Understanding the role of personal risk perceptions during the COVID-19 pandemic: a rapid behavioural science evidence synthesis

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Executive summary

Since the COVID-19 pandemic began in 2020, a variety of public health measures and policies have been implemented across jurisdictions worldwide to support individual and population protection to mitigate risk of transmission and COVID-19 infection. As emerging variants have led to waves of infection, public health measures have been escalated or removed in an effort mitigate the acute and long-term risks while balancing a return to more pre-pandemic activities where and when possible. The waxing and waning of public health measures has likely influenced how personal risks are perceived by individuals and groups across Canada. This varying perception of risk, over time, has contributed to how individuals have taken up, maintained, disengaged, and re-engaged with the core protective behaviours that have become central to all those who have lived through the COVID-19 pandemic. The behavioural sciences have developed a strong foundation of understanding how individuals perceive risk and how that influences their decisions and actions in the moment and over time. Risk perceptions are formed not only by *severity* information (e.g., ICU admissions, long-covid, death) but also importantly, *susceptibility* information about how vulnerable they themselves and others are to the severity of the health impacts being communicated. We sought to identify studies investigating how perceptions of risk have been investigated over time during the COVID-19 pandemic. Findings can inform a more nuanced approach to supporting individuals and populations in deciding when it might be right for them to maintain, disengage or reengage with personal protective behaviours between and within waves and outbreaks during the ongoing pandemic.

Key Findings

- We identified 35 studies (up to 28 June 2022) describing level of risk perceptions (n=13), predictors of risk perceptions (n=14), and how risk perceptions are related to intention to or uptake of vaccination (n=17), face-masking wearing (n=1), or physical distancing (n=2). No published Canadian studies were identified.
- The frequency and method (content, channels, and format) of delivering risk information were associated with risk perceptions; the implication may be that decreasing the frequency/availability of current risk information may undermine one's ability to form risk perceptions that are aligned with current severity and susceptibility.
- An increase in perceived risk was associated with those who have higher levels of trust in scientific and medical sources, and perceiving that someone that is similar to oneself is vulnerable to COVID-19. Believing that responses to COVID-19 are within one's control, achievable, and effective at reducing risk were also associated with perceived risk.
- *Vaccination (17 studies)*: There was a positive but small association between risk perceptions, vaccination uptake and vaccination intentions, though some reported no association once accounting for other factors such as perceived benefits and barriers, cues to action, and self-efficacy, which compared to perceptions of risk, were more reliably related to vaccination intention and uptake.
- *Physical distancing (2 studies)*: Perceived risk was associated with physical distancing, but accurate knowledge of COVID-19 may affect the strength of this relationship.
- *Masking wearing (1 study)*: Greater face-masking was associated with greater perceived severity of getting COVID-19, even accounting for personality.

Key Implications

- **Risk perceptions are key influences on individuals' decision** to engage in, maintain and/or discard personal protective behaviours.
- Perceptions about how susceptible someone is to infection and adverse outcomes, and how severe infection would be on them and others, are **shaped by and depend on having access to information to inform their risk perception**, which could include information from a range of sources and what others around them are doing.
- When public health measures and policies are removed and more of the onus on deciding when, where, and for how long to engage in protective behaviours is devolved to individuals, there remains **a need to continue to provide information to the public from sources that they trust about the current risk levels of COVID-19** (especially if risk level changes) **and what (if anything) has changed** to the level of severity of a COVID-19 infection for themselves or others, or their susceptibility.
- Continuing to provide risk information about severity and susceptibility when public health measures and policies are removed, in a range of accessible (including graphical) formats that communicate uncertainty, **may help individuals in *updating* their personal risk perceptions to better align with the current level of risk** in the geographical areas and personal spaces that they frequent.
- **Removing trusted sources of risk information likely undermines the ability of individuals to draw accurate perceptions of their risk** and thus also their motivation to take personal action to mitigate it, requiring individuals to instead look to informal sources (e.g. the behaviour of others around them and general views) that may not enable risk perceptions to be consistent with actual severity and susceptibility to COVID-19 and its sequelae.
- In circumstances where public health measures and supports are removed and **when the public is called upon to make individual choices for themselves, it is arguably even more important to provide updated, clear, trusted risk information about severity and susceptibility** as part of empowering individuals to make informed decisions about when to take up, discard, or re-engage or not with protective behaviours.
- **Focusing on risk communication alone is likely not enough to change what people do**. Heightened risk without agency to do something about it could lead to discounting risk altogether. Risk communications designed to enable Canadians to update their perception (when needed) of the severity of COVID-19 and their susceptibility should also aim to show what trusted others are doing to maintain protective actions when the risk level warrants it (using narratives), indicate perceived benefits of protective behaviours rooted in the realities of the pandemic as they currently stand, and, providing resources and empowerment that can enhance self-efficacy to enact protective behaviours when the risk levels warrant it.

Background

The rise of SARS-COV-2 in early 2020 as a global pandemic-level health threat saw the need for individuals to assess their personal risk and act accordingly by engaging in protective behaviours to mitigate their risk. Governments and public health organisations at multiple levels put in place numerous public health measures and enacted a variety of policies aimed to encourage and support individuals and groups to decide and act in the interest of personal and collective benefit to get through this pandemic. During the first two years of the pandemic, communication to individuals about their risk of COVID-19 infection and mitigation of risk was largely driven by government public health measures and policies[1,2] put in place to support, encourage, and increase adherence to risk-mitigating protective behaviours. In the initial absence of pharmaceutical interventions (i.e., vaccine or antiviral medication), behavioural policies were introduced aimed at reducing transmission and deaths by decreasing gathering and close contact between individuals including closing businesses, schools, and workplaces; national lockdowns; cancelling mass events and imposing gathering limits; and recommending or (in some places) mandating protective behaviours[3] such as physical distancing, face-masking, and regular testing with either PCR or rapid antigen tests[1,4]. Once vaccines were developed and approved, government and public health unit policies and practices established infrastructures to enable and maximise vaccination uptake according to dosing schedules aimed to establish and maintain the protective benefits of the COVID-19 vaccines in light of emerging variants. In addition to providing the means to get vaccinated, governments across different jurisdictions also used a variety of policy-level levers to encourage greater uptake of vaccination ranging from communication and marketing campaigns, pop-up clinics, requiring proof of vaccination in different settings, and in some instance mandates for particular jobs[5,6]. Thus, for much of the pandemic, governments and public health organisations worldwide have played a significant role in providing support (whether through communication, resources, or policies) to individuals to inform how they navigate their decisions and actions during the COVID-19 pandemic.

Following the waves that have ensued from the Omicron variant of concern, many jurisdictions across Canada and worldwide have scaled back on government-led risk communication and public health measures[7]. This shift has removed much of the information that individuals have used to judge their personal risk to inform what sorts of risk-mitigating actions they should take and when. As individuals' personal risk assessments and resulting maintenance or disengagement from protective behaviours continue to inform how societies emerge from current and future COVID-19 waves, a behavioural science analysis may help to clarify how individuals assess risk, how they adapt their perceptions of risk over time, and which factors are most important for supporting individuals to assess and adapt their risk perceptions.

Behavioural science approach to COVD-19 protective behaviours

A framework designed to aid the understanding of factors that are important for supporting individuals to adapt behaviour according to perceived risk is the capability, opportunity, motivation model (COM-B) of behaviour change[8]. Within the COM-B, factors that influence capability, opportunity, and motivation to perform a behaviour are derived from the

Theoretical Domains Framework[9] (TDF; see Figure 1). The TDF is a synthesised framework of 14 key modifiable factors that are determinants of behavioural intentions and behaviour performance.

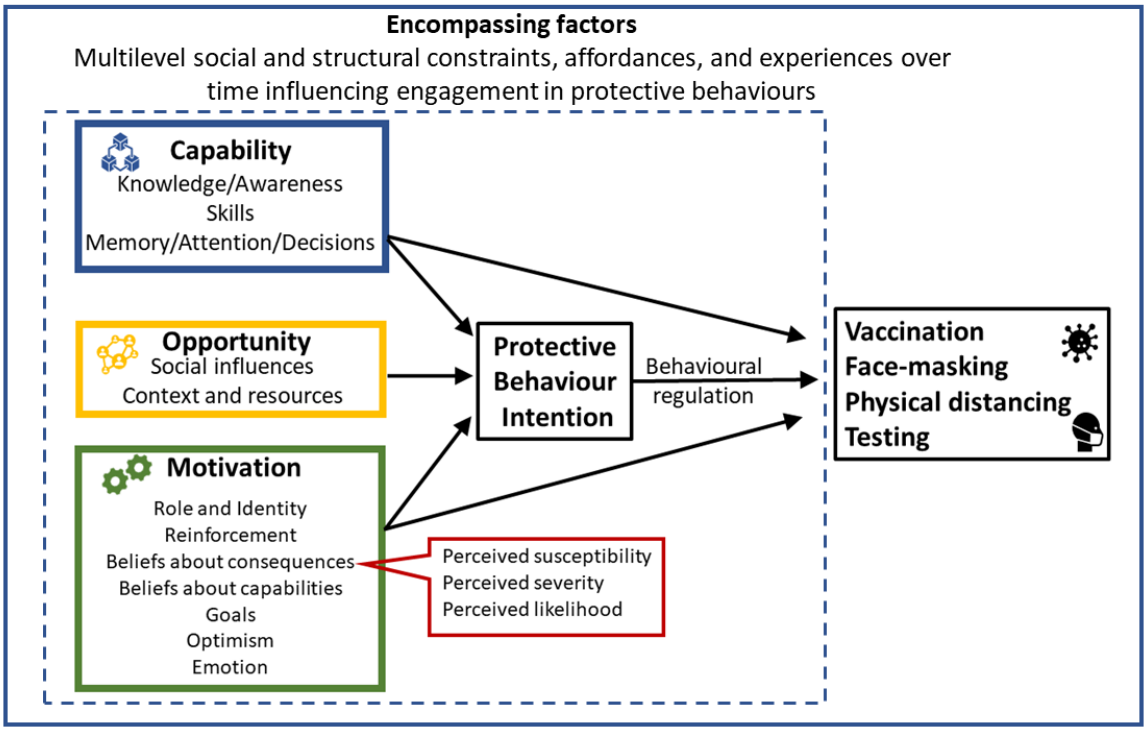

Figure 1. Factors from the COM-B and TDF that may influence protective behaviour intentions and performance

Within the COM-B/TDF framework, risk perceptions are a Motivational factor situated within 'Beliefs about consequences' domain. While risk perceptions are thus a key focus, the above framework demonstrates that there are multiple factors that act in combination to affect taking protective action against a health threat and thus focusing on risk perceptions alone may be necessary but not sufficient.

