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Monograph

Item response theory analysis of benefits and harms of cannabis use in cancer survivors

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Abstract

Medical cannabis with cancer as a qualifying condition has become legalized in more states, but currently there are no standardized measures of perceived benefits and harms of cannabis use in cancer. This study surveyed a population-based sample of cancer survivors (n = 1539) with various types of cancer including breast (25%), prostate (17%), and gastrointestinal (11%) cancers. Item response theory analyses were used to evaluate the items for measuring perceived benefits and harms. Item response theory evaluates survey items by estimating the accuracy (analogous to reliability) and severity reflected by each item. Item response theory analyses showed all the items were accurate (reliable) measures of perceived benefits or harms. The perceived benefits items assessed beliefs well from low to high levels of perceived benefits. The perceived harms items assessed beliefs from moderate to high levels of perceived harms. The items can be used in future studies to standardize measurement while allowing some customization.

Public perceptions of medical and recreational cannabis use have shifted substantially over the past few decades (1,2). Growing patient populations, including cancer patients and survivors, are now using cannabis to manage the effects of their medical conditions or the side effects of medical treatments, for stress relief, for recreation, and for other purposes (3-12). However, cannabis use has been reported to have several potential side effects or harms, including sedation and withdrawal symptoms (13-19). Despite the value of understanding both the perceived benefits and perceived harms of cannabis use as a means of understanding cancer patients' and survivors' health-related decision making and behavior, there is currently no standardized method of assessing these beliefs.

To standardize measurement of perceived benefits and harms of cannabis while still allowing customization in future studies, novel psychometric approaches are needed. Item response theory is a family of statistical techniques for scoring survey and questionnaire data that uses the logistic model (20). Unlike traditional sum scoring, item response theory weights each item by the severity level and accuracy when estimating a score for a belief or symptom such as perceived benefits. This weighting algorithm means different patients can answer different questions but still receive scores on the same metric, as item response theory does not need complete data and estimates the level of belief from the items answered. Future studies could tailor the benefits and harms questions to their needs but use the item response theory scoring algorithm so the scores are comparable to those reported here and to other studies. This also means future studies could limit the number of benefits and harms questions to reduce participant burden while still providing comparable scores.

The current paper reports on the development of item response theory models to evaluate perceived benefits and harms of cannabis use among cancer survivors. Data from a population-based sample in Washington State was used to fulfill 2 aims. First, we tested whether an item response theory model would fit both the perceived benefits and perceived harms questions. This helped inform whether item response theory scoring could be used in future studies. Second, we examined which items could potentially be deleted in future studies because of overlap with other items or lack of fit with the item response theory model. Fulfillment of this second aim would provide a tool and scoring algorithm for future cannabis studies that could be tailored to their aims but still comparable to the present study.

Methods

Participants and procedures

A sample of cancer survivors diagnosed with cancer 6-17 months prior were recruited through the Surveillance, Epidemiology, and End Results registry for the Puget Sound region in Washington State to complete a single survey between June 2022 and November 2022. Eligibility criteria were diagnosis of any type of cancer between April 2020 and December 2021; age 21 to 74 years; able to complete the survey in English; have a valid mailing address; and able to provide informed consent. Eligible people with cancer (n = 10 723) from the registry received a mailed letter explaining the Surveillance, Epidemiology, and End Results registry and a letter inviting them to complete the survey online. Those interested visited the website, read the consent form, and then completed the study if they consented to participate. People who did not respond to the first letter received a single reminder

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letter in the mail. Those who were unable to complete the survey online were able to complete the survey over the phone. The survey asked about cannabis use, perceived benefits and harms of cannabis use, cancer characteristics, and demographics. All study procedures were reviewed by and approved by the institutional review board.

