Preventive Medicine Reports 37 (2024) 102573

Contents lists available at ScienceDirect

Preventive Medicine Reports

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

Review article

A systematic review of cannabis health warning research

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ARTICLE INFO

Keywords:
Cannabis Health Communication
Cannabis labeling
Health warning messages
Health warning labels

ABSTRACT

Background: Cannabis legalization provides an opportunity to communicate with consumers through mandated health warnings on cannabis packaging. However, research on cannabis health warnings is a nascent field. Therefore, a review is needed to synthesize cannabis health warning research and inform ongoing policy discussions.

Methods: This paper used systematic review guidelines to search online databases, including PubMed Central, Scopus, Web of Science, Jstor, Communication and Mass Media Complete, Medline, PsycINFO, and Google Scholar. Search strings combined the terms "cannabis" or "marijuana" with "health warning" or "health warning message" or "warning label" or "health warning label" or "health information label." Results were synthesized narratively.

Results: The search identified 90 research articles. After screening, 17 studies on the impact of cannabis health warnings were retained. Retained studies focused on the hypothetical effects of cannabis health warnings (n = 11; 64.7 %) and "real world" effects of implementing warnings post-legalization (n = 6; 35.3 %). Evidence indicated mandated cannabis health warnings improved noticing and recall of health warning content. Cannabis health warnings describing risks of addiction were consistently rated the least effective. Pictorial cannabis health warnings generally outperformed text-only warnings when displayed on their own, while experiments with warnings on products had mixed results. Cannabis health warnings decreased product appeal, mainly when package branding was minimized.

Conclusions: Health warnings on cannabis packaging are an important strategy to communicate risk to consumers. Mandating warnings increased notice, recall, and health knowledge. Warnings with pictures and describing specific risks were most effective, as was showing warnings without product branding.

1. Introduction

Recreational cannabis is being legalized nationally in many countries, including Uruguay, Canada, and several European countries, including Germany. In the United States (US), recreational cannabis is legal in 24 US states and the District of Columbia (Hall and Lynskey, 2020; National Conference of State Legislatures, 2019). Many countries and US states have also legalized access to medical cannabis for individuals who have received medical authorization.

Cannabis legalization represents a notable shift in substance use policy, with implications for use rates, profile of cannabis products, and public health outcomes. Legalization and normalization have been associated with decreased risk perception (Hasin, 2018; Jones, 2019). Lower cannabis risk perceptions are associated with higher use rates. Despite potential health benefits (Bridgeman and Abazia, 2017) and increasing public consumption and belief that cannabis is safe (Johnston et al., 2014; McGinty et al., 2017), cannabis use can have negative health effects. Cannabis harms include impaired driving (Aydelotte et al., 2019; Chihuri et al., 2017), worsening mental health (Hall and Lynskey, 2020), and potential for developing cannabis use disorder (First, 2013). High-THC products have also been linked to greater severity of dependence (Freeman and Winstock, 2015). As cannabis consumption increases, informing the public about possible harms becomes increasingly important (Wilkinson et al., 2016).

Cannabis legalization provides an opportunity to communicate directly with consumers through mandated health warnings on cannabis packaging (Hammond, 2021). Research on a range of consumer products, including tobacco products, has demonstrated that comprehensive

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https://doi.org/10.1016/j.pmedr.2023.102573
Received 10 October 2023; Received in revised form 18 December 2023; Accepted 20 December 2023
Available online 23 December 2023

health warnings have a broad reach among consumers to deliver important health information at purchase and use (Hammond, 2011). Most countries mandate sets of "rotating" warnings on tobacco products, focusing on a specific health harm using text and pictures (Canadian Cancer Society, 2021; Thrasher et al., 2018). These "comprehensive" tobacco health warnings have been shown to increase risk perceptions and decrease product appeal, including among youth (Hammond, 2011; Hammond et al., 2007; Noar et al., 2016).

Research has outlined principles for effective consumer health warnings. Specifically, health warnings are theorized to work best when consumers (1) pay attention and notice warnings, (2) comprehend the warnings, and (3) react to warnings (e.g., emotional responses) in ways that motivate compliance (Noar et al., 2016; Wogalter et al., 2002). An extensive review of tobacco health warning research, for instance, found that prominent health warnings using attention-grabbing pictures that elicited emotional reactions were the most effective at deterring tobacco use (Hammond, 2011).