What is a risk perception, from a behavioural science perspective, and why does that matter?

Risk perceptions are among the most well-studied aspects of behavioural science, with over 50 years of studies seeking to understand, explain and influence how people perceive a health risk and how that may (or may not) influence their decisions and actions. A risk perception is defined and operationalised as three dimensions proposed within well studied behaviour theories such as the classic models including the Health Belief Model[10] and Protection Motivation Theory[11] as well as more contemporary models such as the Health Action Process Approach[12]: perceived ***likelihood*** (the belief about probability that one will be harmed by a health risk), perceived ***susceptibility*** (belief about vulnerability to a health risk), and perceived ***severity*** (belief about extent of harm if affected by health risk). Each of these can independently shape how an individual forms and changes their risk perceptions and thus it is important for

trusted risk information to touch upon each wherever possible. For example: describing severity information without susceptibility information may lead to an individual thinking it would be bad if they were infected but they may inaccurately perceive how vulnerable they are. Likewise, if risk information focuses only on "everyone is at risk" or "everyone will get it" (i.e. high vulnerability message) but downplay or ignore the severity information, this will likely also lead to skewed risk perceptions.

Appraising a situation as a health threat is one of (but not the only) key driver of adopting protective behaviours to mitigate personal risk, such as vaccination behaviour in a pandemic[13–17]. While there is a very large emphasis placed during this pandemic on risk communication, in pre-SARS-COV-2 studies, the relationship between risk perceptions and protective behaviours was often found to be small[13] (and perhaps smaller than the relative emphasis put on addressing risk perceptions might therefore warrant). Additionally, a significant proportion of prior research on the relationship between risk perceptions and behaviour has used 'intention to perform a protective behaviour' as an outcome, rather than actual behaviour[18]. It is clear from the behavioural science literature that focusing only on risk perceptions is likely insufficient but this is not to say risk perceptions are not an important aspect of what influences what people do or do not do, and thus should be leveraged and addressed using the best of what we know about risk perception formation and change over time.

To appraise a situation as a health threat, there first must be adequate communication of the risk. Risk communication must take into account factors that influence attention and decision-making (i.e., Capability). For example, risk perceptions can be biased as a result of cognitive heuristics such as optimistic bias (i.e. mistakenly believing that the likelihood of experiencing a negative event is lower for the self than others)[19], the format of the risk communication (e.g. numerical format of probabilities, whether risk is visualized)[20], and the trustworthiness of the source[21,22]. Risk communication needs to facilitate both realistic assessment of personal risk and the necessary knowledge and actions to manage the threat, and resources to empower enacting those strategies (i.e., Opportunity). For example, if risk communication evokes high fear (e.g. by focusing only on severity of outcomes such as ICU rates and death without risk information about susceptibility), in the absence of clear messaging around effective strategies to mitigate individual risk and resources to empower enacting those strategies, this can result in feelings of uncontrollability and helplessness[16,23,24]. In turn, individuals may downplay the level of personal risk as a way of coping with the apparent lack of control or helplessness[25].

Having relatively accurate perceptions of personal risk at any given time has been more difficult given the varying or dynamic nature of the personal risk of COVID-19 over time. The novel nature of the SARS-COV-2 virus has meant that our knowledge about how it is transmitted and treated has changed as the science has become clearer, with the emergence of variants of concern adding further need to change what we know about this virus and thus alter risk perceptions. As a result of keeping pace with the evidence and variation over time in healthcare capacity, population levels of immunity from prior infection and vaccination, and personal and population-level engagement in protective behaviours[14,16] jurisdictions have adapted public

health measures over time and varied the level of exposure to COVID-19 related risk information[20,26]. The nature of this pandemic has undoubtedly also influenced how individuals perceive their risk at given times in the pandemic and thus their approach to take up, maintain, or disengage from protective behaviours. For example, past research[27] conducted during the H1N1 influenza pandemic demonstrated a trend in the perceived susceptibility to H1N1 over the period of one month, where perceived risk increased initially before levelling off then decreasing. This was despite continuously rising confirmed cases of H1N1. Willingness to engage in preventive behaviours declined over this time in line with the decline in news coverage on H1N1. Therefore, perceptions of risk and engagement in protective behaviours vary over time, and in conjunction with factors (e.g., amount of exposure to risk information) other than actual incidence of infection or death.

As public health measures are relaxed in many jurisdictions at the time of writing (September 2022), infection waves persisting and variants of concern still looming, taking stock of what we have learned about how levels of risk perceptions and how these have changed over time may help to inform novel approaches to meet Canadians where they are now, to support decisions and actions as susceptibility and severity risk continues to change.

Objectives

- Identify the factors involved in forming and updating risk perceptions in response to COVID-19 which the likelihood of contraction and severe health consequences has varied over time.
- Identify the relationship between risk perceptions and other factors in intending to and engaging in vaccination, physical distancing, face-masking, and regular testing as core personal protective behaviours recommended during the COVID-19 pandemic[28,29].

Methods

Data sources

We conducted a rapid evidence synthesis by conducting a search up to 28th June 2022 in five databases (MEDLINE, PsycINFO, CENTRAL, EMBASE, CINAHL) to identify literature investigating factors associated with COVID-19 risk perceptions, and the influence of COVID-19 risk perceptions and other factors on intention and performance of vaccination, face-masking, physical distancing, and getting tested. The search terms used can be found in Appendix 1.

Title and abstract screening was conducted by one reviewer (GM), with a second reviewer (ZVA) screening 20% of abstracts to determine rater reliability. These two reviewers then discussed conflicts and resolved them by consensus. Full-text screening was conducted largely by a single reviewer (GM or ZVA), with 15% of full-texts double-screened to determine rater reliability. Conflicts at the full-text stage were discussed and resolved by consensus.

Inclusion criteria

- *Population*: general population (adults 18+), including studies with participants with health condition(s).
- *Intervention*: risk communication for COVID-19 (if applicable – not all studies were interventions).
- *Outcomes*:
    - Risk perceptions: operationalized as three behavioural science-informed dimensions[10,11] including *perceived likelihood* (the belief about probability that one will be harmed by a health risk – usually measured with item about % likelihood of an outcome), *perceived susceptibility* (belief about vulnerability to a health risk), and *perceived severity* (belief about extent of harm if affected by health risk). The measurement of risk perception must have been operationalized based on one or more of these definitions. Studies were also included a composite index of perceived susceptibility and perceived severity, defined herein as *general risk perceptions*. The measurement of risk perceptions must have referred to studies where participants provided a subjective judgement of their own perceived likelihood, perceived susceptibility, and/or perceived severity related to COVID-19.
    - Intention: to wear a face-mask, get a COVID-19 vaccination, physically distance, or get tested
    - Behaviour: wear a face-mask, getting COVID-19 vaccination, physical distancing, or getting tested
- *Designs*:
    - Quantitative empirical studies (e.g., self-report surveys of risk perceptions for COVID-19 using cross-sectional, prospective, longitudinal, and repeated cross-section designs).
    - Intervention studies (randomized trials, cluster-controlled trials, quasi-experiments, interrupted time-series).

Exclusion criteria

- *Population*:
    - Studies where others (e.g., parents, health professionals) provide judgements of risk or intentions on behalf of others (e.g., children, patients).
    - Studies where participants are <18 years old or where the effects of interest in participants ≥18 years old cannot be isolated from participants <18 years old.
    - Studies where participants included healthcare workers.
- *Intervention*:
    - Studies using a hypothetical scenario e.g. intentions to get vaccinated prior to an approved vaccine becoming available.
    - Randomised studies testing an intervention's effect on a COVID-19 protective behaviour without evidence that the intervention changed a risk perception.
- *Outcome*:

- Studies where the only measure of perceived health *risk* was about something other than COVID-19 itself i.e. COVID-19 vaccine, economic risk, perceived risk about another health threat during COVID-19.
- Studies where the definition and measurement of risk perceptions did not fit our defined operationalization e.g., fear about COVID-19, concern about COVID-19, dread about COVID-19, fear/concern of getting infected, fear/concern about the consequences of COVID-19 infection.
- Studies measuring risk perception for a population in general e.g. "A lot of people in my community will get COVID-19".
- Studies involving vaccine hesitancy or vaccine acceptance as the only outcome(s).
- Studies comparing COVID-19 to other endemics/pandemics/outbreaks.
- Studies measuring attitudes about or willingness to comply with COVID-19 public health measures generally (e.g. lockdowns), or face-masking, vaccination, physical distancing, or getting tested as the only outcome(s).
- Studies measuring motivation to comply/perform face masking, vaccination, physical distancing, or getting tested as the only outcome(s).
- Studies where the outcome uses a composite of overall adherence or intention or performance of multiple protective behaviours.

- *Additional exclusion criteria*:
  - Qualitative study designs, coding of social media data, evidence syntheses and meta-analyses, editorials/comments to editor/replies to authors.
  - Research not published in peer-reviewed journals e.g., grey literature, conference abstracts, dissertations, pre-prints.
  - Research not published in English.

Data extraction

Data were extracted using standardised extraction forms. Relevant data on sample characteristics, study design, the outcome(s) (e.g. risk perceptions, intention and performance to get vaccinate, get tested, physical distance, and use a face mask), and the main findings were extracted. To maximise relevance, only studies where data collection occurred following approval of COVID-19 vaccines (from December 2020 onwards) were extracted (exception: longitudinal studies of changes in risk perceptions over time that included data before and after December 2020).

Synthesis

Descriptive quantitative synthesis: we sought to map levels of reported risk perceptions over time to visualise any variation in risk perceptions over the time of the data collected. Descriptive statistics were extracted (and, where necessary, means were calculated for studies that reported proportions of observations). Extracted means were normalised into mean scores on a scale between 0 (low perceived risk) and 1 (high perceived risk). Means of risk perceptions for the same time periods were then pooled.

