



Are beliefs about the importance of genetics for cancer prevention and early detection associated with high risk cancer genetic testing in the U. S. Population?

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ABSTRACT

Public attitudes towards germline genetic testing for inherited cancers have been found to be generally positive. Past research demonstrated that diverse causal beliefs and contextual factors are associated with uptake of genetic testing. However, it is unclear how beliefs about genetically informed cancer prevention and early detection ultimately shape testing behaviors. We used data from the National Health Information National Trends Survey (HINTS 5 Cycle 4) to evaluate these beliefs and the relationship between beliefs related to cancer genetics and participation in cancer genetic testing. Overall, 5.24% of the total weighted sample underwent cancer genetic testing, of whom 70.5% (n = 141) had no personal history of cancer, whereas others had a personal diagnosis of breast, ovarian, or colorectal cancer (23.0%), or other cancers (6.5%). In adjusted multivariable analysis, testing was positively associated with personal history of breast, ovarian, or colorectal cancer (OR = 28.37, 95% CI: 10.19–79.04), female sex (OR = 2.97, 95% CI: 1.41–6.26), having high cancer worry (OR = 4.78, 95%: 2.19–10.45), and negatively associated with being Hispanic (OR = 0.37, 95%: 0.16–0.86) or non-Hispanic Asian (OR = 0.12, 95% CI: 0.04–0.33). Belief in the importance of genetics for early detection of cancer was associated with testing (OR = 18.03, 95% CI: 4.07–79.79), whereas belief in the importance of genetics for cancer prevention was not. The association between testing and belief about the importance of genetics for early detection of cancer, but not cancer prevention, is a surprising finding that warrants further research. Better understanding of these beliefs and their potential impact on test uptake may inform population genetic testing efforts.

1. Introduction

Advances in cancer genetics have opened the door to new possibilities for cancer prevention and early detection. Identifying carriers of pathogenic variants through genetic testing can inform preventive strategies such as prophylactic surgery and intensified screening for many hereditary cancers. Despite widespread availability and great progress in the clinical application of germline genetic testing for cancer susceptibility, their delivery and use for cancer prevention remain underutilized (Turnbull et al., 2018). This may, in part, be due to insufficient population awareness of the fact that germline genetic test

results can inform cancer prevention and early detection of cancer.

Beliefs about disease causation contribute to engagement in relevant health behaviors (Leventhal et al., 2016) including undergoing cancer genetic testing (Allen et al., 2019). At the same time, beliefs about using genetics to inform cancer prevention and early detection oppose commonly held beliefs of genetic fatalism, which is the belief that we cannot avoid specific genetically predetermined outcomes, no matter what we do or what happens to us (Resnik and Vorhaus, 2006). This belief adversely affects motivation to engage in risk-reducing behavior (Alper and Beckwith, 1993) and is a likely barrier to genetically-informed cancer prevention. Prior research has identified personal

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perceptions that genetic risk is less controllable (Senior et al., 1999; Haukkala et al., 2015) and less preventable (Senior et al., 2000) than other risk factors. Population awareness of the availability of genetic testing for cancer susceptibility is generally low (Mai et al., 2014) and its impact on test utilization is not well understood. In particular, awareness of the importance of genetics for two related yet distinct concepts - cancer prevention (through chemoprevention and prophylactic surgery) and early detection (through intensive screening) - may also influence genetic test uptake, yet remains unknown. Understanding the degree to which perceptions about genetic susceptibility to cancer align with uptake of cancer genetic testing is an important research question with practical implications, particularly for population genetic screening and cancer prevention.

Public attitudes towards germline genetic testing have been generally positive and research demonstrates that diverse causal beliefs and contextual factors are associated with test uptake (Hann et al., 2017). However, it is unclear how beliefs about genetically informed cancer prevention and early detection ultimately shape behaviors and whether cancer genetics-related beliefs are associated with undergoing cancer genetic testing. Cognitive and affective factors that likely motivate interest in testing include test awareness, perceived likelihood of developing cancer, cancer fatalistic belief, and self-efficacy (Wade et al., 2012; Sherman et al., 2014). Emotions such as worry, anxiety, and fear of cancer and genetic testing act as deterrents to genetic testing (Hann et al., 2017). However, beliefs evolve over time as awareness and understanding grows, possibly due to new public and private efforts to increase awareness (Genetic and Diagnostics, 2021; Institute, 2021). High-risk populations such as those with a cancer family history or clinical indications of cancer susceptibility, frequently express interest and positive attitudes towards genetic testing (Alvord et al., 2020). There is a lack of similar awareness in the general population (McKinney et al., 2020) due to skepticism for genetic testing based on a perceived lower need to learn about genetic risk for cancer, and uncertainty of the need for genetic testing.