Despite extant research, policy guidelines for cannabis health warnings vary widely. In Canada, cannabis packaging must show a universal cannabis symbol, THC and CBD (i.e., cannabidiol) information, and text-only health warning messages (Government of Canada, 2022). The health warnings display a *primary message* (e.g., WARNING Cannabis smoke is harmful) followed by a *secondary message* explaining the harm (see Table 1). The health warnings are printed in black text on yellow background with font sizes equal to the product brand name (see Fig. 1). Canadian labeling regulations are arguably the most comprehensive cannabis health warning regulations in the world (Hammond, 2021).

In the US, the legal status of cannabis differs between national and state levels. At the national level, cannabis is a prohibited Schedule 1 substance (USFDA, 2022). Despite federal prohibitions, recreational cannabis is "legal" in many US states and regulated at the state level. While US jurisdictions with legal recreational cannabis require health warnings, the message content, size, and location of mandated warnings vary considerably (Allard et al., 2022; Cannabis Regulators Association, 2022), resulting in inconsistent labeling across states (Schauer, 2021). To date, no comprehensive policy framework has been adopted to warn US consumers about the possible risks of cannabis consumption.

Debate about communicating cannabis health harms is ongoing. Some scholars advocate tobacco control approaches, like showing pictorial warnings on plain packaging (Al-Hamdani et al., 2021; Barry and Glantz, 2017; Orenstein and Glantz, 2018). Other scholars argue for less restrictive approaches, similar to "responsible use" alcohol labeling (Kees et al., 2019; Newman et al., 2021). Most scholars agree that cannabis legalization requires an evidence-based approach to inform consumers (Kees et al., 2019). However, research on cannabis health warnings is a developing field spanning several disciplines. Therefore, a review is needed to synthesize cannabis warning research and inform urgent and ongoing policy discussions.

This paper sought to review evidence on the impact of health warning messages (i.e., health warnings henceforth) for cannabis packaging. The review was organized around important variables for developing and testing effective health warnings. Specifically, we reviewed the evidence on (1) the impacts of noticing cannabis health warnings, (2) comprehension of mandated warnings, (3) the perceived effectiveness of different risks in cannabis health warnings, (4) the impact of pictorial (vs. text) cannabis health warnings; and (5) the effects of displaying warnings with (or without) product branding. Since there are no published reviews on cannabis health warnings, these results can inform policy about communicating possible risks of cannabis use to the public during shifting regulatory policy.

Table 1
Example of Rotating Canadian Cannabis Health Warning Messages.

Primary Warning	Secondary warning
WARNING: The smoke from cannabis is harmful.	Toxic and carcinogenic chemicals found in tobacco smoke such as polyaromatic hydrocarbons, aromatic amines, and N-heterocyclics are also found in cannabis smoke.
WARNING: Do not use if pregnant or breastfeeding.	Substances in cannabis are transferred from the mother to child and can harm your baby.
WARNING: Do not drive or operate heavy equipment after using cannabis.	Cannabis can cause drowsiness and impair your ability to concentrate and make quick decisions.
WARNING: Frequent and prolonged use of cannabis containing THC can contribute to mental health problems over time.	Daily or near-daily use increases the risk of dependence and may bring on or worsen disorders related to anxiety and depression.
WARNING: Adolescents and young adults are at greater risk of harms from cannabis.	Daily or near-daily use over a prolonged period of time can harm brain development and function.
WARNING: The higher the THC content of a product, the more likely you are to experience adverse effects and greater levels of impairment.	THC can cause anxiety and impair memory and concentration.

Note. The text taken from the "Health Warning Messages" page on Health Canada website.

2. Methods

2.1. Search strategy

This study used PRISMA guidelines for systematic reviews (Moher et al., 2010). Working with a research librarian, we searched online databases, including PubMed Central, Scopus, Web of Science, Jstor, Communication and Mass Media Complete, Medline, PsycINFO, and Google Scholar. Search strings combined the terms "cannabis or marijuana" with "health warning," "health warning message," "warning label," "health warning label," or "health information label." Three searches were conducted, with a final search in April 2023 resulting in 87 references after removing duplicates. Three additional references were identified by reviewing reference lists, resulting in 90 references.

