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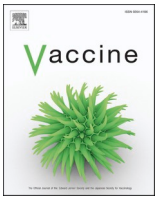

Gender differences in COVID-19 preventative measures and vaccination rates in the United States: A longitudinal survey analysis

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ABSTRACT

Background: Pandemics present challenges for individuals as they face uncertainties, risks, and decisions which influence their attitudes towards public health interventions. This study investigates gender differences in attitudes towards COVID-19 preventive measures and vaccination intentions in the United States, focusing on the link between risk perception and attitudes towards public health guidelines.

Methods: We utilised data from the Understanding America Study, a nationally representative longitudinal survey of U.S. adults from March 2020 to March 2022 to assess how gender differences in health risk perception were associated with attitudes, behaviours, and vaccination intentions, while also evaluating how these gender effects changed over time. We used multilevel logistic regression models to adjust for age, level of education, employment status and income.

Results: Women had a higher risk perception of COVID-19 and exhibited greater compliance with preventive measures compared to men. Women also showed higher agreement with COVID-19 restraining public policy measures. However, this contrasted with attitudes towards the COVID-19 vaccine, where men displayed more positive views and a higher intention to receive the vaccine. This gender effect was persistent over time.

Conclusions: This seemingly paradoxical outcome suggests that while women's heightened risk perception relative to men's leads to greater adherence to non-pharmaceutical COVID-19 preventative public health interventions, it may also result in more negative views towards the novel COVID-19 vaccine. Understanding the complex interactions between risk perception, behaviour, and gender can inform policymakers and health authorities to tailor interventions that address the diverse needs of the population.

1. Introduction

Outbreaks, epidemics, and pandemics present unprecedented challenges for individuals as they face many uncertainties, risks, and decisions [1]. The COVID-19 pandemic is no exception. At the onset of the pandemic with the absence of a vaccine, governments and health authorities worldwide were compelled to evaluate the evolving evidence to develop non-pharmaceutical recommendations that included preventative and restrictive measures, such as social distancing and masking [2,3]. Subsequently, once the vaccines became available, these recommendations expanded to incorporate vaccination as a crucial intervention [4]. The vaccines were then introduced to different segments of the population based on risk and availability [4].

Ultimately, the restrictive measures and vaccine intervention was guidance issued by the government, and the decision to comply with these measures and interventions remained with the individual. When making these decisions, individuals had to assess their perceived risk and consider how their individual behaviours could impact that perceived risk. Previous studies analysing compliance with restrictive measures have consistently found that women tend to exhibit greater levels of compliance than men, particularly related to handwashing, social distancing, use of masks, and proactively seeking medical care [5–14]. Furthermore, across eight countries, women perceived COVID-19 as a greater threat and displayed a greater adherence to preventative measures [6]. However, it has also been documented that women experience more negative attitude towards the COVID-19 vaccine and displayed a lower intention of vaccination when compared to men [15,16].

Risk perception has been defined as a subjective assessment of the actual or potential threat to one's life or psychological well-being [17].

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More specifically, risk perception is composed of perceived vulnerability and perceived severity [18,19]. Risk perception can predict the willingness of an individual to follow public health measures and accept messages from institutions [17]. Moreover, an individual's behaviour is intrinsically linked to their beliefs regarding the consequences of their actions and the associated risk perception regarding those consequences [7]. In the context of COVID-19, risk perception encompasses an individual's perceived probability of contracting the virus and the potential consequences associated with it. It plays a central role in determining the adoption of preventive behaviours. Individuals with a higher risk perception are more likely to engage in protective actions, such as mask wearing, practicing social distancing, and following health guidelines [6]. In the existing literature, the gender difference in health risk aversion has been attributed to several factors [12,20,21]. For example, women display a higher level of health consciousness and prioritize their well-being more frequently [8,22]. Previous studies also found women to be more proactive in seeking information about health-related issues, including infectious diseases, which can enable a better understanding of the importance of preventative measures and reinforce compliance [8,22]. This heightened awareness can lead to a greater perception of risk and subsequently result in more cautious behaviour [23–27].