Unlike diagnostic testing where cancer diagnosis, signs, or symptoms precedes genetic testing, genetically targeted primary prevention of cancer requires testing before cancer diagnosis (Murray et al., 2021). DNA based population screening to guide preventive care has long been discussed, is increasingly being considered in oncology, and has even seen some recent application in limited settings (Grzymalski et al., 2020; Buchanan et al., 2020). In fact, given the clinical and economic effectiveness of testing for certain breast cancer variants, population risk profiling is arguably overdue in certain subpopulations. Thus, understanding factors associated with test uptake is critical for the anticipated DNA-based screening programs' success and contribution to cancer prevention.

Little is known about public beliefs regarding the importance of genetics for cancer prevention and early detection. In the present study, we evaluate these beliefs and explore the relationship between beliefs related to cancer genetics and participation in high-risk cancer genetic testing. We hypothesized that public awareness of the importance of genetics for cancer prevention and early detection will be low but positively associated with cancer genetic testing.

2. Materials and methods

2.1. Participants

Participants were respondents to the National Cancer Institute National Health Information National Trends Survey (HINTS 5 Cycle 4, fielded from February to June 2020, response rate 36.7%). HINTS is a mailed, nationally representative, cross sectional survey of the adult (age 18 or older) civilian non-institutionalized population of the United States. Its content centers on health-related knowledge, perceptions, and behaviors among members of the public; information accessibility, needs, and use of health-related information is also included. A detailed

overview of the history and methodology used for HINTS data collection is available elsewhere (Finney Rutten et al., 2020; Finney Rutten et al., 2012). Sampling involved a two-stage design that drew a stratified sample of addresses, followed by the selection of one adult from each sampled household. Genetic testing was one of the topics of interest in this cycle of HINTS. Detailed methodological information is provided online (Survey, 2020). This study utilized data from a publicly available anonymized database and was thus exempt from ethical compliance and oversight from an institutional review board.

2.2. Measures

2.2.1. Cancer genetic testing

We created a single yes/no variable indicating participants' cancer genetic testing status from the item, "Have you ever had any of the following types of genetic tests?" with yes indicating those who chose 'High-risk cancer testing (for example, BRCA1/2 or Lynch Syndrome)' and no indicating those who chose 'None of the above'. In order to focus on clinical cancer genetic testing, we excluded participants from our analysis who only selected ancestry testing to determine the background or geographic/ethnic origin of an individual's ancestors, e.g., through Ancestry.com or 23 and Me (n = 368) or only selected genetic health risk testing to determine health risk for a variety of health conditions, e.g., through 23andMe (n = 72). Ancestry testing and direct-to-consumer health risk testing are inherently different from clinical cancer genetic testing used for medical decision making.

2.2.2. Risk perceptions

Perceived genetic susceptibility to cancer was measured using one item that asked, "How much do you think genes that are inherited determine whether or not a person will develop [cancer]?" The role of genetics for cancer prevention and early detection were measured using two items, "How important is knowing a person's genetic information for: a) preventing cancer; and, b) detecting cancer early" For all risk perception questions, response options ranged from (Turnbull et al., 2018). A lot to (Resnik and Vorhaus, 2006) Not at all. Responses were dichotomized as Not at all/A little, and Very/Somewhat for analysis.

2.2.3. Cancer beliefs

Cancer worry was measured using the item, "How worried are you about getting cancer?" Response options ranged from (Turnbull et al., 2018). Not at all to (Alper and Beckwith, 1993) Extremely, and were trichotomized as: high cancer worry (extremely/moderately); moderate cancer worry (somewhat); and, low cancer worry (not at all/slightly). Additional potentially relevant beliefs were assessed using participants' agreement with two items, "There's not much you can do to lower your chances of getting cancer", "There are so many different recommendations about preventing cancer, it's hard to know which ones to follow", on a scale of (Turnbull et al., 2018) strongly agree to (Resnik and Vorhaus, 2006) strongly disagree. Cancer fatalism was assessed using the item, "It seems like everything causes cancer," with response options ranging from (Turnbull et al., 2018) strongly agree to (Resnik and Vorhaus, 2006) strongly disagree. Responses to the last three items were dichotomized (strongly agree/somewhat agree vs. somewhat disagree/strongly disagree) for analysis.

2.2.4. Self-efficacy

Self-efficacy regarding the ability to engage in behavior change based on cancer genetic information was assessed using the item "If I found out from a genetic test that I was at high risk of cancer, I would change my behaviors such as diet, exercise and getting routine medical tests," with response options of (Turnbull et al., 2018) strongly agree to (Resnik and Vorhaus, 2006) strongly disagree. Desire to know about mutation status was measured using one item, "How much would you want to know if you have a genetic change that increases your chances of getting cancer?" with response options of (Resnik and Vorhaus, 2006)

Not at all to (Turnbull et al., 2018) A lot that. Both responses were dichotomized for analysis.