Measures

In 2022, the National Cancer Institute (NCI) funded 12 administrative supplements to comprehensive cancer center support grants to study cannabis use among cancer patients. A common set of core survey items were developed, which included 1 set of items assessing perceived benefits of cannabis use and 1 set assessing perceived harms of cannabis use. Measures were developed by drawing on the previous literature on perceived benefits and harms of cannabis use. An iterative process was used to create the items whereby the 12 cannabis supplement study sites provided feedback and suggestions, and the NCI collated the feedback and drafted and finalized the questions. A lead-in question first asked whether participants perceived any benefits ("Do you think that there are any benefits related to cannabis use?") or harms ("Do you think that there are any risks related to cannabis use?") of cannabis use, respectively. If a participant responded yes to the corresponding lead-in question, the participant was then shown a list of 15 possible benefits or 18 possible harms and asked to mark which ones he or she believed were benefits or harms. The question text for the benefits was, "What do you believe are the benefits of using cannabis, even if you've never used it? Select all that apply." The question text for the harms was, "What do you believe are the risks of using cannabis?" Participants who responded no to the lead-in question were marked as not endorsing any of the benefits or harms, respectively. The exact question text can be accessed online at https:// epi. grants. cancer. gov/ clinical/ nci- cannabis- supplement- core- measures- questionnaire. pdf.

Statistical analyses

The perceived benefits and harms items were analyzed using item response theory (21). Item response theory is a family of statistical techniques based on the logistical model. Item response theory has several uses, including scoring questionnaire and survey data and creating measures that are both tailorable and standardized. Most item response theory models used for health measures estimate 2 sets of parameters. The first parameter is called the slope or accuracy parameter and assesses how well the item reflects the underlying belief, in this case perceived benefits and harms of cannabis use. The second parameter is called the severity or difficulty parameter and reflects the intensity of the belief reflected by the item. For example, believing cannabis can relieve stress likely reflects less perceived benefit than believing cannabis can cure or treat cancer. These sets of parameters can then be used to score survey and questionnaire data. The use of these parameters means each participant or study does not have to use the same sets of items but can still have comparable scores on the same metric.

We used the 2 parameter logistic model from the item response theory family of models to analyze the perceived benefits and harms items (22). The 2-parameter logistic is specifically for data with dichotomous (yes or no) response options and estimates 1 slope parameter and 1 severity parameter per item or per benefit or harm in this study. We examined model fit through the root mean square error of approximation, with values below 0.08 considered a good fitting model (23). Slope parameters between 1 and 4 are generally seen in studies using item response theory (24). We also examined whether each item potentially violated the item response theory assumption of local dependence. Item response theory assumes the scores of items are unrelated except for the effect of the underlying belief or symptom or that the model is unidimensional. We used the χ^2 test with a Bonferroni correction for type I error correction to assess for statistically significant local dependence (25). We also examined the severity parameters. Ideally, severity parameters are spread across the levels of the belief to assess perceived benefits and harms more accurately. Items with similar severity parameters could be deleted because of potential overlap. Item response theory also assesses reliability based on the level of the belief instead of assuming reliability is consistent across the level of the belief. We constructed a standard error curve using the 2-parameter logistic item response theory model to show where error is lowest and the measures of perceived benefits and harms are most accurate. The mean and standard deviation of the item response theory scores were set to zero and 1, respectively. To determine whether the item response theory models might differ by cannabis use, we conducted differential item functioning analyses. Differential item functioning uses the same item response theory models but estimates separate parameters by group. We ran the item response theory analyses stratifying by use of cannabis since cancer diagnosis. See the Supplemental Materials (available online) for more detail on the item response theory analyses.

Results

The sample characteristics are reported in Table 1. Of the 10 723 people approached, 1539 completed the perceived benefits and harms portion of the survey (14% response rate). Slightly more than half (56.8%) of participants were assigned female at birth, and a similar percentage (56.8%) identified as female. Most identified as White (91.7%). The most common cancer types were breast (24.9%), prostate (16.5%), and gastrointestinal (10.5%). Most (71.3%) had surgery for their cancer, and a clinically significant minority of the sample had chemotherapy (37.6%) and radiation (40.2%) for their cancer. The most reported perceived benefit of cannabis use was pain management (78.8%), and the least commonly reported was reducing sweating (4.7%). The most reported perceived harm of cannabis was inability to drive (38.7%), and the least commonly reported was increased use of other medication (3.4%).