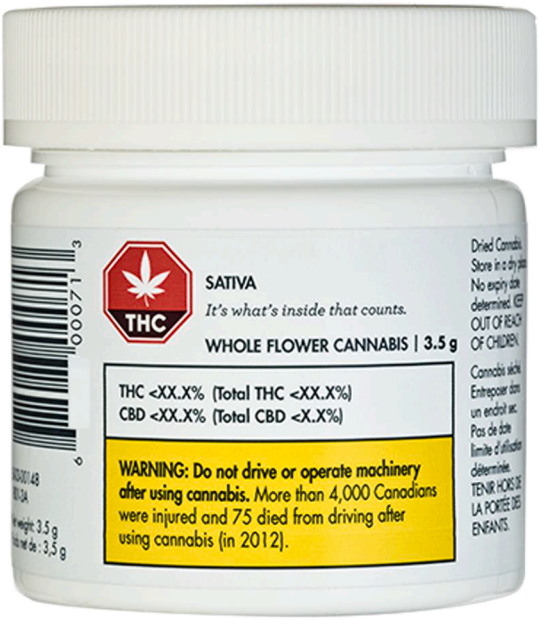
The systematic review used six inclusion criteria: (1) original research reporting the effects of health warnings for cannabis products (i.e., health warnings on packaging); (2) clearly stated objectives; (3) a clear description of the sample; (4) replicable data collection methods; (5) measurable outcomes; (6) and analysis and summary of findings (Hammond, 2011). For the first criterion, *health warning* was defined as messages informing consumers about the risks of consuming cannabis designed to appear on cannabis product packaging. Thus, studies focused on anti-cannabis PSAs or labeling of ingredients or constituents (e.g., THC/cannabinoid content) were omitted.

Two coders and the first author independently reviewed and coded the 90 articles to screen on the above inclusion criteria. Specifically, each study was reviewed and coded independently by one of the two coders and the first author. Coding disagreements were resolved through discussion. A total of 17 articles met the inclusion criteria and were retained for analysis (see Fig. 2). Study results were summarized narratively due to the wide range of approaches used in studies. Since this study is a review of publicly available studies and does not involve human subjects, we did not seek IRB approval.

3. Results

Retained studies were conducted in Canada and the US ($n = 6$; 35.3 %), the US ($n = 6$; 35.3 %), or in Canada ($n = 5$; 29.4 %). All studies were published between 2017 and 2022. Most studies ($n = 10$; 58.8 %) included a combination of adults (18 +) and youth (<18), with no studies exclusively on youth. Study samples ranged from $N = 23$ to 94 for qualitative focus groups and $N = 275$ to 74,549 for quantitative studies, including observational and experimental studies.

The studies were organized into two focus areas: (1) post-



Note. Canada (similar to Uruguay) requires cannabis products to be sold in plain packaging

Fig. 1. Example of cannabis health warnings on packaging as mandated in Canada.

