0.65***	[0.58, 0.73]	0.56***	[0.50, 0.64]
$20,000–$34,999	0.71***	[0.65, 0.78]	0.70***	[0.64, 0.77]
$35,000–$49,999	0.83***	[0.76, 0.92]	0.77***	[0.70, 0.84]
$50,000–$74,999	0.89**	[0.81, 0.97]	0.85***	[0.78, 0.92]
Missing	0.60***	[0.55, 0.65]	0.62***	[0.57, 0.67]
Education (ref: College Degree)				
≤ High School	0.68***	[0.64, 0.73]	0.63***	[0.60, 0.67]
Some College	0.80***	[0.75, 0.85]	0.76***	[0.72, 0.81]
Marital Status: (ref: Married)				
Widowed	0.98	[0.91, 1.04]	0.88***	[0.82, 0.95]
Divorced	0.90**	[0.83, 0.97]	0.91*	[0.85, 0.99]
Never Married	0.97	[0.87, 1.06]	0.83***	[0.75, 0.91]
Live with Child	0.86**	[0.79, 0.97]	0.76***	[0.66, 0.87]
Veteran	1.07	[0.99, 1.15]	1.18***	[1.10, 1.28]
Currently Working	0.75***	[0.70, 0.79]	0.65***	[0.57, 0.67]
Region (ref: North [West Central])				
Pacific	0.79***	[0.71, 0.88]	0.87***	[0.79, 0.94]
Mountain	0.84***	[0.79, 0.89]	0.86***	[0.81, 0.91]
North (East Central)	0.93**	[0.87, 0.99]	0.75***	[0.71, 0.79]
South (West Central)	0.85*	[0.77, 0.94]	0.83***	[0.75, 0.93]
South (East Central)	0.85***	[0.78, 0.92]	0.66***	[0.61, 0.71]
South-Atlantic	0.76***	[0.71, 0.81]	0.70***	[0.66, 0.75]
Mid-Atlantic	0.84***	[0.79, 0.90]	0.66***	[0.62, 0.70]
New England	1.15***	[1.07, 1.24]	0.81**	[0.76, 0.87]
Territories	0.43***	[0.33, 0.55]	0.42***	[0.29, 0.59]
Self-Rated Health: (ref: Good)				
Excellent	0.69***	[0.64, 0.75]	1.00	[0.93, 1.09]
Very Good	0.84***	[0.79, 0.89]	1.11***	[1.04, 1.18]
Fair	1.13**	[1.04, 1.22]	1.06	[0.97, 1.15]
Poor	1.25***	[1.11, 1.41]	0.99	[0.86, 1.13]
Does Not Smoke Cigarettes	1.36***	[1.22, 1.41]	1.53***	[1.40, 1.68]
Alcohol Use (ref: Excessive)				
Moderate	1.10	[0.99, 1.23]	1.09	[0.96, 1.22]
None	0.88*	[0.79, 0.98]	0.86***	[0.76, 0.93]
Some Exercise	1.16***	[1.09, 1.23]	1.16***	[1.09, 1.23]
Wears Seat Belts	3.83***	[3.57, 4.12]	2.94***	[2.69, 3.20]
Annual Checkup	2.50***	[2.32, 2.69]	1.85***	[1.70, 2.02]
F (df)	95.94*** (40, 180824)		81.38*** (40, 180824)	

Note: OR = odds ratio; CI = Confidence Interval; * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

ently predict influenza and shingles vaccine uptake. Our results also put a spotlight on the two-thirds of older adults that have not received the shingles vaccine and provide hints about possible strategies to increase uptake.

5.1. Social determinants

We find that the Black–White vaccination gaps were consistent and robust across both time and vaccination type (ranging from 28 % to 47 % lower odds of vaccination for older Blacks, when compared to Whites). Several factors may drive these disparities, including differences in provider perceptions of patients, as well as the related strength and frequency of provider recommendations—both key drivers of vaccine uptake [15,30]. Moreover, structural racism likely contributes to these lower rates by influencing vaccine knowledge, vaccine hesitancy, medical trust, and healthcare utilization [31].

We also find that Hispanic older adults have similar lower odds of shingles vaccination, compared to Whites. A separate explanation for this is that older Hispanics who are first- or second-generation Americans may face language and cultural barriers that particularly influence shingles vaccination. For example, varicella vaccination (both chickenpox and shingles) is not a part of the national immunization program in Mexico [32], which could influence Mexicans and Mexican-Americans living in the United States. For the influenza vaccine, Hispanic older adults had similar odds of vaccination as Whites in 2017, but similar odds as Blacks in 2020. This relative change reflects an overall increase in flu shot uptake from 2017 and 2020 that was more pronounced among Whites (from 52.9 % to 62.0 %) than Hispanics (from 44.9 % to 47.5 %). Understanding the processes behind this increase remains a topic of future inquiry, but the first year of the COVID-19 pandemic—which may have reminded people about other communicable diseases—was likely a contributing factor. In particular, physicians