2.2.5. Covariates

Based on prior research examining predictors of cancer genetic test uptake, age, sex, education, race/ethnicity, income, personal history of cancer, and family history of cancer were included in the analysis as covariates.

2.3. Statistical analysis

We incorporated survey sampling weights specified for HINTS 5 cycle 4 into our analyses to account for the complex sampling framework used in the HINTS survey and to provide nationally representative estimates of the US population. The computation of full-sample weights included calculating the household-level base weights for each household in the sample; adjustments for non-response; initial person-level weight for adult in responding household; and finally, calibration of survey weights to the American Community Survey 2018. Additional details about specific weighting methodology can be found in the Methodology Report (Survey, 2020). Weighted prevalence of cancer genetic testing was calculated for the overall study sample as well as after stratifying the study population by risk perceptions, cancer related beliefs, and socio-demographic factors. We used weighted multivariable survey logistic regression to identify factors associated with genetic testing. All pre-selected covariates were included in the multivariable model. Statistical significance was determined using a two-sided P value ≤ 0.05. Statistical analyses were conducted using survey analysis procedures SAS/STAT (Version 9.4).

3. Results

Weighted percentages of sociodemographic characteristics stratified by high-risk cancer genetic test status are shown in Table 1. Of the 3,865 total survey respondents, 2,265, representing 158,364,845 of the U.S. population were included in the analyses. According to weighted analysis, the participants were 50.8% female, predominantly non-Hispanic (NH) White (64.9%), well-educated with 73.7% having some college education or higher, and of high socioeconomic status with 45.7% having an annual income of \$75,000 or more. Nearly equal proportions were within the age categories of 18 to <35 years (28.3%), 35 to <50 years (27.7%), and 50 to <65 years (28.5%). Overall, 5.24% (n = 142, weighted n = 8,368,022) of the total sample underwent cancer genetic testing. Of those who underwent high-risk cancer genetic testing, 70.5% had no personal history of cancer, whereas others had a personal diagnosis of breast, ovarian, or colorectal cancer (23.0%), or other cancers (6.5%); 93% believed that genetics was a lot or somewhat important for cancer prevention, and 98.3% believed genetics was a lot or somewhat important for early detection of cancer. (Table 1).

Table 2 summarizes the univariate and multivariate analyses of factors associated with undergoing high-risk genetic testing. In multivariable regression, participants who reported moderate (OR = 2.37, 95%: 1.12–5.01) and high cancer worry (OR = 4.78, 95%: 2.19–10.45) were more likely to undergo testing compared to those with lower cancer worry. Belief in the importance of genetics for early detection of cancer was also significantly associated with testing (OR = 18.03, 95% CI: 4.07–79.79) whereas belief in the importance of genetics for cancer prevention was not significantly associated with testing. Undergoing cancer genetic testing was not significantly associated with comparative risk perceptions, the belief that “everything causes cancer” or that there are “too many recommendations” about cancer prevention strategies, desire to know about mutation status, or self-efficacy regarding behavior change based on a cancer genetic test result (all P-values > 0.05). Of the sociodemographic and clinical covariates, females were more likely to report having undergone cancer genetic tests (OR = 2.97, 95% CI: 1.41–6.26), whereas Hispanics and NH Asians were less likely to have

Table 1
Descriptive statistics (N = 2,265) of survey respondents stratified by high-risk cancer genetic testing status.