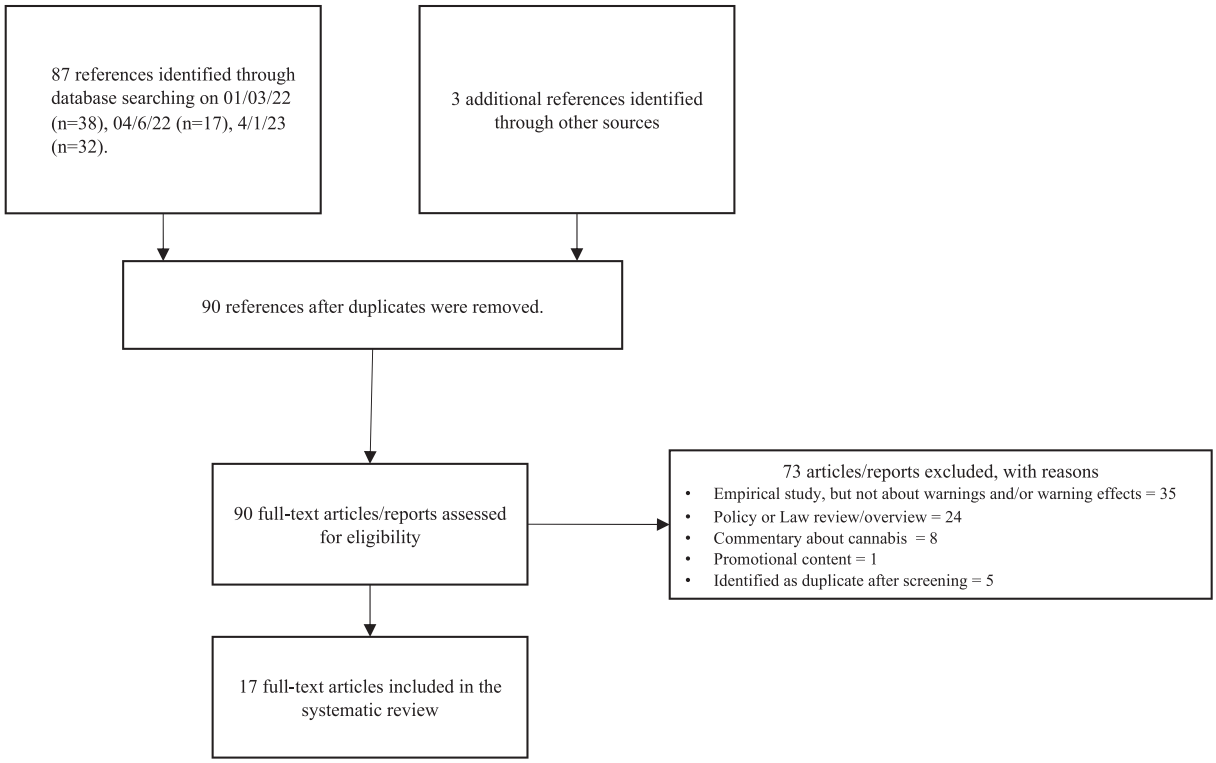


Fig. 2. PRISMA diagram showing the study screening process.

implementation studies assessing the "real-world" impact of health warnings following cannabis legalization in Canada ($n = 6$; 35.3 %); and (2) studies assessing the hypothetical effectiveness of warnings within an experimental design, including studies that experimentally manipulated the content or design of warnings ($n = 11$; 64.7 %). Supplemental Table 1 provides the characteristics of the studies.

3.1. Real-world effect of mandated cannabis health warnings

3.1.1. Notice and recall

Three post-implementation studies (Goodman and Hammond, 2021, 2022; Goodman et al., 2022) assessed the "real world" effects of mandated warnings before and after Canadian legalization of recreational cannabis using data from the same study, the International

Cannabis Policy Study (ICPS), which is a quasi-experimental study using repeat-cross-sectional surveys over time in Canada and the US (Hammond et al., 2020).

An ICPS survey of 16–65-year-olds ($N = 72,549$) in Canada and the US (illegal and legal jurisdictions) collected data pre- and post-Canadian legalization in 2018 (Goodman and Hammond, 2021). Results showed participants in Canada (vs. legal and illegal US jurisdictions) reported higher levels of noticing cannabis health warnings in the year following legalization compared to the year prior to legalization. Canadian health warnings included mandated features (e.g., description of single health risks with black text on yellow background; see example in Fig. 1).

Another ICPS study collected data before Canadian legalization in 2018 and again in 2019 (Goodman and Hammond, 2022). The sample included 16–65-year-olds ($N = 72,459$) from Canada and the US (legal and illegal jurisdictions), and primary outcomes included noticing health warnings in the prior year and health knowledge about cannabis risks (e.g., "Can it be harmful to use marijuana when pregnant or breastfeeding?"). Noticing cannabis health warnings—across jurisdictions in Canada and the US—was associated with greater health knowledge about cannabis risks.

An ICPS survey of 16–65-year-olds ($N = 38,448$) in Canada and the US (legal and illegal jurisdictions) measured free recall and recognition of cannabis health warnings in 2018 and 2019 and 2020 (Goodman et al., 2022). Free recall measures asked participants if they recalled seeing specific warning messages on cannabis products in the past 12 months. Among Canadian participants, free recall of > 1 cannabis health warning increased from 5 % before legalization in 2018 to 13 % in 2019 and 15 % in 2020 (Goodman et al., 2022). Moreover, participants in Canada and legal US jurisdictions were more likely to recall and recognize risks in the health warnings (e.g., risk of impaired driving) versus illegal US jurisdictions without mandated warnings.

3.1.2. Consumer comprehension

Three qualitative studies (Donnan et al., 2022; Kosa et al., 2017; Ventresca and Elliott, 2022) assessed post-implementation comprehension of cannabis health warnings. Kosa et al. (2017) conducted 12 focus groups in Colorado and Washington State (both legal states) in 2016. The researchers showed 21+-year-olds ($N = 94$) cannabis edible packaging to assess comprehension. Health warnings on packaging were text-only and described multiple risks in a composite paragraph. Participants said the cannabis health warnings were easy to understand. However, they raised concerns about certain warnings. For instance, most Colorado groups found the oversight warning (e.g., "This product was produced without regulatory oversight for health, safety, or efficacy") confusing, leading some to question whether the products were regulated. The Washington groups expressed confusion about the intoxication warning (e.g., "The intoxicating effects of this drug may be delayed by two or more hours"), since it conflicted with product instructions (Kosa et al., 2017).