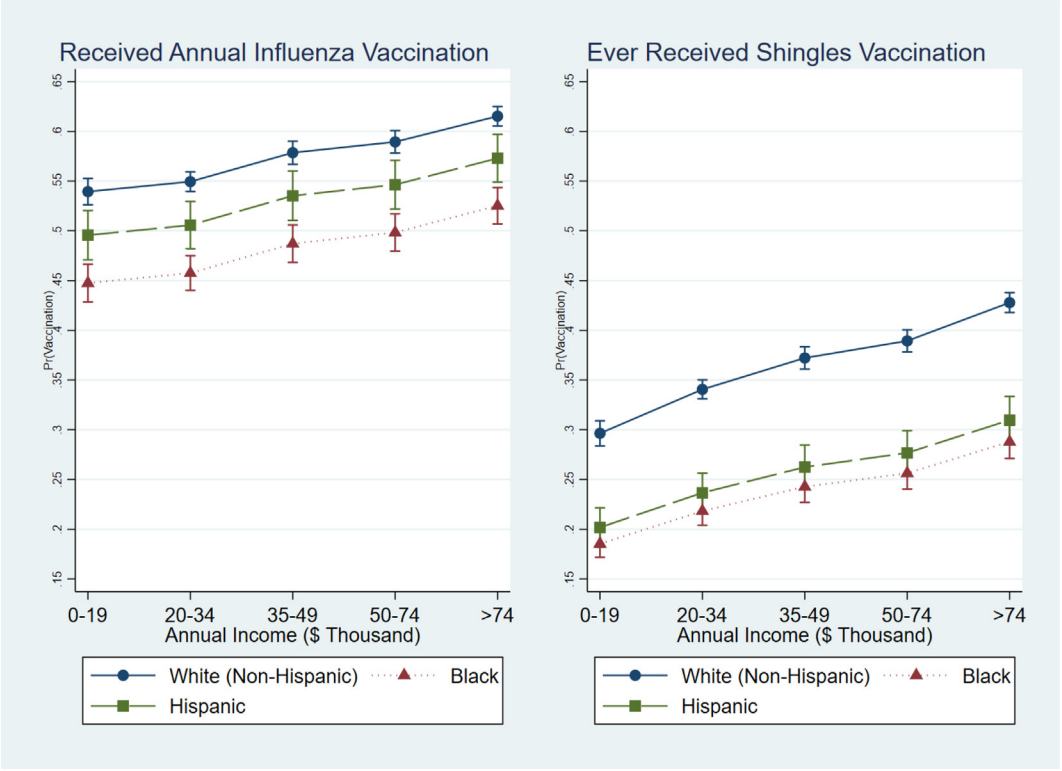

Fig. 1. Predicted Marginal Probability of Vaccination (with 95 % Confidence Intervals); by Racial/Ethnic Group, Behavioral Risk Factor Surveillance System Data, 2017 and 2020 Waves. (N = 389,165).

appeared to have more-heavily promoted influenza vaccinations [33], while some individuals took steps to reduce the risk of infection (e.g., wear masks and become vaccinated).

While we found no gender differences in flu shot uptake in 2017, women had greater odds of influenza vaccination in 2020. Similar to the 2020 Hispanic–White influenza vaccine disparity, this was primarily the result of a steeper increase in vaccine uptake among women (from 51.3 % to 60.4 %) when compared to men (from 50.4 % to 56.8 %) across these three years. Reasons why (non-Hispanic) White women appear to have been particularly apt to increase their uptake during this time remains an important research question. For the shingles vaccine, we also found that men have lower odds of vaccination when compared to women (24 % and 20 % lower in 2017 and 2020, respectively). One reason for this is that women tend to engage in more regular physician visits and adhere to physician advice [34]. Moreover, these gendered behavior differences may be particularly salient for the shingles vaccine, since health provider recommendation appears to be crucial to its acceptance [26].

With respect to associations between health and vaccination, we found a clear negative gradient between SRH and flu shot uptake that mirrored prior studies [19]. For shingles vaccination, however, our results were inconsistent and did not follow these patterns. Interestingly, a supplemental analysis revealed that the overall modest increase in shingles vaccination between 2017 and 2020 was primarily driven by those with poor SRH (24.3 % of this group had received the shot in 2017, increasing to 30.3 % in 2020). A likely contributing factor to this increase is that Zostavax was not recommended for adults who were immunocompromised [21]; while Shingrix does not have this limitation. Moreover, since physicians generally tend to place greater emphasis on vaccinating those with chronic conditions [11], the release of Shingrix may have provided a renewed impetus to vaccinate this population. Conversely, it is still unknown why those with very good or excellent health have reduced odds of getting a flu shot but not the shingles vaccine. One explanation is that the flu shot requires an annual dose (which some in these categories may not feel they need), while the shingles vaccination sequence is offered as a single event that provides lifetime protection.