Narrative synthesis: We narratively synthesised findings across studies by outcome (e.g. risk perceptions, and health protective behaviours), with findings reported focusing on intention or actual performance of protective behaviours synthesised separately.

Findings

Search results

We identified 3889 records, 1433 of which were duplicates, leaving 2456 unique records. Of these, 222 papers met the inclusion criteria. Further details of the identification and screening of records are presented in a PRISMA diagram in Appendix 2.

After constraining included studies to data collection from December 2020 onwards to maximise relevance, this provided 35 studies describing levels of risk perceptions (n=13) or predicting risk perceptions (n=14), predicting intention to or getting vaccinated (n=17), intention and adherence to face-masking (n=1), and intention or engaging in physical distancing (n=2). There were no studies identified with data collection from December 2020 onwards for getting tested.

Herein, we present a narrative synthesis of literature examining risk perceptions, and their relation to intention and performance of vaccination, physical distancing, and face-masking. First, how risk perceptions have varied over time during the COVID-19 pandemic is described. Second, we examine what factors have been associated with risk perceptions and, where possible, how that association has changed over time. Third, the association between risk perceptions, intention and performance of vaccination, physical distancing, and face-masking are described. Lastly, additional factors, alongside risk perceptions, that contribute to intention and engaging in vaccination, physical distancing, and face-masking are presented. Within each section for the outcomes of interest, findings are organised by experimental, longitudinal surveys, and cross-sectional surveys.

Question 1: How have risk perceptions varied over time during the COVID-19 pandemic?

We identified 13 studies that observed levels of risk perceptions assessed as early as March 2020 and as recent as November 2021. Of these 13 studies, three presented levels of risk perceptions over multiple time points[30–32]. Another 10 studies provided cross-sectional observations of risk perceptions[33–42]. Five studies reported risk perceptions from samples of the Chinese population, three reported risk perceptions from the USA, as well as the UK (n=2), Belgium (n=1), Italy (n=1), and India (n=1). The pooled means of perceived susceptibility, perceived severity, and a general measure risk perceptions (comprised of both perceived susceptibility and perceived severity) are presented in Figure 1.

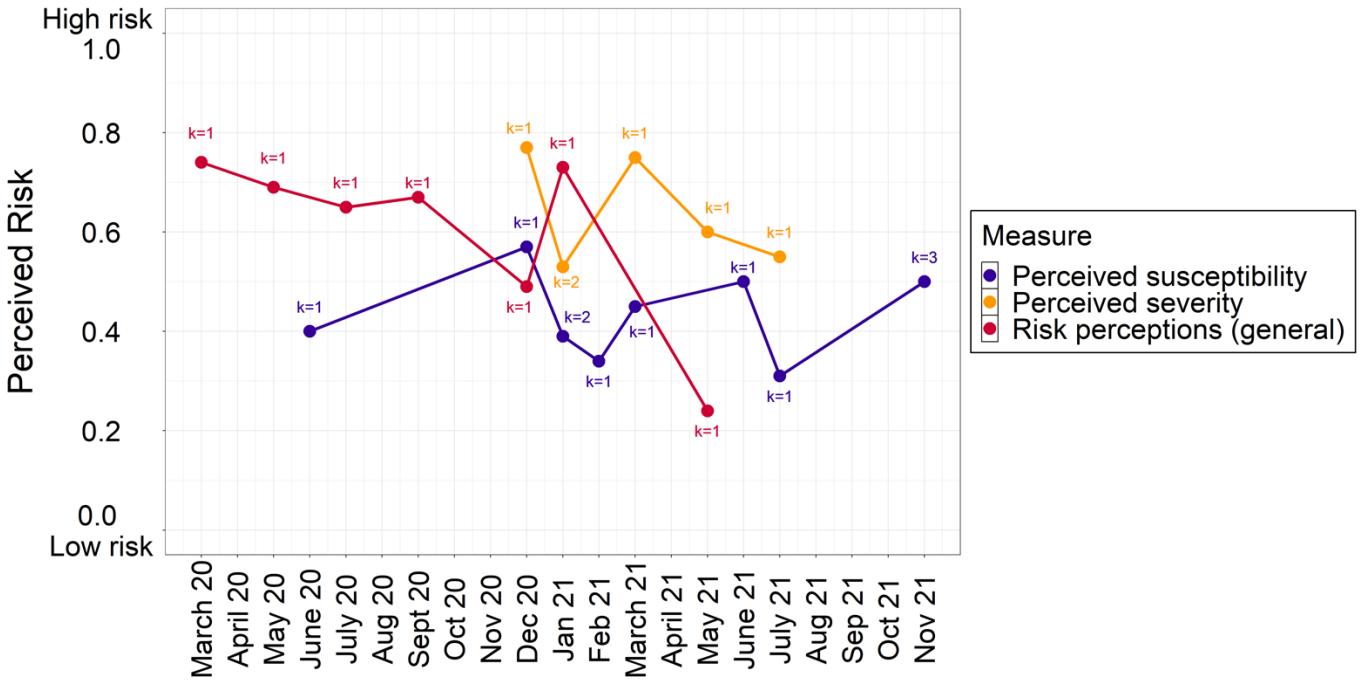

Figure 2. Levels of risk perceptions over time (March 2020 – November 2021)
Note: 'k' denotes number of means pooled per time-point; multiple means can be reported from one study

Where risk perception means are reported pre-December 2020, these were extracted from longitudinal studies which reported at least one observation post-December 2020. As shown in Figure 2, perceived susceptibility, perceived severity, and general risk perceptions fluctuated over time with no obvious trends, although general risk perceptions appeared to generally have a downward trend over time. While the number of datapoints is limited, it appears that perceived severity remained higher than perceived susceptibility across time. In other words, while the severity of getting COVID was relatively high over the time period of the available data, the vulnerability to getting COVID was itself lower, indicating a missed opportunity to align susceptibility risk information with severity risk information.

Question 2: What factors are associated with COVID-19 related risk perceptions?

A summary of the evidence of factors that influence risk perceptions from both randomized trials and survey-based evidence is presented in Box 1. For more details on each individual study, see the following sections describing randomized trials and Tables 1a to Table 1d describing cross-sectional survey-based evidence.

Box 1. Narrative evidence summary for factors that influence risk perceptions

Taken together, across the randomized trials and survey evidence, there were several factors that influenced risk perceptions. How risk information was interacted with (e.g. content, channel, and format) was influential in the formation of COVID-19 related risk perceptions. Higher perceived risk was associated with:

- Greater frequency of receiving risk information and greater willingness to spread risk information
- Getting information from trusted sources, such as health authorities or scientific journals (as opposed to non-official sources)
- Using cumulative death incidence rather than weekly death incidence
- Using graphical forecasts with more uncertainty was important in predicting greater perceived susceptibility and severity.
- Using a celebrity, with whom individuals have a sense of familiarity and a friendship-like bond, to illustrate vulnerability to Omicron variants increased perceived susceptibility by reducing optimistic bias about individual vulnerability to COVID-19 variants.

- Perceived benefits and perceived barriers of protective behaviours were inconsistently related to perceived susceptibility and perceived severity, while costs of engaging in protective behaviours and rewards for not engaging in protective behaviours were inversely associated with perceived susceptibility and perceived severity. Feeling confident, efficacious and in control of engaging in protective behaviours were consistently positively correlated with risk perceptions.
- Trust in medical professionals and science seemed more important than trust in government in influencing risk perceptions. Across cross-sectional survey evidence, trust in government appeared to have small negative associations with risk perceptions or no association. That said, people who had more liberal political ideology and views (i.e., less individualistic, more prosocial attitudes), compared to conservative ideologies, perceived themselves as having higher risk.
- Individual differences may be worth accounting for as men appeared to report lower risk perceptions after viewing graphical information about their risk.

Randomized trials: We identified 3 diverse experimental studies[43–45] that assessed factors in individuals' perception of COVID-19 risk. None of the identified experimental studies collected data from Canadians.

A US trial[43] recruited n=1350 California and New York residents (45.37% women, *M* age = 32.74 years) in December 2020. Participants viewed COVID-19 incidence information (either: cumulative deaths or weekly incidence of deaths) presented in different ways (either: past incidence with no forecast, past information plus a forecast using 50% confidence interval, or past incidence with 6 different forecast models) that was specific to their geographical location (either: California or New York). Participants then judged perceived risk (pre and post viewing incidence information) of being exposed to COVID-19, contracting COVID-19, experiencing severe side effects of COVID-19, or experiencing hospitalization from COVID-19 for themselves, an average 22-year old in their geographical region, and an average 78-year old in their geographical region. Overall, this study found that perceived risk increased more after being presented with cumulative incidence data compared to being presented with weekly incidence data. **Viewing weekly incidence data (which can be variable, fluctuating up and down) was more likely to cause no change in risk perception** or decreased risk perceptions. The **strongest increase in perceived susceptibility and perceived severity came from viewing incidence information presenting a forecast with 6 models** (i.e. demonstrating more uncertainty) compared to no forecast. See Figure 3 for an example.