Perceived benefits of cannabis use

Item response theory parameters for the perceived benefits analysis are reported in Table 2. The model fit the data well (root mean square error of approximation = 0.06). The slope parameters indicated all the perceived benefits items accurately measured beliefs (>1). As shown in the item map (Figure 1, A), the severity parameters for the perceived benefits items covered a large range of beliefs and ranged from 1 standard deviation below the mean to 2 standard deviations above the mean. For example, pain had a severity parameter of -1.13 indicating it measured perceived benefits at 1.13 standard deviations below the mean of the total scores. Nausea and vomiting had a severity parameter of 0.28 standard deviations above the mean of the total scores and assessed a higher level of perceived benefit than pain. The standard error curve (Figure 2, A) showed error was lowest (and reliability highest) from 1.5 standard deviations below the mean to 3 standard deviations above the mean. The tests of local dependence indicated 4 items might violate

Table 1. Demographics and cancer characteristics

Characteristic	Mean (SD)
Age, years	60.28 (11.42)
Sex at birth	No. (%)
Male	653 (42.4)
Female	874 (56.8)
Unknown	12 (0.8)
Gender	
Male	653 (42.4)
Female	870 (56.8)
Transgender, other, unknown	16 (1.1)
Race and ethnicity	
White	1412 (91.7)
Black, African American	40 (2.6)
Native American	42 (2.7)
Asian	72 (4.7)
Pacific Islander	11 (0.7)
Hispanic	57 (3.7)
Cancer type	
Head and neck	11 (0.7)
Gastrointestinal	161 (10.5)
Lung	86 (5.6)
Melanoma	105 (6.8)
Breast	383 (24.9)
Gynecologic	113 (7.3)
Prostate	254 (16.5)
Other (bone, thyroid, brain, kidney, bladder, other)	426 (27.7)
Cancer treatment	
Surgery	1096 (71.3)
Chemotherapy	579 (37.6)
Radiation	619 (40.2)
Hormonal	375 (24.3)
Immunotherapy	117 (11.5)
Ever used cannabis before diagnosis, even once	1078 (70.0)
Used cannabis after diagnosis (includes cannabidiol only)	626 (40.7)
Perceived benefits	
Pain management	1212 (78.8)
Relief of stress, anxiety, or depression	1129 (73.4)
Relief from neuropathy (numbness or tingling in your hands or feet)	289 (18.8)
Relief from sweating symptoms (eg, hot flashes, night sweats)	73 (4.7)
Improved sleep	804 (52.2)
Improved nausea or vomiting	649 (42.2)
Increased appetite	719 (46.7)
Increased energy or reduced fatigue	153 (9.9)
Increased sexual interest or activity	161 (10.5)
Decreased use of other medications	457 (29.7)
Decreased use of illicit substances other than cannabis	188 (12.2)
Managing side effects from cancer treatment	845 (54.9)
Treatment of or cure for cancer	133 (8.6)
Treatment of another medical condition (ie, seizures, chronic pain)	438 (28.5)
Enjoyment or recreation	745 (48.4)
Perceived harms	
Daytime sleepiness	337 (21.9)
Headache	79 (5.1)
Irritability	100 (6.5)
Impaired memory	520 (33.8)
Difficulty concentrating	582 (37.8)
Dizziness or falls	129 (8.4)
Disruption in sleep	108 (7.0)
Inability to drive	595 (38.7)
Lung damage	582 (37.8)
Addiction to cannabis	468 (30.4)
Increased stress, anxiety, or depression	140 (9.1)
Increased appetite or weight gain	343 (22.3)
Increased use of other prescribed medications	52 (3.4)
Increased use of illicit substances other than cannabis	236 (15.3)
Increased risk of development of other diseases	92 (6.0)
Legal risks	363 (23.6)
Job loss or negative career impact	505 (32.8)
Negative reactions from family members or friends	425 (27.6)

assumptions of the item response theory model: pain, stress, sleep, and recreation. The differential item functioning tests showed 6 items might function differently by use of cannabis: pain, sleep, energy, sexual interest, managing side effects, and recreation. However, tests of the differential item functioning effect size suggested this was negligible (see Supplementary Materials, available online).