A series of 8 focus groups in 2018 showed images of cannabis edibles to Canadian young adults (18–24-year-olds; $N = 57$) to gauge understanding (Ventresca and Elliott, 2022). The study occurred one month after legalization but 11 months before edibles were legal for purchase. Participants viewed sample images of edible packaging and asked for their impressions. The cannabis health warnings were the mandated design, with primary and secondary text warnings describing single risks with black text on yellow backgrounds. Participants unanimously agreed that packaging should contain warnings to protect children. However, several participants expressed mixed reactions to the warnings for adults. Some described the warnings as "extreme" and felt the warnings described cannabis as more dangerous than alcohol. Participants also discussed how the effects described in the warnings conflicted with personal experience using edibles without adverse outcomes (Ventresca and Elliott, 2022).

A 2020–2021 study interviewed Canadian adults (19–60+-year-olds; $N = 23$) to understand better the factors influencing cannabis purchase decisions (Donnan et al., 2022). Findings revealed that participants were "generally indifferent" to cannabis health warnings as a factor influencing purchase decisions (Donnan et al., 2022). Participants discussed how cannabis packaging could be excessive, and many commented that health warnings were an important packaging feature. Some participants revealed that they wanted health warnings on packaging as a quality assurance measure.

3.2. Effects of hypothetical cannabis health warnings

3.2.1. Effects of different cannabis warning risks

As shown in Table 1 and Fig. 1, cannabis health warnings describe risks of different harms. We identified five studies assessing the efficacy of the risks communicated in the warning messages (Kowitt et al., 2022; Leos-Toro et al., 2019; Mutti-Packer et al., 2018; Pepper et al., 2020; Winstock et al., 2021).

An ICPS experiment sampled 16-to-30-year-olds ($N = 870$) before Canadian legalization (Leos-Toro et al., 2019). Participants were randomly exposed to four of eight hypothetical cannabis health warnings on risks of (1) impaired driving, (2) pregnancy, (3) mental health, (4) co-morbid use, (5) youth use, (6) addiction, (7) dose, and (8) secondhand smoke. The risks were based on mandated warnings in Canada and US states. Risks were presented as pictorial (vs. text-only) warnings formatted like Canadian warnings (e.g., description of a single risk, black text on yellow background, prominent font). Outcomes were perceived effectiveness and believability—key constructs for effective health warnings (Hammond, 2011; Noar et al., 2016; Wogalter et al., 2002). Risks for pregnancy and impaired driving were rated highest on perceived effectiveness, and risks for pregnancy and co-morbid use were highest on believability. Addiction was rated lowest for perceived message effectiveness and believability, respectively.

The lack of efficacy for addiction risks was found in other studies. For example, Mutti-Packer et al. (2018) conducted an experiment that randomly assigned Canadian participants (17–55-year-olds; $N = 656$) to view hypothetical cannabis products with varied branding and health warnings (present vs. absent). The health warnings were text-only (e.g., "WARNING Regular use of this product may be habit-forming and result in addiction or dependency") and described risks for (1) brain development, (2) impaired driving, (3) mental health, (4) overdose, and (5) addiction. Outcomes were product appeal, perceived effectiveness, believability, and fear evoked from warnings. The health warning describing the risk for brain harm was rated highest for perceived effectiveness, believability, and fear, and the addiction warning was lowest on those outcomes.

Pepper et al. (2020) conducted an experiment that randomly assigned adults (21+-year-olds; $N = 1,000$) in legal US jurisdictions to view one of four health warnings displayed on cannabis flower or edible products. The text was adapted from mandated Canadian warnings about psychosis (e.g., "WARNING: Regular use of cannabis can increase the risk of psychosis and schizophrenia") and US warnings about addiction (e.g., "WARNING May be habit forming;" Washington State), lack of FDA oversight (e.g., "WARNING: This product has not been analyzed or approved by the FDA"; Massachusetts), or impaired driving ("WARNING: Do not drive or operate heavy machinery while using marijuana"; Colorado). Outcomes included perceived effectiveness and believability. The warnings on addiction and psychosis were each rated significantly lower for believability than those about impaired driving (Pepper et al., 2020). Addiction was also rated significantly less effective compared to impaired driving.

A 2018–2019 survey of youth and adults (16-to-36+year-olds; $N = 8,729$) from Canada and the US (legal and illegal jurisdictions) showed participants six text-only warnings (Winstock et al., 2021). Warnings were adapted from Canadian warnings (e.g., risks of dependence, impaired driving, smoke harm, and harms for youth brain development), and two were created by researchers (e.g., risk for lack of motivation and memory). Participants rated the cannabis health warnings

and indicated whether the warnings would encourage them to consider changing behaviors (e.g., "Does [addiction message] make you think about using less cannabis?"). The risk of impaired driving was rated the highest for encouraging behavior change and the addiction risk warning was rated the lowest.