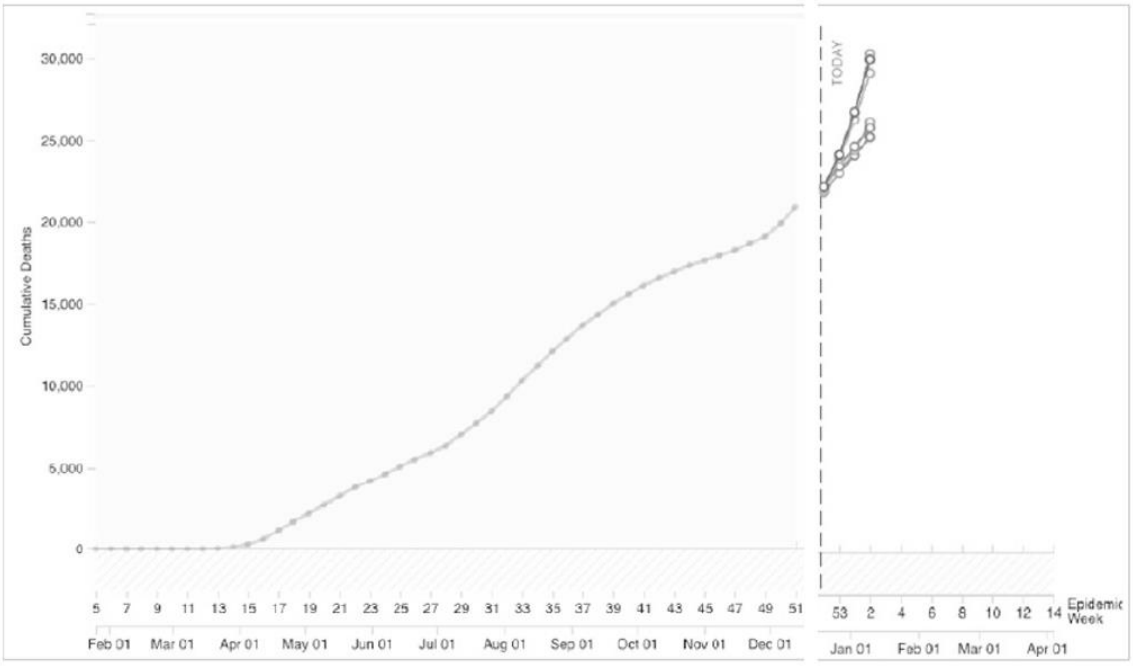

Figure 3. Example of representing cumulative incidence with 6 forecast models

Another US-based trial[45] (n=502) presented COVID-19 risk information in different formats the measured political partisanship. In a first study, participants were randomly delivered either a *text format* of gender-specific information on risk of COVID-19 mortality (intervention group) or a general article about COVID-19 (control group). In a second study, participants were

randomly assigned to be presented with the same gender-specific risk information as in study 1, but in a *graphical format* (intervention group) or the same control text article as study 1 (control intervention). In both study 1 and study 2, following delivery of the intervention and control conditions, the participants then rated their perceived likelihood of contracting COVID-19 and perceived severity if they were to contract it. After being presented with information on their risk in a text format, there were no significant differences in perceived likelihood or perceived severity by gender or treatment. **Being presented with gender-specific information on their risk in a graphical format led to men's perceived severity being significantly lower** than in the control condition. Furthermore, there was an overall association between perceived risk and partisanship across intervention and control conditions in study 1 and 2, where participants who voted for Joe Biden in the previous election reported higher risk perceptions compared to Trump voters.

A third US trial[44] (n=228) conducted in April 2021 (66.2% females; *M* age = 42.66 years) examined the effect of parasocial relationships (i.e. a one-sided relationship such as a friendship-like bond that an individual engages in with a media persona) with celebrities on optimistic bias (i.e. mistakenly believing that the likelihood of experiencing a negative event is lower for oneself than someone else) and perceived risk. Participants were asked to provide the names of 3-5 celebrities who they felt were "like friends", then were provided with risk information from the US CDC website on variants of concern. Participants then viewed a list of celebrities who supposedly had been diagnosed with a variant of concern. The intervention then randomized participants to whether one of the celebrities that they listed as being 'like friends' was on the list of having had COVID or not. Findings showed that **seeing that a celebrity viewed as 'like a friend' having had COVID increased their own perceived susceptibility to a variant of concern**. The effect of the parasocial relationship on perceived susceptibility occurred indirectly, where exposure to information that a celebrity, with whom participants felt a parasocial relationship, was diagnosed with a variant of concern (vs being exposed to a general list of celebrities diagnosed with a variant of concern) reduced optimistic bias about getting sick from COVID-19. Reduced optimistic bias in turn led to greater perceived susceptibility to variants of concern.

Survey-based evidence: We identified 11 cross-sectional studies assessing associations between risk perceptions and risk information and communication, institutional trust, protective behaviours, and other behavioural factors (none from Canada). Due to the diversity of the studies (e.g. variables analysed, samples), it was not possible to draw conclusions about changes in associations with risk perceptions over time.

Table 1a. Summary of findings of the association between sources/types of information and risk perceptions from cross-sectional surveys

Author	Sample	Time period	Analyses	Main findings

Tadese et al. (2021)	N=682; Ethiopian students (*M* age = 23.35 years; 43.4% female; 83.6% undergraduates)	December 2020	Multivariate analyses with demographics, residence, faculty, diabetes status, personal and family/friends' history of COVID-19 infection, use of social media, and use of trusted sources of information as predictors of risk perceptions (a general measure including both perceived severity and susceptibility).	The likelihood of having high perceived risk decreased with: • Greater use of Facebook for COVID-19 information • Greater use of websites/articles from non-official sources for COVID-19 information The likelihood of having high perceived risk increased with: • Getting COVID-19 information from the ministry of health • older age (i.e. age 26-35 compared to younger) • being in an open relationship • having a father who attended elementary school • having diabetes
Guo et al. (2022)	N=724; Chinese population (57.5% women; 54.7% ≤29 years old; 31.9% 30-39 years; 17.1% ≥40 years; 67.3% bachelors degree or graduate degree)	May 2021	Bivariate correlations	Higher perceived risk was correlated with: • Higher frequency of receiving content about risk (i.e. information about spread, severity, symptoms, and government mitigation of COVID-19; *r*=.13) • Higher frequency of hearing risk warnings across channels of communication (i.e. TV/radio or social media or newspapers; *r*=.15) • Higher frequency of receiving risk warning information across formats (i.e. text (short message/blog post), graph, short video (e.g. TikTok), long videos (e.g. news broadcast); *r*=.12) • hazard-related behaviour preparedness (i.e. perceptions of risk mitigation effectiveness; *r*=.18) • resource-related hazard behaviour perception (i.e. willingness to expend resources to accumulate

				knowledge/supplies for prevention; *r*=.15) • stakeholder perception (i.e. trust in risk warning; *r*=.11) • information interaction (i.e. willingness to spread risk warning; *r*=.24).
			Structural equation model predicting protective behaviour intentions. Paths were defined between perceived risk and risk waring information, and between perceived risk and information interaction.	• Higher risk perceptions were related to more information interaction (i.e. willingness to spread risk warning). • Risk warning information (comprising a latent construct of risk warning content, type, and channel) did *not* predict risk perceptions.
Corea et al. (2022)	N=795; Italian people attending a centre to receive a booster vaccination dose (*M* age = 32.9 years; 60.4% female; 58.9% students; 10.8% chronic health condition)	November 2021	Multivariate analyses	Greater perceived severity was associated with: • Greater likelihood of getting information about booster doses from official government sources and scientific journals. • Being a woman • Being married or cohabitating • Higher perceived health status

Table 1b. Summary of findings of the association between trust in institutions and risk perceptions from cross-sectional surveys				
Author	**Sample**	**Time period**	**Analyses**	**Main findings**
Schneider et al. (2021)	N=6281; n=700-1000 per time-points. (48.4% Male *M* age=42.1; 6.3 % No formal education above 16 years; 10.16 % Professional or technical qualifications above 16 years; 26.4% School education up to age 18 years; 39.3% bachelors degree; 17.9% Postgraduate degree	January 2021	Multivariate analyses predicting perceived risk (based on a general measure encompassing both perceived susceptibility and perceived severity). Five separate cross-sectional analyses conducted for samples from March 2020, May 2020, July 2020, September 2020, January 2021.	In analyses in January 2021 and all other time-points, the likelihood of high perceived risk increased with: • Greater trust in medical professionals • Less conservative political ideology • Direct experience with COVID-19 • More pro-sociality (i.e. willingness to engage in behaviour that benefits others or society as a whole) • Less individualistic worldview • Greater personal efficacy to limit the spread of COVID-19 • Gender • Trust in government and trust in science, as well as collective efficacy, were not related to risk perceptions in January 2021. The lack of association between risk perceptions and trust in government in January 2021 differed from models of cross-sections from March, May, and July 2020, where there was a negative association. A positive association between risk perceptions and trust in science had been observed in May and September 2020, but not March 2020, July 2020, or January 2021.
Wang et al. (2021)	Chinese population (*M* age = 27.87, 54.5% male)	January 2021	Bivariate correlations	Greater perceived susceptibility was correlated with: • Less government trust (*r*=-.15) • More fear of COVID-19 (*r*=.38) • More anxiety (*r*=.29) • Less optimism (*r*=-.14)

Table 1c. Summary of findings of the association between protective behaviours and risk perceptions from cross-sectional surveys				
Author	**Sample**	**Time period**	**Analyses**	**Main findings**
Wong & Yang (2021)	N=1532; US sample (*M* age =46.89; 56.4% women; 52.2% White; 50.7% educated to college degree level or higher; 46% vaccinated)	May 2021	Bivariate correlations with risk perceptions (general measure with both perceived susceptibility and severity)	Higher risk perceptions toward the pandemic were correlated with: • More engagement in protective behaviours (*r*=.70) • Less risky pandemic behaviours (*r*=-.32) • Greater vaccine acceptance (*r*=.55) • Lower perceived risk for the vaccine (*r*=-.08). • More positive general affect toward the pandemic (*r*=.06) • More positive affect toward the vaccine (*r*=.44). • More negative emotion (encompassing anger, disgust, fear and sadness) toward the pandemic (*r*=.23) • More negative emotion toward the vaccine (*r*=.07). • More positive emotion toward the pandemic (encompassing feeling encouraged, hope, joy and pride) (*r*=.21) • More positive emotion toward vaccines (*r*=.46)
Getachew et al. (2022)	N=239; Ethiopia secondary school teachers	February and March 2021	Multivariate analyses	The likelihood of having high perceived risk increased: • twofold in those whose frequency of engaging in protective behaviours was above the mean compared to those with below-average frequency of protective behaviours. • With having up-to-date COVID-19 information • With having children