Perceived harms of cannabis use

The item response theory parameters for the perceived harms items are reported in Table 2. The item response theory model fit the perceived harms items well (root mean square error of approximation = 0.06). The slope parameters ranged from 1.27 to 2.55, indicating all items accurately measured beliefs. The severity parameters ranged from half a standard deviation above the mean to slightly more than 2 standard deviations above the mean (Figure 1, A; Table 2). The standard error curve (Figure 2, B) showed the perceived harms items measured beliefs most reliably from the mean to just below 3 standard deviations above the mean. Of the 18 items, 5 were flagged as possibly having local dependence: difficulty concentrating, inability to drive, lung damage, negative career impacts, and negative reactions from others. Three items had statistically significant differential item functioning, but the effect size was negligible (Table 2, Supplementary Materials, available online): addiction, increased appetite, and increased use of other illicit drugs.

Discussion

The use of item response theory for scoring measures of perceived benefits and harms of cannabis in cancer could have potential use in future studies. The items tested here can be adapted and used in future studies with the item response theory scoring, allowing comparison to this study and to other studies using the same items. All the benefits and harms items measured the associated beliefs well, as shown by the accuracy parameters, and measured a range of beliefs, as shown by the severity parameters. However, the perceived benefits items measured a wider range of beliefs than perceived harms. The item maps and standard error curves suggest that the perceived benefit items measure a wide enough range of beliefs for use in most studies, whereas the perceived harms items are best used in studies of those who on average perceive at least some level of harm from cannabis use such as general population studies or people who have not used cannabis. Although all items can be used in future studies, our analyses suggest certain items could be deleted from future studies to reduce burden. Three perceived benefit items—sleep, energy, and recreation—could be deleted. Sleep and recreation both had statistically significant local dependence statistics and differential item functioning by cannabis use and had severity parameters similar to other perceived benefits. Energy had a severity parameter similar to several other items. Although pain and stress had significant local dependence statistics, both were the only items assessing lower levels of benefits and are commonly reported potential cannabis benefits and ultimately

Table 2. Item response theory parameters

Item	Accuracy (slope)	Severity (difficulty)	Statistically significant local dependence[a]	Statistically significant differential item functioning by use since cancer diagnosis[a]
Benefits				
Pain	1.69	−1.13	**0.0001**	**0.0001**
Stress	2.20	−0.77	**0.0001**	0.4138
Neuropathy	1.46	1.36	0.2825	0.0698
Sweating	2.29	2.11	0.1438	0.4285
Sleep[b]	1.72	−0.07	**0.0007**	**0.0001**
Nausea, vomiting	1.72	0.28	0.8326	0.0104
Appetite	1.79	0.12	0.0396	0.2245
Energy[b]	1.69	1.83	0.0138	**0.0022**
Sexual interest	1.48	1.93	0.5231	**0.0020**
Decrease other medications	1.94	0.71	0.7191	0.5459
Decrease other illicit substances	2.17	1.47	0.4061	0.7737
Manage side effects	2.08	−0.14	0.1399	**0.0001**
Treat or cure cancer	1.61	2.00	0.7160	0.1780
Treat other condition	1.58	0.83	0.5519	0.0281
Recreation[b]	1.29	0.07	**0.0002**	**0.0001**
Harms				
Sleepiness	1.80	1.07	0.0075	0.0943
Headache	1.94	2.18	0.0224	0.0037
Irritability	2.43	1.83	0.0997	0.9318
Impaired memory	2.28	0.55	0.0056	0.4114
Difficulty concentrating	2.47	0.41	**0.0001**	0.7398
Dizziness[b]	2.17	1.74	0.1243	0.2646
Sleep disruption	2.15	1.87	0.3094	0.0433
Inability to drive[b]	1.89	0.41	**0.0001**	0.9123
Lung damage	1.27	0.53	**0.0001**	0.7231
Addiction	1.52	0.78	0.0041	**0.0007**
Increased stress	2.33	1.64	0.7594	0.3926
Increased appetite	1.66	1.10	0.0259	**0.0002**
Increased use of other medications	2.55	2.18	0.5576	0.0739
Increased use of other illicit drugs	1.44	1.58	0.6384	**0.0001**
Developing other diseases	1.94	2.08	0.5029	0.6145
Legal	1.74	1.01	0.0036	0.7820
Negative career impacts[b]	2.13	0.59	**0.0001**	0.9093
Negative reactions from others	2.10	0.78	**0.0018**	0.7666