3.2.2. Pictorial vs. text-only warnings

Research has demonstrated that health warnings with pictures and text (i.e., pictorial warnings) are more effective than text-only warnings for impacting attitudes and behavior (Hammond, 2011). Our review identified five experimental studies testing pictorial (vs. text-only) cannabis health warnings. Three studies assessed cannabis health warnings apart from cannabis products (Kim et al., 2022; Leos-Toro et al., 2019; Zhang et al., 2022), and two assessed warnings displayed on products (Kowitt et al., 2022; Shi et al., 2019).

The above-mentioned Leos-Toro et al. (2019) experiment was conducted in Canada in 2017—one year before legalization—and randomly assigned 16–30-year-olds to view hypothetical pictorial (vs. text-only) cannabis warnings. Warnings were black text on a yellow background and described different harms (e.g., risks of impaired driving, smoke toxicity, harm to mental health, etc.). Outcomes included perceived effectiveness and believability of the warnings. The pictorial warnings (vs. text-only) were rated higher on perceived effectiveness and believability across different themes used in warnings.

A 2020 experiment in the US randomly assigned young adults (18–26-year-olds; $N = 523$) to view variations of mandated California cannabis health warnings (Kim et al., 2022). The mandated warning listed several risks in one composite paragraph. Experimental variations of the California warning included (1) adding text on the risk of mental health; (2) presenting health risks individually (i.e., single-theme warnings vs, composite paragraph); (3) "enhancing" the content design with yellow background, bigger font, and simple language; and (4) adding a picture of the described health risk. Outcomes were warning recall, negative emotions, and perceived message effectiveness. Exposure to the enhanced pictorial warning resulted in greater recall, negative emotions, and perceived message effectiveness than either the mandated California text-only warning or the text-only warning with added information about mental health.

A 2021 experiment of adults (18–35-year-olds; $N = 275$) in legal US jurisdictions randomized participants to view pictorial (vs. text-only) cannabis health warnings. The warnings used Canadian design principles (e.g., description of single risk, black text on yellow background, prominent font, etc.). They described the risks of impaired driving, worsened mental health, high-THC products, and smoke toxicity. Outcomes were emotions, perceived efficacy and perceived threat of cannabis harms, and perceived message effectiveness (Zhang et al., 2022). No significant differences were found between pictorial and text-only conditions. However, repeated measures tests showed that negative emotions and perceived efficacy were significantly higher after health warning exposure (vs. before) regardless of the message type. Moreover, higher levels of post-exposure negative emotion were associated with higher perceived message effectiveness, indicating that negative emotions from seeing cannabis health warnings—either format—were predictive of perceived message effectiveness.

Two studies tested pictorial (vs. text-only) warnings on cannabis products. Shi et al. (2019) conducted a discrete choice experiment with adults (21+-year-olds; $N = 2400$) in legal US jurisdictions. Participants randomly viewed a hypothetical cannabis product with (1) no health warnings, (2) text-only health warnings from Colorado and Washington State (e.g., risks for pregnancy, youth, driving, dependence, and dose), (3) a text-only warning about lack of FDA regulation, or (4) a warning about impaired driving with an image (e.g., image text: "Drive high: Get a DUI"). The primary outcome was product preference, and participants had a greater preference for products *with* the pictorial warning (vs. no-warning attributes).

Kowitt et al. (2022) randomly assigned adults (18+-year-olds; $N = 841$) in the US to view one of three cannabis health warnings about (1) addiction (text-only), (2) impaired driving (text-only), or (3) impaired driving (pictorial). The warnings were adapted from mandated Alaskan warnings and were displayed on hypothetical cannabis edibles. The impaired driving pictorial warning was perceived as more "grown-up" than the warning about addiction. However, there were no significant differences between pictorial and text-only warnings on other important outcomes, including cognitive risk perceptions or emotional responses.

3.2.3. Effects of branding with warnings

We identified four studies (Goodman et al., 2019; Goodman et al., 2021; Leos-Toro et al., 2021; Mutti-Packer et al., 2018) testing the effects of combining branding and cannabis health warnings. The Mutti-Packer et al. (2018) experiment described above assigned Canadians (17–55-year-olds) to view cannabis products with varied branding (plain vs. branded) and health warnings (present vs. absent). The warning condition showed text-only warnings (e.g., "WARNING: Regular use of this product may impair brain development…"). The branded packages without warnings were rated most appealing by participants. However, products with plain packaging and warnings were more appealing than plain packages with no warnings.