Table 1d. Summary of findings of the association between other behavioural factors and risk perceptions from cross-sectional surveys				
Author	**Sample**	**Time period**	**Analyses**	**Main findings**
Su et al. (2021)	N=557; Chinese sample (55.1% female; 16.5% 18-24 years, 43.5% 25-35 years, 40% 36+ years; 68.2% junior college educated, 24.4% bachelors degree or higher; 49.4% self-employed, 20.8% students)	March 2021	Bivariate correlations between Health Belief Model constructs	Greater perceived susceptibility was correlated with: • Higher perceived severity (*r*=.24) • Higher perceived benefits of the COVID-19 vaccine (*r*=.12) • Lower perceived barriers to the COVID-19 vaccine (*r*=-.42) There were negligible correlations between perceived severity and: • Perceived benefits (*r*=.06) • Perceived barriers (*r*=-.09)
Al-Hasan et al. (2021)	N=372; multinational study (63.0% North America, 29.4% Middle East, 3.7% Asia, 4.0% Europe; 59.9% Female; 33.1% 18-27 years, 38.4% 28-37 years, 28.6% 38+ years)	December 2020 and January 2021	Bivariate correlations between Health Belief Model constructs	No statistically significant bivariate associations detected between perceived severity and perceived benefits, perceived barriers, or action cues
Griffin et al. (2022)	N=438; unvaccinated UK residents aged 50-64 years old	March 2021	Bivariate correlations between Protection Motivation	Greater perceived severity was correlated with: • Higher perceived susceptibility (*r*=.56)

	(*M*=55.61 years; 60.3% female; 96% White)		theory constructs	• Higher moral norms to get vaccinated (*r*=.38) • Higher social norm to get vaccinated (*r*=.29) • Higher response efficacy for vaccination (both *r*=.21) • Higher self-efficacy for getting vaccinated (*r*=.21). • Lower response cost (i.e. getting vaccinated; *r*=-.16) • Lower maladaptive response rewards (beliefs about benefits of not vaccinating *r*=-.38) Greater perceived susceptibility was correlated with: • Higher moral norms to get vaccinated (*r*=.57) • Higher social norms to get vaccinated (*r*=.42). • Higher response efficacy (*r*=.43) • Higher self-efficacy (*r*=.42) • Lower response cost (*r*=-.37) • Lower maladaptive response rewards (*r*=-.54).
Fan et al. (2021)	N=3145; Chinese students (*M* age = 20.80 years; 50.2% female; 96.2% studying in bachelors programs)	January 2021	Bivariate correlations of Theory of Planned Behaviour constructs	Greater perceived susceptibility was correlated with: • Perceived behavioural control for getting vaccinated (*r*=.48) • Less knowledge about the vaccine (*r*=-.15) • Less positive attitudes towards vaccination (*r*=-.09) Perceived susceptibility was not related to subjective norms around vaccination or past vaccination behaviour (i.e. for influenza).

Influence of risk perceptions and other factors on COVID-19 vaccination intention and uptake

Vaccination behaviour

A summary of the evidence of the influence of risk perceptions and other factors on COVID-19 vaccination uptake from both randomized trials and survey-based evidence is presented in Box 2. For more details on each individual study, see the following sections.

Box 2. Narrative evidence summary of the influence of risk perceptions and other factors on COVID-19 vaccination uptake

In summary, the evidence for the influence of risk perceptions on COVID-19 vaccination uptake is mixed. There were no randomized trials. In both prospective survey studies one in Belgium in early 2021, the other in the UK in March 2021), there were small to moderate bivariate associations between risk perception and vaccination uptake several months later[31,48]. A cross-sectional survey study[47] in August 2021 reported small increased odds of being vaccinated with greater perceived severity. All three studies defined vaccination uptake as having received the first dose. Thus, we cannot speculate on the relationship between risk perceptions for subsequent doses. Additionally, all three survey samples were convenience samples and not fully representative of their respective populations.

We identified three studies[30,46,47] that examined the relationship between vaccination uptake and risk perceptions along with other factors (none in Canada).

The first of these studies used a two-wave prospective design in a sample of Belgian residents (n=5802)[30] to investigate the role of types of motivation as mediators in the relationship between risk perceptions and vaccination uptake. Data collection for T1 was between late December 2020 to end of January 2021, when vaccines were only available to a limited group of elderly and high-risk individuals, and T2 data being collected between May 21 until May 31 2021, when the majority of the adult population had been invited to receive a vaccine[30]. The sample was on average middle aged (*M*=57.26 years), a higher proportion of women (62%) than men, with 41% reporting a comorbid health condition. This study demonstrated a small but statistically significant, positive bivariate correlation (*r*=.20) between T1 risk perceptions (a composite measure which included both perceived susceptibility and perceived severity dimensions) and T2 vaccination uptake. In a structural equation model, there was a small but statistically significant positive total effect of T1 risk perceptions on T2 vaccination uptake (b=.16, p<.001), controlling for T1 pandemic-related health concerns. Risk perceptions were associated with getting vaccinated because it was an internally endorsed choice which aligned with personal values (T1 autonomous motivation; b=.23 p<.001), and negatively related with getting vaccinated because there is external pressure to comply (T1 controlled motivation; b=-.35 p<.001). Greater risk perceptions were also related to less amotivation related to distrust of the vaccine (T1 distrust-

based amotivation; b=-.13 p<.05) and amotivation related to effort to get vaccinated (T1 effort-based amotivation; b=-.15, p<.05). Significant indirect effects demonstrated that the positive relationship between T1 risk perceptions and T2 vaccination uptake was fully mediated by having greater T1 autonomous motivation. Additionally, T1 controlled motivation weakly predicted T2 vaccination uptake (b=.08 p<.001), and the indirect effect suggested that the greater the perceived risk, the less likely that people were to get vaccinated because of controlled motivation.

A second two-wave prospective study[47] recruited a smaller online sample (n=438) of unvaccinated UK residents aged 50-64 years old (*M*=55.61 years; 60.3% female; 96% White) using the crowdsourcing website, Prolific. The first time-point was March 1st 2021, just as 50-64 years age group were invited to get vaccinated in the UK. The follow-up (T2) survey was conducted on May 25th 2021, when all UK adults had been invited for vaccination. There were weak to moderate strength positive bivariate correlations between vaccination uptake and perceived susceptibility (*r*=.40) and perceived severity (*r*=.29). Vaccination uptake was also weakly to moderately correlated with response efficacy (*r*=.28) and self-efficacy (*r*=.27), and moderately to strongly correlated with social norms (*r*=.37) and moral norms (*r*=.51). Negative bivariate correlations were reported between vaccination uptake and the perceived costs of getting vaccinated (*r*=-.37) and beliefs about the benefits of not getting vaccinated (*r*=-.51) In a multivariate logistic model that included demographics, perceived susceptibility, perceived severity, maladaptive response rewards (defined as beliefs about benefits of not vaccinating), response efficacy, self-efficacy, response costs, moral norms, social norms, and intention to vaccinate, only greater intention was related to greater vaccination uptake.

The third of these studies was a cross-sectional survey with data collected in August 2021 of participants residing in Greece[46], at which time vaccines had become available for all adults in Greece[48]. The sample (n=1959) was middle aged, majority female (75.3%), educated to degree level, with a high proportion holding a graduate degree (42.4%), and reported being in good health. Higher odds of being vaccinated were associated with increasing age, being educated beyond elementary school, those who work in healthcare compared to non-healthcare occupations, having not been previously diagnosed with COVID-19, and having had past influenza vaccinations. Furthermore, the probability of being vaccinated was higher with greater perceived severity, knowledge regarding COVID-19, and trust in COVID-19 vaccines and scientists regarding information about the COVID-19 vaccines. On the other hand, lower odds of being vaccinated were associated with having self-perceived knowledge about COVID 19 vaccines, being more concerned about COVID-19 vaccination side effects and trusting a family doctors more for COVID-19 vaccine information.

Vaccination intention

A summary of the evidence of the influence of risk perceptions and other factors on COVID-19 vaccination intention from both randomized trials and survey-based evidence is presented in Box 3. For more details on each individual study, see the following sections describing randomized trials and Table 2a to Table 2e describing cross-sectional survey-based evidence.

Box 3. Narrative evidence summary of the influence of risk perceptions and other factors on COVID-19 vaccination intention

Across the evidence, there was a lack of prospective or longitudinal analyses, so our conclusions are drawn from one randomized trial and cross-sectional analyses. There was evidence that vaccination intention was stronger when the messages were**:**

- **framed as a loss** (i.e. as the disadvantages of not getting vaccinated),
- **presented as a first-person personal narrative**. The use of a first-person narrative account when communicating risk increased risk perceptions and perceived benefits, and reduced perceived barriers, which in turn increased vaccination intentions.

Of 13 cross-sectional studies that examined the relationship between perceived severity and vaccination intention along with other factors, there was a positive association between perceived severity and vaccination intention in 8 of these, and no association in the remaining studies. Similarly, of 11 studies that investigated the association between perceived susceptibility and vaccination intention, 6 reported a positive relationship while the remaining reported no relationship. Thus, **perceived severity and perceived susceptibility are not consistently associated with vaccination intention**. Risk perceptions are frequently measured with other Health Belief Model constructs (e.g. perceived benefits, perceived barriers, cues to action) and Protection Motivation Theory constructs (e.g. response efficacy, response costs, self-efficacy), and these were more consistently associated with vaccinated intention than risk perceptions. There was some evidence that risk perceptions played a contributing role in the relationship between government trust and communication and intention to get vaccinated[37,53]. There was also some evidence that the association between risk perceptions and vaccination intention is explained by its association to other variables, namely beliefs about the utility of the vaccine, beliefs about control over getting the vaccine, beliefs about the social norms of getting vaccinated, autonomous motivation, and less distrust-related amotivation.

Randomized trials: One study[49] was identified that experimentally investigated whether an intervention on risk perception could enhance vaccine intention. Ye et al.[49] conducted an online experiment in a sample of Chinese college students (n=298) in March 2021 which manipulated how messages were framed and presented. Participants were shown messages that included information about COVID-19 and COVID vaccines, with the messaging randomly assigned to either being framed to convey benefits of getting vaccinated (gain frame) or the disadvantages of not getting vaccinated (loss frame), and either being presented from a first-person perspective (narrative) or from a general perspective (non-narrative). The effects of message framing on health beliefs (i.e., perceived susceptibility, perceived severity, perceived benefits, perceived barriers), and vaccination intention were investigated. **Vaccination intention was stronger when messages were framed as a loss, and when the message was presented as a personal narrative**. The effect of narrative messaging on vaccination intention was mediated by health beliefs such that narrative messages, compared to non-narrative messages, increased perceived severity and perceived benefits, and decreased perceived costs. In turn, greater perceived severity and perceived benefits, and less perceived costs predicted greater vaccination intention. The same effect of narrative messaging was not observed between perceived susceptibility and vaccination intention.