[a] Bold indicates statistical significance after Bonferroni correction (alpha benefits = 0.0033, alpha for harms = 0.0028).
[b] Recommended for deletion.

were retained. For harms, dizziness, inability to drive, and negative career impacts could be removed. Although 2 items (inability to drive, negative career impacts) had statistically significant local dependence statistics and all 3 had severity parameters overlapping with other items, most of the items could be because of other harms from cannabis (ie, negative career impacts because of cognitive effects). Future studies could also use the severity parameters to build brief measures that cover the entire breadth of beliefs. If the study goal is to estimate the overall perception of how harmful or beneficial cannabis is, with less concern for evaluating specific harms and benefits, these items could be deleted. However, if the study focuses on characterizing the level of reporting of individual items such as sleep, all items could be retained given the evidence for their reliability in the item response theory analysis. Overall, the perceived benefits and harms items were sound measures and can be used in future studies.

The study findings also have several implications for future studies on perceived benefits and harms of cannabis use. Item response theory seems to be a feasible and useful method for scoring perceived benefits and harms of cannabis use on surveys of cancer patients. These modern psychometric methods could be used in subsequent studies to provide comparable yet tailored measures of perceived benefits and harms. Although future studies would have flexibility in which benefits and harms are included, our results suggest pain and stress relief should always be included as potential benefits because they measure lower levels of perceived benefits and did not have other benefits with similar severity parameters. The perceived benefits and perceived harms measures can also be used to study decision making among cancer patients for using cannabis and how different information interventions affect perceptions of benefits and harms. The measures can be used in public opinion surveys to assess overall perceived benefits and harms as well as individual items. The items could be varied over time as needed, but the overall scores could still be compared. The measures have broad potential applications in medical, public health, and social science research.

The item response theory severity parameters suggest several priorities for future studies testing the benefits and harms of cannabis use in cancer. Pain and stress relief were 2 of the most reported perceived benefits and had low severity parameters, suggesting even people with low perceptions of benefits could see cannabis helping with pain and stress management. Additional studies addressing whether and how cannabis reduces pain and stress could help address these beliefs. Cognitive impairments (difficulty concentrating, impaired memory) were commonly reported perceived harms of cannabis use and had low severity parameters. Similar to perceived benefits, additional research on the extent of these effects from cannabis use could answer important concerns of cancer patients. The results of the item response theory analysis suggest both directions for future cannabis research and ways to improve measurement of perceived benefits and harms of cannabis.