This paper aims to investigate the link between gender and risk perception, attitudes towards, and behaviour with respect to public health guidelines and recommendations. These relationships may help explain gender differences in COVID-19 vaccine intentions in the United States of America (U.S). We hypothesise that because women have an increased COVID-19 risk perception and view the consequences more severely than men, they will be more likely to agree and adhere to restrictive measures to reduce the probability of contracting the disease. However, we hypothesise this heightened risk perception would also result in women having more negative views on the novel COVID-19 vaccine relative to men. Understanding the intricate relationship between risk perception, behaviour, and gender can provide insight into the best ways to promote adherence to future preventative measures and interventions.

To evaluate this hypothesis, we use a large nationally representative longitudinal survey of U.S. adults reporting their views on public health interventions and guidelines introduced, and on protective behaviours during the COVID-19 pandemic from the early stages in March 2020 until March 2022. We assess gender differences in health risk perception and model how these gender differences are associated with attitudes towards public health interventions, behaviours and COVID-19 vaccination intentions. Further, we evaluate how these gender effects change over time.

2. Methods

We used data from the Understanding America Study, a national representative longitudinal study of U.S adults managed by the University of Southern California Center for Economic and Social Research [28]. The panel-based survey uses address-based sampling from the US Postal Service Computerized Delivery Sequence file containing all postal addresses. Participants aged 18 and over are invited to complete the surveys online in English or Spanish and tablets are provided to those without internet access. At the early stages of the COVID-19 pandemic in March 2020, a panel of around 7000 participants participated in UAS surveys focusing on a wide range of issues related to the pandemic, including perception of the health consequences of COVID-19, protective behaviours, vaccination intentions and views on public health measures. We used data from Waves 1 to 31 corresponding to the time period between 10 Match 2020 and 30 March 2022 (Supplementary material, Table S1). The full survey questionnaire is available in Supplementary material, Appendix 1.

2.1. Measures and outcomes

Risk perception of COVID-19 was measured using the response to the question "chance of getting infected with COVID in next 3 months", where the responses were on a scale of 0 to 100 percent. Given our objective of assessing gender differences in health risk perception and changes in perception over time, for ease of interpretation, we constructed a binary measure, identifying responses above the 80th percentile as high perceived risk of getting COVID-19, following visual inspection of the distribution of participant responses. As a sensitivity measure, we also used responses to "chance hospitalized if get coronavirus" and "perceived risk of death due to COVID" as additional measures of COVID-19 risk perception, where responses above the 80th percentile were identified as high perceived risk of getting hospitalised from COVID-19 and high perceived risk of death from COVID-19, respectively. We also measured risk perception using binary variables where responses above the 60th percentile were identified as high perceived risk of getting infected, hospitalised or dying from COVID-19.

To measure agreement on restraining COVID-19 public policy measures and guidelines, we created an index of agreement on COVID-19 restraining measures using the responses to the following measures: safe visiting with relatives or friends in their home; safe to play on playground; safe to go to the grocery store; effectiveness of avoiding restaurants; effectiveness of avoiding the public; effectiveness of avoiding travel; effectiveness of avoiding high risk people; effectiveness of wearing face mask; effectiveness of washing hands; effectiveness of seeing a doctor when healthy but worried about exposure; effectiveness of seeing a doctor when sick; and effectiveness of avoiding hospitals and health clinics. Using a similar approach to Galasso et al. [6], we created dummy variables equal to 1 if the respondent completely or somewhat agrees with a measure or guideline, and 0 otherwise, and we calculated the average over all questions to derive the index score (Cronbach's alpha: 0.74).