Survey-based evidence: We identified 15 studies that investigated the relationship between vaccination intention and risk perceptions and other factors using cross-sectional analyses between December 2020 and August 2021[30,32,35,36,41,47,50–58]. There were no studies that met our criteria with prospective or longitudinal analyses predicting later vaccination intention (none from Canada). Due to the diversity of the studies (e.g. variables analysed, samples), it was not possible to draw conclusions about changes in associations between risk perceptions and vaccination intention over time.

Table 2a. Summary of findings the association vaccination intention and risk perceptions and other behavioural factors from cross-sectional surveys

Author	Sample	Time period	Analyses	Main findings
Griffin et al. (2022)	N=438; unvaccinated UK residents aged 50-64 years old (*M*=55.61 years; 60.3% female; 96% White)	March 2021	Bivariate correlations between Protection Motivation theory constructs	Greater intention to get vaccinated was correlated with: • Higher perceived susceptibility *r*=.59 • Higher perceived severity *r*=.37 • Lower maladaptive response rewards *r*=-.64 • Higher response efficacy *r*=.43 • Higher self-efficacy *r*=.62 • Lower response costs *r*=-.58 • Higher moral norm *r*=.73 • Higher social norm *r*=.55

			Multivariate regression models (adjusted for age, gender, ethnicity, level of economic deprivation, COVID-19 diagnosis, self-isolation, and influenza vaccination) with Protection Motivation constructs predicting intention to get vaccinated	Greater intention to get vaccinated was associated with: • Higher perceived susceptibility • Lower maladaptive response rewards • Higher response efficacy • Higher self-efficacy • Lower response costs • Higher moral norm Perceived severity *was not* associated with vaccination intention.
Ung et al. (2022)	N=552 Macao residents; represen-tative of the population in Macao; 79.5% aged between 25 and 54 years; 59.4% females; 88% bachelors degree or above.	May 2021	Bivariate correlations between Protection Motivation theory constructs	Greater intention to get vaccinated was correlated with: • Higher perceived severity *r*=.12 • Higher perceived susceptibility *r*=.15 • Less maladaptive response rewards i.e. worry about vaccine safety *r*=-.22, time spent getting vaccine *r*=-.17 • Higher self-efficacy *r*=.44-.61 • Higher response efficacy *r*=.36-.37 • Lower response cost *r*=-.24 • Better social attitudes toward vaccine *r*=.51 • Higher moral norm *r*=.66 • Higher social norm *r*=.32-.51 • Less agreement of having bad past experience with vaccines *r*=-.15

			Multivariate regression model	Greater vaccine intention was associated with: • Greater perceived susceptibility • Greater self-efficacy • Greater moral norm • Greater facilitating factor (i.e. a rewarding system such as time off from work) • Greater social norm • Lower response cost • Less reliance on online sources (such as internet, social media) for accurate information about COVID-19 vaccination Perceived severity had *no association* with vaccination intention
Al-Hasan et al. (2021)	N=372; multinational study (63.0% North America, 29.4% Middle East, 3.7% Asia, 4.0% Europe; 59.9% Female; 33.1% 18-27 years, 38.4% 28-37 years, 28.6% 38+ years)	December 2020 and January 2021	Bivariate correlations between Health Belief Model constructs	Greater intention to vaccinate was correlated with: • Higher perceived severity (*r*=.25) • More action cues (*r*=.27) • Greater perceived benefits (*r*=.55) • Less perceived barriers (*r*=-.67)
			Multivariate regression model including action cues, perceived severity, benefits, barriers, availability, information sources, social media sources, government efforts, knowledge of covid, and demographics	Greater intention to vaccinate was associated with: • Greater perceived severity • More action cues • Greater perceived benefits • Less perceived barriers
Berni et al. (2022)	N=3800; Moroccan population; 57.2% Men;	January 2021	Multivariate structural equation model with	Greater intention to get vaccinated was associated with: • Greater perceived susceptibility • Greater perceived severity

	21.2% 18–29 years, 44.5% 30–44 years, 29.3% 45–59 years, 5% >60 years; 55.4% Married; 42.6% elementary or high school educated, 25.3% Bachelor's degree, 32% Master's and PhD		latent constructs of perceived susceptibility, perceived severity, perceived barriers, perceived benefits, self-efficacy and cues to action	• Greater perceived benefits • More cues to action • Greater self-efficacy • Less perceived barriers
Jiang et al. (2021)	N=1039 Chinese sample; 71.7% 18–29 years, 12.8% 30–39 yeas, 15.5% 40+ years; 52% female; 44.6% College students, 27.2% Public transportation workers, 28.2% Health care workers; 71.4% Bachelors degree educated or above	January to February 2021	Multivariate analyses with socio-demographics, perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action	Likelihood of intention to get vaccinated in college students and transportation workers increased with: • Greater perceived benefits • More cues to action • Lower perceived barriers Likelihood of intention to get vaccinated in healthcare workers increased with: • More cues to action • Lower perceived barriers Perceived susceptibility and perceived severity were *unrelated* to intention to get vaccinated in multivariate analyses.

Mahmud et al. (2021)	N=1387 Saudi Arabian sample; 61% male; one third of the study participants belonged to the age group 18–29 years and the other third belonged to the 30–39 years age group. Most of them had tertiary education (85%) and one in five were healthcare workers/professionals (21%).	First quarter of 2021	Multivariate analyses adjusted for gender, age, ethnicity, regions, education, occupation, chronic disease, diagnosis of COVID-19, receipt of flu vaccine,	Higher likelihood of intention to get vaccinated was associated with: • Greater perceived susceptibility • Greater perceived severity • Greater perceived benefits • More cues to actions • Less perceived barriers
Miyachi et al. (2022)	N=1776 Japanese graduate and undergraduate students (*M* age=20.9 years); 53.6% male	March to May 2021	Mean differences	• Perceived severity was significantly higher in those who had active intention to get vaccinated compared to no intention to get vaccinated. • Perceived severity was significantly higher in those with moderate intention to get vaccinated compared to no intention to get vaccinated.
			Multivariate analyses adjusted for age, sex, study course, smoking, drinking and exercise habits, and total scores of concerns	Higher likelihood of active intention to get vaccinated (compared to no intention) was associated with: • Greater perceived severity (i.e. that COVID-19 is life threatening) • Greater perceived benefits • Less perceived barriers (i.e. side effects, feeling troublesome, parent disagreement)

				• Greater perception of serious social consequences for not getting vaccinated Higher likelihood of moderate intention to get vaccinated (compared to no intention) was associated with: • Greater perceived benefits • Less perceived barriers (i.e. side effects, feeling troublesome, parent disagreement) • Greater perception of serious social consequences for not getting vaccinated • Less concerns about COVID-19 *No association* was observed between perceived susceptibility and active intention to vaccinate compared to no intention, or moderate intention to vaccinate compared to no intention.
Yan et al. (2021)	N=1255 Chinese sample; 53% women; 41.3% were 55 years old or above, and 45.6% had completed upper secondary education. A majority (61.7%) were working persons.	December 2020 to January 2021	Mean differences	Compared to people who didn't intend to get vaccinated, people who intended to get vaccinated had significantly: • Higher levels of perceived susceptibility • Higher perceived severity of the disease • Higher perceived benefits • Higher cues to action • Lower perceived barriers
			Multivariate model (adjusted for gender, age, education, employment) with Health Belief Model constructs, COVID-19 specific factors, and trust in authorities	The likelihood of having intention to get vaccinated increased with: • Higher levels of perceived susceptibility • Higher levels of self-efficacy • Higher levels of cues to action Perceived severity was *not* associated with likelihood of intention to vaccinate.

Yang et al. (2021)	N=621 Chinese sample; *M* age = 28.75 years; 56.4% female; Median education level was diploma or Bachelors degree	March 2021	Multivariate structural equation path model including information sources predicting perceived susceptibility, perceived severity, perceived benefits, perceived barriers and cues to action; and perceived susceptibility, perceived severity, perceived benefits, perceived barriers and cues to action predicting intention to get vaccinated.	Greater intention to get vaccinated was associated with: • Greater perceived benefits • Less perceived barriers • More cues to action Perceived susceptibility and perceived severity *were not* associated with intention to get vaccinated.

Table 2b. Summary of findings the association vaccination intention and information/knowledge from cross-sectional surveys

Author	Sample	Time period	Analyses	Main findings
Al-Hasan et al. (2021)	N=372; multinational study (63.0% North America, 29.4% Middle East, 3.7% Asia, 4.0% Europe; 59.9% Female;	December 2020 and January 2021	Bivariate correlations between Health Belief Model constructs	Greater intention to vaccinate was correlated with: • Lower use of entertainment social media (e.g. youtube) for covid information *r*=-.19 • Greater knowledge of COVID-19 treatments *r*=.16
			Multivariate regression model including	Greater intention to vaccinate was correlated with • More knowledge of COVID-19 treatments

	33.1% 18-27 years, 38.4% 28-37 years, 28.6% 38+ years)		action cues, perceived severity, benefits, barriers, availability, information sources, social media sources, government efforts, knowledge of covid, and demographics	

Table 2c. Summary of findings the association vaccination intention and trust in institutions from cross-sectional surveys

Author	Sample	Time period	Analyses	Main findings
Al-Hasan et al. (2021)	N=372; multinational study (63.0% North America, 29.4% Middle East, 3.7% Asia, 4.0% Europe; 59.9% Female; 33.1% 18-27 years, 38.4% 28-37 years, 28.6% 38+ years)	December 2020 and January 2021	Bivariate correlations between Health Belief Model constructs	Greater intention to vaccinate was correlated with: • Less agreement with stricter government strategy *r*=-.17 • Less perceived effectiveness of government COVID-19 policy *r*=-.22
			Multivariate regression model including action cues, perceived severity, benefits, barriers, availability, information sources, social media sources, government efforts, knowledge of	Only in models that included perceived benefits and *not* perceived barriers - greater intention to vaccinate was associated with: • Less agreement with stricter government strategy • Less perceived effectiveness of government COVID-19 policy In models that included perceived barriers but *not* perceived benefits, there was *no association* between intention and agreement with government strategy or intention and perceived effectiveness of government policy.