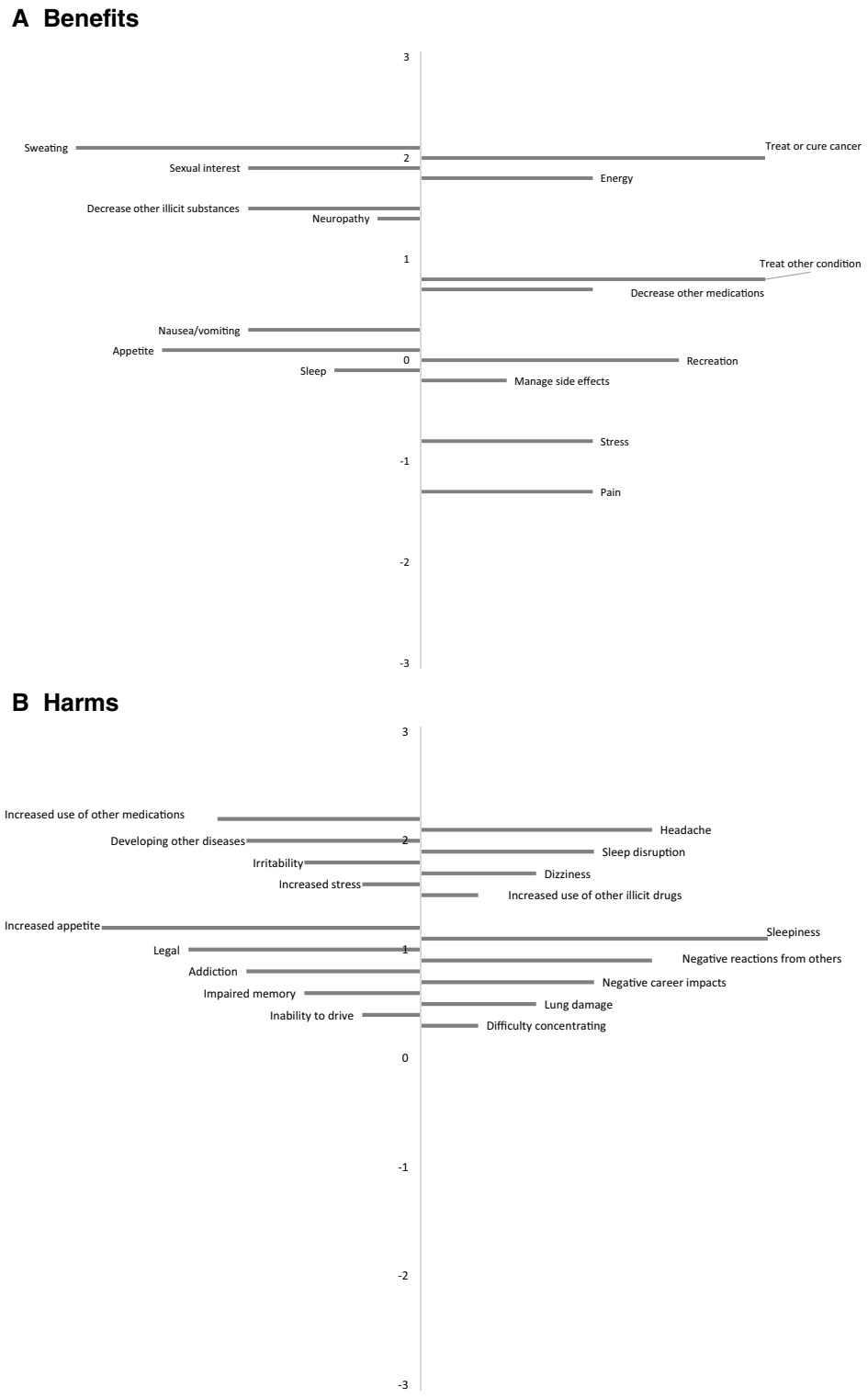

Figure 1. Item maps. Each y-axis represents the severity parameters for each item and uses a standard normal measurement scale (mean of zero, standard deviation of 1).

The limitations of this study should be acknowledged. The sample was from a single region of the United States, and the region had legalized cannabis use for several decades. The other 11 supplement sites used clinic- or health-care system–based samples unlike our population-based sample, and nearly all were in states that also had legalized cannabis. Combining samples may have diversified geographic representation, however, it would still not have created a nationally representative sample. Comparison of scores using the item response theory model should take the characteristics of this location into account as the item response theory scores here are likely to be more positive than those in regions that do not have legalized cannabis use. The wording of the perceived benefits and harms questions differed from past studies, meaning these item response theory parameters likely cannot be used to combine data from prior studies. However, data from future studies that use a similar question format could still harmonize the scores with data from the NCI