To measure compliance with public health rules and guidelines, we created an index of compliance with public health rules using responses to the following measures: had close contact (within 6 ft) with people not living with you in past 7 days; washed hands; gone out to a bar, club, or other place where people gather in past 7 days; gone to a friend, neighbour, or relative's residence in past 7 days; had visitors at your residence in past 7 days; attended a gathering with more than 10 people in past 7 days; remained in residence except for essential activities in past 7 days; avoided contact with high-risk people; avoided public spaces; worn a facemask; avoided restaurants; and worked or studied from home. The responses were yes or no binary answers, and we calculated the index score by averaging the answers to all questions (Cronbach's alpha: 0.77).

We measured attitudes towards COVID-19 vaccination by creating an index of positive views on the COVID-19 vaccine by using the responses to the following questions: how likely to get coronavirus vaccine once available; COVID-19 vaccines have many known harmful side effects; COVID-19 vaccines provide important benefits to society; COVID-19 vaccines may lead to illness and death; COVID-19 vaccines are useful and effective; trust in vaccine manufacturing process; and trust in governmental approval process. Once again, we generated the index score by averaging out the respondents' answers to all questions (Cronbach's alpha: 0.89). Cronbach's alpha for indices reported in Supplementary material, Tables S2–S4.

We included gender, age group, education level, employment status and household income quartile and ethnicity as covariables in the regression models. Gender was identified using the response of either "Male" or "Female" to the question "what is your gender". The ethnicities included were White, Black, Spanish/Hispanic/Latino, American Indian or Alaska native, Asian, and Hawaiian/Pacific Islander. Educational levels were defined as: some college, Bachelor's or higher; high school; and less than high school. Employment status was defined as: full-time; part-time; self-employed; unemployed; and retired. Survey

weights were applied to make these covariables nationally representative.

2.2. Analytical approach

We estimated the effect of gender on outcomes using multilevel logistic regression models [29] for binary outcome variables and multilevel mixed-effects linear regression [30] for continuous outcome variables, with an individual-level random effect to control for repeated measurements.

To estimate the initial level and rate of change of an outcome by gender, we used the following specification (reported as Model A in the results):

$$y_{it} = \alpha_i + \beta_1 Gender_i + \beta_2 Time_{it} + \beta_3 X_{it}$$

where for outcome y_i at wave t, α_i = individual-level intercept, β_1 = the coefficient of interest; β_2 = vector of coefficients for each survey wave t; β_3 = vector of control variables.

To assess the effect of gender over time, we included gender and time interaction terms as follows (reported as Model B in the results):

$$y_{it} = \alpha_i + \beta_1 Gender_i + \beta_2 Time_{it} + \beta_4 (Gender_i * Time_{it})$$

And the equivalent for the corresponding binary outcomes:

$$\Pr(y_{it} = 1) = logit^{-1}(specification)$$

Survey weights were applied to the regressions to adjust for unequal probabilities of selection. The survey weights are calculated using a two-step method aligned with the UAS Weighting Procedure [28]. Initially, base weights adjust for the varying probabilities of selecting UAS members. Subsequently, final weights are established through post-stratification, matching the sample to the U.S. adult population. The weights are derived using the six most recent Current Population Survey (CPS) Basic Monthly Surveys from the U.S Census Bureau relevant to the survey's completion date. We assumed non-responses were missing at random and used full information maximum likelihood estimation to handle missing data. The analysis was conducted using R Statistical Software (R Core Team 2023) and STATA (StataCorp LLC).

3. Results

The distribution of men and women across age groups was broadly similar though there were more women in the youngest age group and more men in the older age groups (Table 1). More women had a high school degree, and more men had a bachelor's degree or higher. There was a higher proportion of women working part-time compared to men. In terms of income, there were more men in the 4th quartile.