			covid, and demographics	
Liu & Huang (2021)	N=811 US sample represent-ative of Houston area; 54.1% females; *M* age = 37.86 years; 50.7% self-identified as Caucasian, 19% as African American, 20.5% as Hispanic, and 8.1% as Asian; median educational level was "some college, no degree" (measured on a seven-point scale, *M* = 4.71).	December 2020	Multivariate analyses controlling for age, gender, ethnicity, education, income, native status, ideology, health insurance status, and infection risk for self and family.	Greater vaccination intention was associated with: • Higher perceived susceptibility • Higher perceived severity • greater control mutuality (defined as the perception that both organizations, such as public health units, and the public have equal control of decision-making) • greater commitment to organization-public relationship • More COVID-19 vaccine information seeking Furthermore, the relationship between trust (defined as the willingness and confidence of organizations and the public to rely on the other party) and intention to get vaccinated occurred indirectly where increases in trust was related to increases in perceived susceptibility and severity, which in turn predicted increases in vaccination intention.
Su et al. (2021)	N=557; Chinese sample (55.1% female; 16.5% 18-24 years, 43.5% 25-35 years, 40% 36+ years; 68.2%	March 2021	Multivariate structural equation model	Greater government communication was associated with greater vaccination intention and this association was stronger for: • Individuals from the private sectors than for those from the public sectors • Individuals with objectively good health status than individuals with poor health status.

	junior college educated, 24.4% bachelors degree or higher; 49.4% self-employed, 20.8% students)			Furthermore, the association between government communication and greater vaccination intention occurred indirectly where: • Increases in government communication were associated with increases in perceived severity, which in turn was associated with increases in vaccination intention • Increases in government communication were associated with increases in perceived benefits of vaccination, which in turn was associated with increases in vaccination intention • Increases in government communication were associated with decreases in perceived barriers to vaccination, which in turn was associated with increases in vaccination intention There was *no indirect relationship* between government communication and vaccination intention through perceived susceptibility.
Yan et al. (2021)	N=1255 Chinese sample; 53% women; 41.3% were 55 years old or above, and 45.6% had completed upper secondary education. A majority (61.7%) were working persons.	December 2020 to January 2021	Multivariate model (adjusted for gender, age, education, employment) with Health Belief Model constructs, COVID-19 specific factors, and trust in authorities	Accounting for Health Belief Model constructs and COVID-19 related factors, compared to people who didn't intend to get vaccinated, people who intended to get vaccinated had significantly: • Greater acceptance to governmental measures to prevent COVID-19 • Greater trust in authorities (e.g. government, healthcare professionals)

Table 2d. Summary of findings the association vaccination intention and COVID-19 related factors from cross-sectional surveys

Author	Sample	Time period	Analyses	Main findings
Yan et al. (2021)	N=1255 Chinese sample; 53% women; 41.3% were 55 years old or above, and 45.6% had completed upper secondary education. A majority (61.7%) were working persons.	December 2020 to January 2021	Multivariate model (adjusted for gender, age, education, employment) with Health Belief Model constructs, COVID-19 specific factors, and trust in authorities	Accounting for Health Belief Model constructs and trust in authorities, compared to people who didn't intend to get vaccinated, people who intended to get vaccinated had significantly: • More direct experiences related to other pandemics (e.g. H1N1) • Less concern about the safety and side effects of the vaccines • Less self-reported knowledge about COVID-19
Mohamad et al. (2021)	N=3402 Syrian general population; 64.2% Female; 49.1% 18–30 years, 50.9% aged 31+ years; 13.6% reported having chronic conditions; 58.7% employed before the pandemic.	December 2020 to January 2021	Multivariate analyses	Greater likelihood of intending to get vaccinated was associated with: • Believing in the natural origin of the coronavirus, • Higher vaccination knowledge • Younger age (i.e. 18-30 years compared >30 years) • Not having children Lower likelihood of intending to get vaccinated was associated with: • Perceiving that the severity of COVID for one's own life is not severe • Not feeling fear about COVID • Being a woman • Residing in an urban area • Being a non-smoker There was no association between vaccination intention and perceived susceptibility or studying or working within the medical field.
Phillips et al. (2022)	N=4846 UK sample; comprising of mostly women (66.1%) and	March to April 2021	A multivariate regression	Lower likelihood of intending to get vaccinated was associated with: • being more fearful of trusting the vaccine • being more fearful of vaccine consequences.

	older adults (<50 years: 21.5%; 51–60 years: 19.2%; 61–70 years: 35.7%; 71+ years: 23.5%)			• Having no pre-existing medical condition Greater likelihood of intending to get vaccinated was associated with: • being more fearful of COVID-19 • being middle aged or older compared to younger • not being college educated. There was *no association* between vaccination intention and: perceived susceptibility, psychological distress, gender, ethnicity, self-reported exposure to COVID, perceived control over preventing COVID-19 transmission to either self/household or community.

Table 2e. Summary of findings the association vaccination intention and motivation from cross-sectional surveys

Author	Sample	Time period	Analyses	Main findings
Schmitz et al. (2022)	N=8887 non-vaccinated Belgian inhabitants. *M* age = 49.93 years; 61% females; 71% had a higher degree (i.e., bachelor, master, or Ph.D.); 75% reported that they had no comorbidity factors associated with COVID-19.	December 2020	A multivariate structural equation model with pandemic related health concerns, risk perceptions, autonomous motivation, controlled motivation, and amotivation predicting intention to get vaccinated.	Controlling for pandemic-related health concerns, intention to get vaccinated was associated with: • Greater perceived risk • Greater autonomous motivation • Lower distrust-related amotivation • Greater controlled motivation • Greater effort-based amotivation Furthermore, the association between risk perceptions and greater vaccination intention occurred indirectly where: • Increases in risk perceptions were associated with increases in autonomous motivation, which in turn was associated with increases in vaccination intention • Increases in risk perceptions were associated with decreases in distrust-related amotivation. In turn, decreases in distrust-related amotivation was associated with increases in vaccination intention

Drazkowski & Trepanowski (2021)	N=551 Polish sample; *M* age = 45.34 years; 50.1% male; 40.3%; Educated to Bachelors degree level or higher; 9.1% gotten sick with COVID-19; 70.4% know someone who has gotten sick with COVID-19	December 2020	Bivariate correlations	Greater intention to get vaccinated was correlated with greater perceived severity *r*=.51.
			Structural equation modelling was performed with age, sex, knowing someone afflicted by covid, and latent constructs of reactance, beliefs about control over getting vaccinated, beliefs about the utility of the vaccine, beliefs about social norms abut getting vaccinated, and perceived severity.	Greater perceived severity was associated with greater intention to get vaccinated indirectly where: • Increases in perceived severity was associated with increases in social norms beliefs about the vaccine, which in turn was associated with intention to get vaccinated • Increases in perceived severity was associated with increases in utility beliefs about the vaccine, which in turn was associated with intention to get vaccinated • Increases in perceived severity was associated with increases in control beliefs about the vaccine, which in turn was associated with intention to get vaccinated Additionally, knowing someone afflicted by COVID-19 and age were associated with intention to get vaccinated but only indirectly where: • Knowing someone afflicted with COVID-19 was related to increases in perceived severity, which was associated with increases in social norms beliefs about the vaccine, which in turn was associated with intention to get vaccinated • Knowing someone afflicted with COVID-19 was related to increases in perceived severity, which was associated with increases in utility beliefs about the vaccine, which in turn was associated with intention to get vaccinated • Knowing someone afflicted with COVID-19 was related to increases in perceived severity, which was associated with increases in control beliefs about the vaccine, which in

				turn was associated with intention to get vaccinated • Increasing age was related to increases in perceived severity, which was associated with increases in social norms beliefs about the vaccine, which in turn was associated with intention to get vaccinated • Increasing age was related to increases in perceived severity, which was associated with increases in utility beliefs about the vaccine, which in turn was associated with intention to get vaccinated • Increasing age was related to increases in perceived severity, which was associated with increases in control beliefs about the vaccine, which in turn was associated with intention to get vaccinated

Influence of risk perceptions on physical distancing

A summary of the evidence of the influence of risk perceptions and other factors on physical distancing is presented in Box 4. For more details on each individual study, see the following sections.

Box 4. Narrative evidence summary of the influence of risk perceptions and other factors on physical distancing

Overall, the evidence we identified for the influence of risk perceptions on physical distancing is limited and remains equivocal and perhaps a function of time period in the pandemic. While there was a positive association between physical distancing and perceived severity in an August 2021 study[61], there appeared to be a negative relationship between physical distancing and perceiving high risk of exposure or severe infection, except when levels of knowledge about COVID-19 were high in a December 2020 study [60].

Two cross-sectional studies[59,60] were identified that examined the relationship between physical distancing adherence and risk perceptions, as well as other factors. No studies were identified where only intention to physically distance was the outcome. Additionally, no studies were identified with Canadian participants. Due to the limited number of the studies (which were diverse), it was not possible to draw conclusions about changes in associations between risk perceptions and physical distancing over time.

One of the cross-sectional studies[59] collected data from a large sample (n=4096) of the German general population (*M* age = 45.5 years; 49.4% women) in December 2020. They examined the moderating effect of knowledge about COVID-19 on the relationship between risk perceptions and adherence, mediated by perceived COVID-19 threat (i.e. fear about COVID-19). The conditional mediation model demonstrated a direct effect where perceiving high personal risk of exposure was related to lower adherence to physical distancing, and this negative relationship is strongest at low levels of knowledge and become less negative with increasing knowledge. That is, at higher levels of knowledge, risk of exposure had a stronger positive effect on adherence. Similarly, perceived risk of severe infection was negatively related to physical distancing when knowledge and perceived threat were lowest, but this relationship became less negative with increasing knowledge, disappearing at high levels of knowledge.