A 2018 study from the ICPS randomly assigned 16–65-year-olds ($N = 27{,}045$) from Canada and the US (legal and illegal jurisdictions) to view hypothetical cannabis products (full branding, brand logo only, or non-branded, plain packaging), Canadian health warnings (text-only: present vs. absent), and product type (e.g., rolled joints) (Goodman et al., 2019). Product appeal was a primary outcome. The cannabis products with text-only cannabis health warnings (e.g., "WARNING Do not use if breastfeeding or pregnant…") were rated less appealing than products without warnings (Goodman et al., 2019). There were no statistically significant interactions between cannabis health warnings and the presence of branding.

A 2019 experiment randomly assigned participants (16–65-year-olds; $N = 45{,}378$) from Canada and the US (legal and illegal jurisdictions) to view cannabis products with different health warnings and branding (Goodman et al., 2021). This experiment varied the presence of cannabis health warnings (Canadian, California, or no warning) and brand imagery (e.g., full branding vs. single color background) on packs of pre-rolled joints. Canadian and US warnings described risks of (1) driving/operating machinery, (2) pregnancy/breastfeeding, and (3) youth use. The Canadian warnings had several single-theme risks and US warnings had the risks in one composite paragraph. Product appeal, perceived harm, and warning recall (i.e., "describe up to three health effects mentioned in the messages") were primary outcomes. Products with Canadian warnings were rated least appealing, and there was an interaction such that products with full branding and either the Canadian or US warnings were rated less appealing than those with full branding and no warnings. Products with Canadian warnings (vs. US warnings or no warnings) were rated significantly more harmful. Warning recall was significantly higher for products with Canadian versus US cannabis health warnings or no warnings, respectively.

4. Discussion

This is the first systematic review of cannabis health warning research. Such a review is necessary because cannabis policy is being liberalized in many jurisdictions, with implications for public health, including the need to inform consumers about possible risks of use. Policy discussions about how to effectively warn people about cannabis risks are ongoing. This review sought to inform these discussions by synthesizing current research on cannabis health warnings.

A main finding of this review is that mandating cannabis health warnings improved important indicators of informing the public about health risks. Evidence from population-based surveys showed that mandated cannabis health warnings increased notice, recall, and recognition of warning content (Goodman and Hammond, 2021;

Goodman et al., 2022). Moreover, noticing cannabis health warnings was associated with increased knowledge about health risks (Goodman and Hammond, 2022). These population-based studies provide evidence that mandated warnings improved several theoretically important variables (Noar et al., 2016) for effective consumer health warnings (Hammond, 2011).

The efficacy of different cannabis health warnings is another important finding. Cannabis health warnings typically focus on different risks, including pregnancy, mental health, youth use, impaired driving, and risk of developing dependence (i.e., cannabis use disorder). Risks of pregnancy (Leos-Toro et al., 2019), brain development (Mutti-Packer et al., 2018; Winstock et al., 2021), and impaired driving (Pepper et al., 2020) were perceived as most effective and believable, although support varied across studies. Results of experimental (Leos-Toro et al., 2019; Mutti-Packer et al., 2018; Pepper et al., 2020) and survey (Winstock et al., 2021) research showed that cannabis health warnings about the risks of addiction were generally the least effective and believable. These data inform policymakers focused on the most effective way to message about cannabis risks. Describing risks for pregnancy, brain harm, and impaired driving may be perceived as effective and believable, especially when compared to addiction.

The addiction risk messages in reviewed studies were adapted from mandated warnings in Canada (e.g., "WARNING Regular use of this product may be habit-forming and result in addiction or dependency"; Mutti-Packer et al., 2018) and the US (e.g., "WARNING May be habit forming"; Pepper et al., 2020). The lack of effectiveness for warnings about addiction risks is important for two reasons. First, if existing addiction warnings are ineffective, research should continue to develop and improve the warnings. Second, a lack of believability for addiction warnings is concerning and touches on broader misperceptions about cannabis dependence. Cannabis use disorder is an established health risk (First, 2013); with approximately 10 % of cannabis users going on to develop the disorder (Volkow et al., 2014). Cannabis health warnings are an ideal platform to inform consumers about these risks. However, our review found existing addiction warnings were consistently the lowest rated. Thus, future research should continue to develop and assess cannabis health warnings about the risk of developing cannabis use disorder.

A consistent finding was that Canadian warnings were more effective than US designs (e.g., Goodman et al., 2021). Canadian warning designs align with best practices for comprehensive health warnings (Strahan et al., 2002; Wogalter et al., 2002), including features like warning statements with single-theme risks displayed in black text on attention-grabbing backgrounds. Comparatively, the less rigorous designs used in the US combine multiple risks in comprehensive paragraphs using a small font printed on plain backgrounds (e.g., Kim et al., 2022). These findings comport with policy analyses that cannabis health warning mandates in legal US states were inconsistent with rigorous standards for protecting public health, such as those established for tobacco products (Barry and Glantz, 2017; Orenstein and Glantz, 2018). Practitioners and policymakers in the US (and aboard) should consider the growing body of evidence demonstrating that comprehensive cannabis health warnings outperform less rigorous designs.