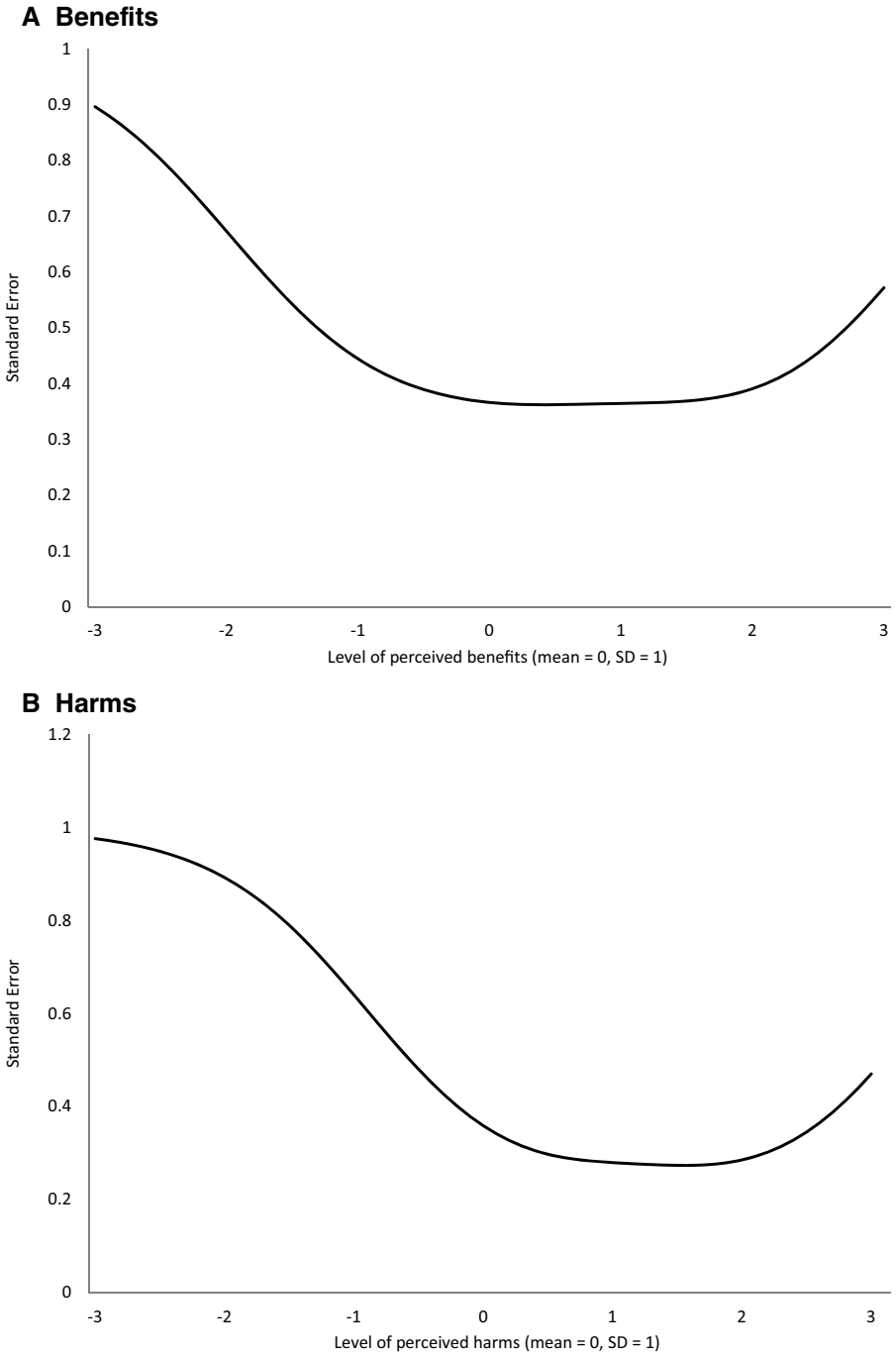

Figure 2. Standard error curves.

supplement studies. Our response rate was also somewhat low (14%), and this might have been because of noncannabis users assuming the survey was not meant for them. Replication in population-based surveys that are anonymous and with higher response rates is warranted. Although a fairly extensive list of benefits and harms were used, this study did not assess all possible perceived benefits and harms. The limitations are balanced by the strengths, including a population-based sample and a comprehensive list of perceived benefits and harms.

This study suggests the feasibility and potential utility of using item response theory to score measures of perceived benefits and harms of cannabis use in cancer. Future studies can either use the same measures with item response theory scoring or select the items most relevant to their aims and use the item response theory scoring to compare level of perceived benefits and harms with this sample. Additional research is needed on whether certain perceived benefits and harms (pain relief, stress reduction, cognitive problems) are caused by cannabis use. Cancer patients have interest in and concerns about cannabis use, and more studies are needed to ensure patients have quality information to make decisions about their care.

Data availability

Individual data underlying this article cannot be publicly shared due to the sensitive nature of the data and to protect the privacy of the individuals who participated. De-identified data from this

study is kept at Fred Hutchinson Cancer Center. Contact the corresponding author Salene Jones (smjones3@fredhutch.org, 1100 Fairview Ave N, Seattle, WA USA 98109) for access.

Author contributions

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Conflicts of interest

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