We observed differences between the genders in mean individual perception regarding the seriousness of the COVID-19, where more women had higher perceived risk of getting infected, hospitalised or dying from COVID-19 (Table 1 and Supplementary material, Fig. S1). Similarly, a higher proportion of women expressed agreement with COVID-19 restraining public policy measures and complied with public health and social distancing rules and guidelines (Supplementary material, Fig. S2). However, this pattern reversed for COVID-19 vaccination, where a higher proportion of men expressed positive views about the COVID-19 vaccine and expressed intentions to receive the COVID-19 vaccine.

Estimates from the multilevel logistic regression models for risk perception of COVID-19 by gender is presented in Table 2. Model A specifications report estimates for the initial level and rate of change of COVID-19 risk perception by gender, after controlling for confounding factors. The coefficients for men indicate that men have lower perceived risk of getting infected, hospitalised or dying from COVID-19. The coefficients for the linear slope and quadratic slope terms in the regressions for high perceived risk of getting infected and dying from COVID-19 suggest that over time, the odds of a respondent having a high perceived risk increased initially, but the rate of this increase slowed down. For high perceived risk of hospitalisation due to COVID-19, the linear and quadratic slope terms indicate a decrease in the odds of high risk perception but the rate of this decrease slowed down over time.

The model B regression specifications assess the effect of gender on risk perception of COVID-19 over time. The odds ratio for the gender and wave interaction terms for high perceived risk of getting infected from COVID-19 suggests the odds of men having high risk perception

Table 1
Survey weight adjusted summary statistics by gender, mean (standard error).

	Gender	
	Men	Women
High perceived risk of getting COVID-19	0.19	0.23
	(0.002)	(0.002)
High perceived risk of death from COVID-19	0.20	0.24
	(0.002)	(0.002)
High perceived risk of getting hospitalised due to COVID-19	0.21	0.23
	(0.002)	(0.002)
Index of agreement on COVID-19 restraining measures	0.77	0.80
	(0.001)	(0.001)
Index of compliance with public health and social distancing rules	0.64	0.67
	(0.001)	(0.001)
Index of positive views on the COVID-19 vaccine	0.63	0.54
	(0.002)	(0.002)
Likely to get COVID vaccine	0.62	0.52
	(0.003)	(0.003)
Age group		
18–29	0.09	0.16
	(0.001)	(0.002)
30–39	0.24	0.27
	(0.002)	(0.002)
40–49	0.16	0.16
	(0.002)	(0.002)
50–59	0.17	0.16
	(0.002)	(0.001)
60–69	0.19	0.16
	(0.002)	(0.001)
70+	0.16	0.10
	(0.002)	(0.001)
Education level		
Associate/Bachelor's or higher	0.48	0.43
	(0.002)	(0.002)
High school	0.43	0.49
	(0.002)	(0.002)
No high school	0.08	0.08
	(0.001)	(0.001)
Employment status		
Full-time	0.59	0.56
	(0.002)	(0.002)
Part-time	0.05	0.14
	(0.001)	(0.002)
Retired	0.28	0.22
	(0.002)	(0.002)
Self-employed	0.08	0.08
	(0.001)	(0.001)
Unemployed	0.01(0.00)	0.01(0.00)
Income quartile		
1	0.26	0.38
	(0.002)	(0.002)
2	0.32	0.32
	(0.002)	(0.002)
3	0.29	0.23
	(0.002)	(0.002)
4	0.13	0.08
	(0.001)	(0.001)
Gender	0.48	0.52
	(0.002)	(0.002)

Table 2
Risk perception by gender – estimates for repeated measures logistic regression, odds ratios.