The results of pictorial (vs. text-only) cannabis health warnings showed nuanced results. Studies testing cannabis health warnings when not displayed on cannabis products found pictorial warnings were perceived as more effective and believable (Leos-Toro et al., 2019) and produced stronger emotional reactions (Kim et al., 2022). Another study found that post-exposure measures of emotion predicted perceived health warning effectiveness regardless of whether participants viewed a pictorial or text-only cannabis health warning (Zhang et al., 2022). Collectively, these experimental effects comport with previous research by highlighting the primary roles of believability, perceived effectiveness, and negative emotions as explanatory variables for cannabis health warning effects (Hammond, 2011). Given the small pool of studies testing pictorial warning features, caution is warranted in interpreting the results. Research should continue to evaluate different cannabis health warning designs to assess if exposure effects comport with findings in related domains, such as tobacco and alcohol warnings.

Past research showed that plain packaging with health warnings decreased tobacco product appeal and helped dissuade initiation (Gallopel-Morvan et al., 2015; Moodie et al., 2011; Moodie and Mackintosh, 2013). In our review, the results of Mutti-Packer et al. (2018), Goodman et al. (2019), and Goodman et al. (2021) found that branded products without cannabis health warnings were rated as the most appealing. This finding broadly comports with previous research on tobacco warnings. However, Mutti-Packer et al. (2018) departed from the other studies by finding greater appeal for plain cannabis product packaging *with* text-only cannabis health warnings. To explain this counterintuitive finding, Mutti-Packer et al. (2018) suggested that cannabis health warnings may have provided novel information to participants unaware of harms and, thus, could have been more appealing. More research is needed to assess the impact of branding and cannabis health warnings.

5. Strengths and limitations

Study results should be considered with strengths and limitations. Strengths include using established PRISMA guidelines to search, identify, and screen studies. This process yielded 90 studies, which were reduced to a sample of 17 for analysis. Using a narrative approach allowed for analyzing different methods and theoretical approaches across cannabis health warning studies. The results provide helpful information for future research and ongoing policy discussions. There is limited "real-world" regulatory experience available to evaluate the post-implementation impact of cannabis legalization, and the results of this paper help in those efforts.

Limitations include a relatively small number of studies, likely reflecting the nascent field of cannabis health warning research. The studies reviewed featured various research designs with diverse samples from different geographic locations. Across these locations, cannabis policies shifted over time toward liberalization, and study effects should be considered alongside important contextual factors, including the legal status of jurisdiction. There are differences between the health warnings tested in studies for the design and message content, which reflect different regulations in jurisdictions that have legalized cannabis. The heterogeneity of cannabis health warnings should be considered when interpreting results. The studies identified were from Canada or the US. While our search strategy was comprehensive, relevant studies could have been missed. For instance, the search results included published studies and "grey" literature, such as student theses. However, our search of academic databases may not have identified research reports from governmental agencies that may also provide data on cannabis health warning effects.

6. Conclusions

As cannabis policy becomes liberalized, strategies for informing the public about possible risks becomes increasingly important. Health warnings should meet established criteria for effectiveness, and research on health warning design should ideally proceed implementation on consumer packaging. However, the unique legal status of cannabis has contributed to an environment where cannabis products are sold in markets with limited scientific literature on cannabis health warnings and, indeed, the health effects of cannabis. This review sought to inform ongoing policy discussions about the best ways to warn consumers about possible risks of cannabis harm.

Funding sources

Research reported in this publication was supported by the National Institute on Drug Abuse (K01DA057395). The content is solely the responsibility of the authors and does not necessarily represent the official

views of the National Institutes of Health or National Institute on Drug Abuse. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Ethics approval

This study is a review and does not involve human subjects.

Contributions

ZBM deigned the study, led the acquisition of the data, analyses, interpretation of results and all manuscript writing. DH and BF consulted on the study design and assisted with writing and editing the manuscript. All authors approved of the final manuscript before submission.

CRediT authorship contribution statement

Zachary B. Massey: Conceptualization, Data curation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing. **David Hammond:** Conceptualization, Writing – original draft, Writing – review & editing. **Brett Froeliger:** Writing – original draft, Writing – review & editing.

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 data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2023.102573.

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