One of the more surprising results of this study is that, unlike other healthy behaviors, abstaining from alcohol was generally associated with *lower* vaccination odds for both vaccines. Mechanisms behind these relationships remain untested, but we offer three possible explanations. One, unlike many other health behaviors (e.g., exercise, wearing seatbelts, healthy eating) alcohol abstention is, generally, a passive behavior. It is also one that, similar to vaccines, involves avoiding a "foreign substance". Two, religiosity may be a lurking variable, as it has been linked to alcohol abstention [35] and cited as one reason to decline vaccines [36]. Three, there are certain psycho-social traits that may be associated with both vaccinations and alcohol consumption. For example, research suggests risk-aversion may be one explanation for vaccine hesitancy [25] and those who do not drink alcohol may share this trait.

5.2. Older adult vaccination: Changes and challenges

When Shingrix was released in 2017, physicians and public health officials were optimistic that it would lead to a marked increase in vaccinated older adults. Unfortunately, the percentage of Americans aged 60-plus that have ever received the vaccine rose only 2.2 points across three years. This is somewhat surprising, particularly since the percentage of those receiving their annual flu shot showed a greater increase over this time (7.9 percentage points) and older adults have overwhelmingly embraced the COVID-19 vaccine [37]. Future research on shingles vaccination needs to identify possible reasons and solutions for this relative lack of enthusiasm, and we offer some possibilities for

consideration. For example, COVID-19 and influenza have a much higher mortality rate than shingles, which kills only about 100 people per year [38]. Indeed, since shingles is related to chickenpox, and most current older adults both experienced and survived that infection [39], some individuals may underestimate the vaccine's importance. If the American public, in the case of influenza (and COVID-19) has been persuaded by "worst-case scenarios", then physicians and public health officials looking to promote shingles vaccination may want to stress both common (blisters, pain, fever) and uncommon yet serious (postherpetic neuralgia, pneumonia, encephalitis) side effects that could accompany the disease.

Another possible explanation for this tepid increase in shingles vaccination is that most older adults are not aware of this vaccine change nor understand what it means. It may also be that some individuals are hesitant to take a relatively new vaccine due to concerns over safety or long-term effectiveness. Other possible concerns are that Shingrix requires two doses (compared to Zostavax's single dose) or that side effects may limit activity for a few days after the second dose (CDC, 2018a). Last, it may be that this period (2017–2020) is one of increased vaccine politicization and/or vaccine fatigue that attenuated further gains. Clearly, there is relatively less public discourse and public health messaging for the shingles vaccine, when compared to the flu shot. There may also be relatively less physician guidance. For example, while physicians may have pushed to expand influenza vaccinations during the COVID pandemic [33], we are not aware of analogous shingles vaccine promotion.

5.3. Limitations

The BRFSS is an ideal nationally representative dataset for our research questions but comes with important limitations. For one, the BRFSS vaccination module is only included every-three years, which prohibits us from identifying annual trends. It is also unclear whether any changes between 2017 and 2020 were influenced by COVID-19, the introduction of the Shingrix vaccine, or other causes. Further, even though Shingrix was introduced shortly after the 2017 BRFSS wave, the alignment between vaccine and survey wave was not precise. That is, Zostavax was still approved and administered, albeit in much lower quantities, until November 2020. Unfortunately, the BRFSS does not ask questions about some individual-level characteristics that may be associated with vaccine uptake and other covariates in our analyses (e.g., health literacy, prescription medicine information, political affiliation). Finally, while we were able to examine an array of health behaviors, we were unable to consider additional health behavior questions (e.g., sleeping patterns, eating habits) that were asked inconsistently across waves.

6. Conclusion

Less than optimal uptake of readily available vaccines contributes to numerous preventable illnesses among older adults. This is a worldwide problem, with many developed and aging countries facing challenges with older adult vaccine perception, literacy, and advice [40]. Although the influenza vaccine is particularly important for older adult mortality—and the shingles vaccine is primarily administered to those over age 50—we believe researchers will benefit by comparing vaccination patterns and rationale to other age groups. For example, there is evidence that the relationship between income and vaccination uptake is different for children [41], when compared to the results we present here for older adults.

By examining the social determinants for two different vaccines, this paper suggests a possible advantage to tailoring vaccine promotion strategies by social group and vaccine type. In particular, there needs to be emphasis placed on low-income individuals, members of minoritized racial/ethnic groups, and the "younger old" (aged 60–70). One hurdle is that, when compared to other healthy behaviors (e.g., healthy eating, exercise), there appears to be relatively low public knowledge about vaccine effectiveness and how vaccines work. For older adults, these issues are compounded by inconsistent and infrequent vaccine messaging, as well as decreases in vaccine effectiveness as people age [40]). In the absence of greater vaccine literacy or successful public information campaigns, some older adults may perform their own knowledge gathering. In some cases, this could lead to increased misconceptions and vaccine hesitancy [42]. Acknowledging these vaccination gaps may be even more vital in the coming decades, as (a) current vaccines are modified/improved; and (b) novel vaccines are introduced to combat existing and future pathogens [7].

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.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2022.09.061.

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