	High perceived risk of getting COVID-19		High perceived risk of death from COVID-19		High perceived risk of getting hospitalised due to COVID-19	
	Model A β[CI]	Model B β[CI]	Model A β[CI]	Model B β[CI]	Model A β[CI]	Model B β[CI]
Men	0.580[0.515,0.654]	0.817[0.626,1.066]	0.527[0.455,0.611]	0.695[0.495,0.978]	0.695[0.602,0.802]	0.959[0.661,1.391]
Linear slope(Wave)	1.007[0.987,1.027]	1.028[1.003,1.055]	1.031[1.006,1.057]	1.034[1.001,1.068]	0.926[0.903,0.949]	0.936[0.903,0.971]
Men * Wave	–	0.957[0.920,0.996]	–	0.995[0.947,1.046]	–	0.978[0.930,1.028]
Quadratic slope(Wave^2)	0.999[0.998,0.999]	0.998[0.997,0.999]	0.997[0.996,0.998]	0.997[0.996,0.998]	0.999[0.998,1.000]	0.999[0.998,1.000]
Men * Wave^2	–	1.001[1.000,1.002]	–	0.999[0.998,1.001]	–	1.00[0.999,1.002]
Number of respondents	7,885	7,885	7,884	7,884	7,707	7,707
Number of observations	151,056	151,056	151,014	151,014	141,206	141,206

Controls: age, education, income, employment status and ethnicity. Standard errors clusters at the individual level.

decreased over time compared to women. However, there was no statistically significant time effect between men and women for high perceived risk of being hospitalised or dying from COVID-19. We report the average marginal effects for gender in Supplementary material, Table Estimates for the multilevel logistic regression models for risk perception of COVID-19 by gender measured using binary outcome variables for responses above the 60th percentile were similar to the regression results for outcome variables constructed using responses above the 80th percentile(Supplementary material, Table S6).

We report the association of gender with attitudes towards restraining public policy measures, compliance with public health rules and guidelines introduced during the COVID-19 pandemic in Table 3, where Model A specifications present estimates for the initial level and rate of change of the indices. The mean agreement score for men was, on average, lower than for women. However, there is no evidence of a significant change in the gender association over time (Model B specification). For compliance with public health measures, once again, men on average, had lower compliance than women. Further, as indicated by the positive coefficient for the interaction term of gender with time, there was a significant change in the association of gender over time for compliance, with the gender difference in compliance reducing slightly (i.e., men approaching the level of compliance demonstrated by women).

Assessing the association of gender with attitudes towards COVID-19 vaccination, the gender effect reversed, where men, on average, had a higher positive attitude towards COVID-19 vaccination than women (Table 3). Importantly, a significant trend was observed in the association of gender with vaccination attitudes over time. Initially, men had a higher positive attitude towards COVID vaccination than women. For women, the mean score of positive vaccine attitudes increased over time, although this rate of increase slowed down over time. For men, the increase in positive vaccine attitudes over time was smaller compared to that of women. Therefore, while both men and women's positive vaccine attitudes increased over time, the increase was less pronounced for men, although the slowing rate of increase in positive vaccine attitudes over time was slightly less pronounced for men than for women.

When assessing the willingness to get vaccinated against COVID-19, we observed a gender effect over time, where men expressed a higher willingness to get vaccinated compared to women, over time (Fig. 1).

4. Discussion

In this study, we found that women had a higher risk perception of COVID-19 than men. Women also had a higher level of agreement with restraining COVID-19 public policy measures and guidelines, and had better compliance with the public health rules and guidelines introduced during the pandemic. However, as hypothesised, the association with gender reversed when assessing vaccine attitudes and intentions, where men had a higher probability of getting the COVID-19 vaccine and had a more positive attitude towards COVID-19 vaccination compared to women. This gender effect was persistent over time.

Various factors, such as social, cultural, geographic, and individual characteristics, can shape behaviour and determine the level of compliance with recommended guidelines [17]. A risk perception

Table 3
Differences between men and women on agreement with restrictive measures, compliance with health rules, and attitudes towards the COVID19 vaccine – estimates for multilevel mixed-effects linear regression.