The second of these cross-sectional studies[60] collected data from a moderately-sized sample (n=351) of the Iranian general population (*M* age = 29.2 years; 66.4% women; 81.1% had academic degree) in August 2021. In bivariate analyses, physical distancing was moderately correlated with perceived severity (*r*=.31), as well as age (*r*=.24), gender (*r*=.22), extraversion (*r*=.62), agreeableness (*r*=.36), conscientiousness (*r*=.47), neuroticism (*r*=-.50), public trust (*r*=.34), and face-masking (*r*=.62). A multivariate regression analyses demonstrated that greater physical distancing adherence was predicted by older age, being a woman, greater perceived severity, extraversion, agreeableness, conscientiousness, public trust, and less neuroticism.

Influence of risk perceptions on face masking

A summary of the evidence of the influence of risk perceptions and other factors on physical distancing is presented in Box 5. For more details on each individual study, see the following sections.

Box 5. Narrative evidence summary of the influence of risk perceptions and other factors on face-masking

In summary, while no randomized trials or longitudinal survey-based evidence was identified, there was evidence of a positive but small association between perceived severity and face-masking adherence. Although the lack of identified evidence of the relationship between risk perceptions and face-masking after vaccines became available, and the cross-sectional nature of the study, make it difficult to draw conclusions on the reliability of the association.

Only one (cross-sectional) survey study[60] was identified which investigated the relationship between face-masking adherence and risk perceptions in conjunction with other variables. As only one cross-sectional study was identified, we cannot comment on the relationship between risk perceptions and face-masking wearing over time. The cross-sectional study conducted with Iranians[60] also reported the relationship between risk perceptions, personality, public trust, and face-masking adherence. Bivariate correlations demonstrated that face-masking adherence was correlated with perceived severity (*r*=.24), as well as age (*r*=.22), gender (*r*=.19), extraversion

(*r*=.36), agreeableness (*r*=.43), conscientiousness (*r*=.49), neuroticism (*r*=-.28), public trust (*r*=.30), and physical distancing (*r*=.62). In the multivariate analyses, greater adherence to face-masking was associated with being older and female, greater perceived severity, extraversion, agreeableness, conscientiousness, public trust, and less neuroticism.

Conclusions and implications

We identified 35 studies that examined levels of COVID-19 risk perceptions, factors predicting those risk perceptions, and the relationship between risk perceptions (alongside other factors) in predicting vaccination, physical distancing, and social distancing. Overall, due to a lack of longitudinal study designs and diversity in cross-sectional evidence (e.g. variables analysed, samples), it was not possible to draw conclusions about how associations between risk perceptions and protective behaviours varied over time. More high quality, prospective and longitudinal evidence is needed to understand how and why risk perceptions vary over time, and the influence of risk perceptions in performing protective behaviours over the course of a pandemic.

Thirteen studies described levels of risk perceptions. Perceived susceptibility, perceived severity, and a combined measure of general risk perceptions all fluctuated from the Dec 2020 to November 2021 time points of data reported in identified studies. There were 14 studies identified that investigated factors that influence risk perceptions. Based on the evidence that we gathered, risk perceptions are associated with receiving clear information about the virus and risk mitigation measures, in graphical format which includes some uncertainty, and having trust in scientific and medical sources of information. While there was some evidence that presenting risk information to men led to lower perceived risk, there was also some evidence that perceived susceptibility was influenced by whether individuals feel that someone who is "like them" (i.e. a celebrity with whom an individual feels a bond) is vulnerable to COVID-19. Trust in government was inconsistently associated with risk perceptions, with some weak, negative associations being observed. Lastly, there was some evidence that risk perceptions were influenced by engaging in protective behaviours and feeling that behavioural responses to COVID-19 were within one's control, achievable, and effective at reducing risk.

We identified 17 studies that analysed the relationship between vaccination uptake or intention and risk perceptions, along with other factors. The evidence for and association between risk perceptions and vaccination uptake and intention was inconsistent. While some studies reported positive associations between risk perceptions and vaccination intention and uptake, these tended to be weak. Thus, it may be that perceiving that there is a health risk is a necessary condition for taking protective action, such as vaccination, but it is not sufficient. Other factors that were more consistently associated with vaccination uptake and intention were perceived benefits, perceived barriers, response efficacy, response costs and self-efficacy. Additionally, the influence of risk perceptions on vaccination intention may be explained by its association to other variables, such as believing in the utility of the vaccine, that one has control over getting the vaccine, and that others are getting vaccinated. Perceiving that COVID-19 is a

health risk may also be associated with vaccination intention because one truly wants to get vaccinated and endorses that choice, rather than feeling one has to get vaccinated or feeling no motivation to get vaccinated due to distrust.

Two studies were identified that examined the relationship between risk perceptions and physical distancing, and one study was found that examined risk perceptions and face-masking. Similar to the associations between risk perceptions and vaccination, risk perceptions appeared to have a weak but positive relationship with physical distancing and face-masking. The exception to this was a study from December 2020 that reported that the relationship between risk perceptions and physical distancing was conditional on knowledge about COVID-19. Overall, there was a lack of evidence on the relationship between risk perceptions and physical distancing and face-masking once vaccines were approved. More research is required to understand the role of perceived risk in these protective behaviours after individuals were vaccinated.

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Appendix 1

Search term record		
Database	**Line**	**Search terms**
Ovid MEDLINE & Embase & Cochrane Central Register of Controlled Trials	1	((perceiv* or percept*) adj5 risk*).tw,kf.
	2	risk factors/ and (perceiv* or percept*).tw,kf.
	3	((perceiv* or percept*) adj3 illness*).tw,kf.
	4	health perception*.tw,kf.
	5	((risk* adj3 awareness) or perceived severity or perceived susceptib* or perceived vulnerability or threat severity or risk vulnerability).tw,kf.
	6	or/1-5
	7	(announcement or persuasive communication or scientific communication or social communication).tw,kf.
	8	(emergenc* or crisis* or catastroph* or disaster* or outbreak).tw,kf.
	9	(communication* or campaign* or information* or plan* or message* or alert* or awareness or recommendation* or guideline* or guidance or measure* or warning*).tw,kf.
	10	(traffic light or tier* or multi-tier* or level or stage* or vary* or uncertaint*).tw,kf.
	11	or/7-10
	12	(health or public health or risk).tw,kf.
	13	11 and 12
	14	Masks/
	15	(mask* or physical distanc* or social distanc* or test* or vaccination* or immuni?ation*).tw,kf.
	16	COVID-19 Vaccines/
	17	(protecti* behavio?r* or preventi* behavio?r).tw,kf.
	18	intention/ or (behavio?r adj2 intention*).tw,kf. or intention*.ti.
	19	risk reduction behavior/
	20	((behav* adj3 adjust*) or (behav* adj3 adapt*) or (behav* adj3 chang*)).tw,kf.
	21	(Compliance or adhere*).tw,kf.
	22	or/14-21
	23	COVID-19/
	24	(covid or covid19 or covid2019 or sars cov 2).tw,kf.
	25	23 or 24
	26	6 and 13 and 22 and 25
PsycINFO	1	TI,AB,IF(risk percept* OR risk severity OR risk susceptib* OR health percept* OR perceived severity OR threat severity OR perceived susceptib* OR perceived risk OR risk vulnerability)
	2	TI,AB,IF(announcement or persuasive communication or scientific communication or social communication)
	3	TI,AB,IF(emergenc* or crisis* or catastroph* or disaster* or outbreak)

	4	TI,AB,IF(communication* or campaign* or information* or plan* or message* or alert* or awareness or recommendation* or guideline* or guidance or measure* or warning*)
	5	TI,AB,IF(traffic light or tier* or multi-tier* or level or stage* or vary* or uncertaint*)
	6	2 OR 3 OR 4 OR 5
	7	TI,AB,IF(health or public health or risk)
	8	6 AND 7
	9	TI,AB,IF(mask* OR vaccin* OR immuni?ation OR test* OR social distanc* OR physical distanc* OR test* OR "protecti* behav*" OR "preventi* behav*" OR "transmission reduci* behav*" OR risk reduc*)
	10	TI,AB,IF(behav* adjust* OR behav* adapt* OR behav* chang*)
	12	9 OR 10
	13	1 AND 8 AND 11 AND 12
EBSCO CINHAL	S1	TI ((risk percept* OR risk severity OR risk susceptib* OR health percept* OR perceived severity OR threat severity OR perceived susceptib* OR perceived risk OR risk vulnerability)) OR AB ((risk percept* OR risk severity OR risk susceptib* OR health percept* OR perceived severity OR threat severity OR perceived susceptib* OR perceived risk OR risk vulnerability))
	S2	TI ((announcement or persuasive communication or scientific communication or social communication)) OR AB ((announcement or persuasive communication or scientific communication or social communication))
	S3	TI ((emergenc* or crisis* or catastroph* or disaster* or outbreak)) OR AB ((emergenc* or crisis* or catastroph* or disaster* or outbreak))
	S4	TI ((communication* or campaign* or information* or plan* or message* or alert* or awareness or recommendation* or guideline* or guidance or measure* or warning*)) OR AB ((communication* or campaign* or information* or plan* or message* or alert* or awareness or recommendation* or guideline* or guidance or measure* or warning*))
	S5	TI ((traffic light or tier* or multi-tier* or level or stage* or vary* or uncertaint*)) OR AB ((traffic light or tier* or multi-tier* or level or stage* or vary* or uncertaint*))
	S6	(S2 OR S3 OR S4 OR S5)
	S7	TI ((health or public health or risk)) OR AB ((health or public health or risk))
	S8	S6 AND S7
	S9	TI ((mask* OR vaccin* OR immuni?ation OR social distanc* OR physical distanc* OR test* OR protective behavio?r OR preventive behavio?r OR transmission reducing behavio?r OR risk reduc*)) OR AB ((mask* OR vaccin* OR immuni?ation OR social distanc* OR

		physical distanc* OR test* OR protective behavio?r OR preventive behavio?r OR transmission reducing behavio?r OR risk reduc*))
	S10	TI ((behav* adjust* OR behav* adapt* OR behav* chang*)) OR AB ((behav* adjust* OR behav* adapt* OR behav* chang*))
	S11	S9 OR S10
	S12	"COVID" OR (MH "COVID-19+") OR (MH "COVID-19 Pandemic") OR "SARS-CoV-2" OR "coronavirus"
	S13	S1 AND S8 AND S11 AND S12

Appendix 2

PRISMA diagram