	Index of agreement on COVID-19 restrictive measures		Index of compliance with public health rules		Index of positive views on the COVID-19 vaccine	
	Model A β[CI]	Model B β[CI]	Model A β[CI]	Model B β[CI]	Model A β[CI]	Model B β[CI]
Men	−0.024 [−0.031,−0.016]	−0.010 [−0.021,0.001]	−0.017 [−0.026,−0.008]	−0.022 [−0.035,−0.009]	0.031[0.021,0.044]	0.234[0.051,0.417]
Linear slope(Wave)	−0.002 [−0.003,−0.001]	−0.001 [−0.002,−0.000]	0.011[0.010,0.012]	0.011[0.010,0.012]	0.025[0.018,0.032]	0.031[0.021,0.041]
Men * Wave	–	−0.001 [−0.003,0.000]	–	0.001[−0.001,0.003]	–	−0.012 [−0.026,0.003]
Quadratic slope (Wave^2)	−0.000 [−0.000,−0.000]	−0.000 [−0.000,−0.000]	−0.001 [−0.001,−0.000]	−0.000 [−0.001,−0.000]	−0.000 [−0.001,−0.000]	−0.001 [−0.001,−0.000]
Men * Wave^2	–	0.000[−0.000,0.000]	–	−0.000 [−0.000,0.000]	–	0.000[−0.000,0.000]
Number of respondents	7,126	7,126	7,894	7,894	7,173	7,173
Number of observations	138,867	138,867	151,782	151,782	58,813	58,813

Controls: age, education, income, employment status and ethnicity. Standard errors clusters at the individual level.

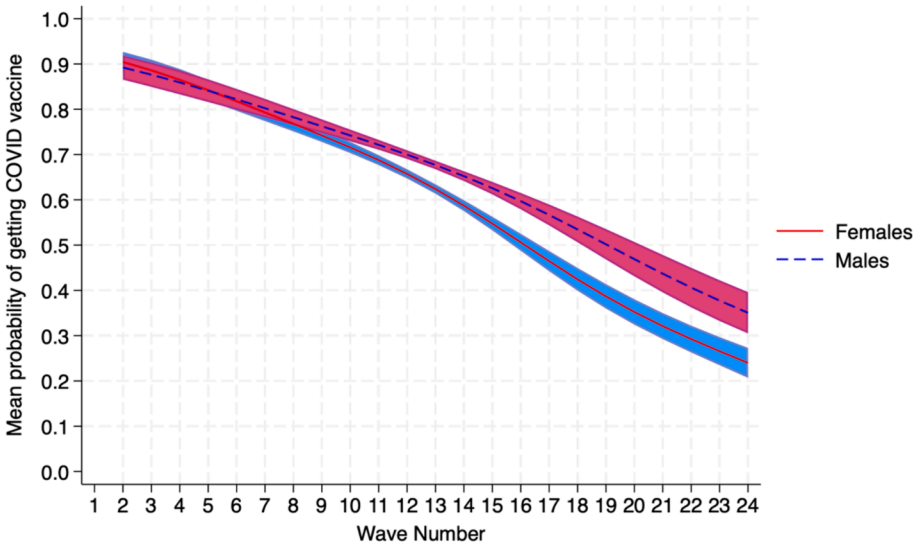

Fig. 1. Predicted probability of getting COVID19 vaccine based on estimates for repeated measures logistic regression with likelihood of getting the COVID19 vaccine as dependent variable. Controls: age, education, income, employment status and ethnicity. Shaded region represents 95 % confidence intervals.

framework posited by a previous study as specific to COVID-19 includes subjective and sociocultural factors [17]. Some of the former include perception of the nature of the virus, transmission location, and prevention measure efficacy; knowledge about the virus, probability of death, and the scope of the pandemic; personal experience; trust (political, social, and in the self); and attitudes, such as fatalism, self-determination or acknowledgement of risks. The sociocultural factors include vertical culture, describing a demand for strict rules and criticism of non-compliance, and individual rights, such as the right to act and choose. Understanding these components is crucial to developing effective health risk communication.

In this study, we found that women viewed COVID-19 and its consequences more seriously than men and exhibited higher adherence to non-pharmaceutical restrictive measures. This concords with the results from previous studies examining adherence to COVID-19 governmental guidelines. Moreover, women's general heightened risk perception and risk aversion has been documented beyond COVID-19 [8,31–40]. For example, during the 2003 SARS outbreak, women perceived the risk of SARS to be greater and had a higher level of compliance with precautionary behaviours and infection control policies [17]. Other than in an outbreak scenario, this phenomenon is also seen with the seasonal influenza [23].

Socially constructed norms and roles may also influence gender difference in health risk aversion. Women often assume caregiving roles within families and communities, making them on average more attuned to the health and safety of others [8,41,42]. As societal norms and gender roles play a role in shaping behaviour during a health crisis, a heightened sense of responsibility and empathy can motivate women to adopt preventive measures to protect themselves and those around them [8,43,44]. Another study found that the gender difference in adherence to prevention measures attenuated once women's greater reported fear and negative emotional experiences during the COVID-19 pandemic were taken into account [45].

We found that women expressed more negative attitudes toward the COVID-19 vaccine. One of the measures included in the corresponding index was that of trust. The existing literature illustrates that trust in government institutions plays a substantial role in an individual's risk perception, their adoption of recommended measures, and their confidence in the government's ability to adequately respond [8,45,46]. A study examining gender differences in COVID-19 preventative behaviours found generally low levels of trust towards governmental institutions in Chile, with women exhibiting the lowest levels of trust [8], and, like men, attributing the most responsibility for protecting their health to themselves [8]. Lower trust in government could be one factor contributing to the more negative attitudes women on average have towards the novel COVID-19 vaccine.

We also found women had a lower probability of getting the COVID-19 vaccine, and this gender effect was persistent over time. This finding is supported by a previous meta-analysis and a study analysing women's intention to receive the COVID-19 vaccine, the former of which suggested that is due to the belief, more common among women, that the vaccine was unsafe and that its risks were larger than its benefits [15,16]. The fact that some of the misinformation surrounding the COVID-19 vaccine were of specific concern to women's health, such as reducing fertility and increasing the risk of miscarriage [47], could have influenced vaccination intentions of women.

Our findings were consistent with our hypothesis that women would be more likely to comply with government restrictive measures but less likely to receive the vaccine due to a heightened risk perception regarding COVID-19 generally and regarding the novelty of the COVID-19 vaccine specifically.

A few limitations should be noted. Our regression results indicate associations but are not causal effects. Second, the UAS survey relies on self-reported measures, therefore we were unable to incorporate data on actual vaccine uptake or actual behaviour during the pandemic resulting in potential response bias. Lasty, the study results may not be generalisable to settings outside of the U.S.

This study found that women in the U.S. perceived risks regarding COVID-19 more seriously than men, were more supportive of restrictive policies and compliant with guidelines, but had more negative attitudes towards and were less likely to receive the COVID-19 vaccine. The findings support an interpretation of gender differences in risk perception as contributing to these contrasting attitudes and decisions. Understanding the complex relationships between gender, risk perception, and behaviour can inform policymakers and health authorities in designing more effective strategies for promoting and sustaining preventive behaviours through tailored interventions that address the needs of all segments of the population and foster a culture of proactive health management.

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Contributors

SJ, ME, TO and EM conceived of and designed the study. SJ acquired the data. SJ and TO conducted the statistical analyses. All authors interpreted the data. SJ and ME drafted the manuscript, and all authors critically reviewed and contributed revisions to the final version of the paper. SJ, TO and EM accessed and verified the data. All authors approved the final version of the manuscript.

CRediT authorship contribution statement

Sahan Jayawardana: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Mikaela Esquivel:** Writing – review & editing, Writing – original draft, Conceptualization. **Tin Orešković:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Elias Mossialos:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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.

Data availability

Data will be made available on request.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2024.06.012.

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