Variable	Categories	Underwent high-risk cancer genetic testing		No genetic testing	
		N	Wtd %	N	Wtd %
Sex	Male	30	20.0	880	50.9
	Female	111	80.0	1208	49.1
Age Group	18 to less than 35	10	8.9	317	29.4
	35 to less than 50	32	34.3	426	27.4
	50 to less than 65	54	41.8	663	27.8
	65 to less than 75	30	10.8	448	10.6
	75 or older	11	4.2	191	4.9
Race/Ethnicity	NH White	91	79.4	1263	64.1
	NH Black	12	9.2	277	11.9
	Hispanic	17	7.8	288	16.4
	NH Asian	2	0.7	79	4.5
	NH Others	7	2.9	70	3.0
Education	Less than high school	12	7.1	98	5.4
	12 years or completed high school	20	21.0	344	20.7
	Some college	42	43.3	640	42.3
	College graduate or higher	64	28.6	989	31.5
Income	Less than 20,000	20	13.5	302	13.5
	20,000 to less than 35,000	11	3.3	246	10.1
	35,000 to less than 50,000	16	10.0	248	11.6
	50,000 to less than 75,000	24	26.5	352	19.2
	75,000 or more	60	46.7	791	45.7
Cancer Worry ¹	Not at all or Slightly	29	14.6	940	41.7
	Somewhat	40	29.2	581	30.8
	Extremely or Moderately	70	56.2	578	27.5
Perceived Genetic Susceptibility ²	A lot or Somewhat	128	95.3	1737	84.2
	A little or Not at all	10	4.7	334	15.8
Importance of Genetics for cancer prevention ³	Very or Somewhat	126	93.0	1646	82.3
	A little or Not at all	13	7.0	425	17.7
Importance of genetics for early detection of cancer ³	Very or Somewhat	136	98.3	1772	87.6
	A little or Not at all	4	1.7	301	12.4
Fatalistic belief ⁴	Strongly/ Somewhat agree	97	68.3	1433	72.2
	Strongly/ Somewhat disagree	42	31.7	654	27.8
Prevention not possible ⁵	Strongly/ Somewhat agree	31	22.6	562	30.0
	Strongly/ Somewhat disagree	108	77.4	1529	70.0
Too many recommendations ⁶	Strongly/ Somewhat agree	94	74.7	1526	75.1
	Strongly/ Somewhat disagree	44	25.3	562	24.9
Self-efficacy ⁷	Strongly/ Somewhat agree	124	86.7	1861	90.4
	Strongly/ Somewhat disagree	15	13.3	224	9.6
Desire to know about mutation status ⁸	A lot or Somewhat	127	89.6	1621	78.5

(continued on next page)

Table 1 (continued)

Variable	Categories	Underwent high-risk cancer genetic testing		No genetic testing	
		N	Wtd %	N	Wtd %
Personal history of cancer	A little or Not at all	13	10.4	460	21.5
	No cancer history	91	70.5	1806	92.9
	Breast/ovarian/rectal/colon cancer	32	23.0	30	0.6
Family history of cancer	Other cancers	18	6.5	258	6.6
	Yes	122	89.9	1539	71.3
	No/Not sure	16	10.1	532	28.7

NH: Non-Hispanic; ¹How worried are you about getting cancer?; ²How much do you think genes that are inherited determine whether or not a person will develop [cancer]?; ³How important is knowing a person's genetic information for: a) preventing cancer; and, b) detecting cancer early; ⁴It seems like everything causes cancer; ⁵There's not much you can do to lower your chances of getting cancer; ⁶There are so many different recommendations about preventing cancer, it's hard to know which ones to follow; ⁷If I found out from a genetic test that I was at high risk of cancer, I would change my behaviors such as diet, exercise and getting routine medical tests; ⁸How much would you want to know if you have a genetic change that increases your chances of getting cancer?

undergone tests compared to NH Whites (OR = 0.37, 95% CI: 0.16–0.86 and OR = 0.12, 95% CI: 0.04–0.33 respectively). Compared to those without personal history of cancer, having a personal history of breast, ovarian, or colorectal cancer was associated with higher odds of undergoing testing (OR = 28.38, 95% CI: 10.19–79.04). Neither family history of cancer, age, education, nor income was associated with cancer genetic testing.

Separate multivariable logistic regressions for individuals with and without personal history of cancer (Supplementary Table S1) shows that beliefs about the importance of genetics for early detection of cancer, cancer worry, older age, and female sex was positively associated with genetic testing among those without personal history of cancer. Among those with personal history of any cancer, significant predictors of testing include female sex, older age, and education.

4. Discussion

Our findings show that beliefs about the importance of genetics for both cancer prevention and for early detection of cancer was high in the U.S. population, however only the latter belief was associated with having had cancer genetic testing. Of the small proportion of survey respondents who underwent cancer genetic testing, the majority had a family history, but not a personal diagnosis of cancer. This suggests that the opportunity to learn results from testing that may inform cancer prevention and early detection potentially motivated testing decisions. Adjusting for a number of relevant covariates, results from the present study confirm previous reports of cancer genetic testing being associated with female sex, higher cancer worry, and personal history of cancer; and adds empirical data on underutilization of testing among Hispanic and non-Hispanic Asian individuals. These findings confirm most previous studies where psychosocial and demographic characteristics (e.g., knowledge of cancer genetics, risk perceptions, fatalistic beliefs) were important for engagement with testing (Agurs-Collins et al., 2015; Wade et al., 2012; Sherman et al., 2014), though it contradicts one where attitudinal and psychosocial variables (e.g., risk perceptions, cancer beliefs) were not associated with uptake of tests for *BRCA1/2* or Lynch Syndrome (Roberts et al., 2019). It is important to note that survey items on belief in importance of genetics for cancer prevention and early detection included in our analyses were unavailable in previous

population based surveys. These findings also offer new insights regarding the relationship between cancer genetic testing and beliefs about cancer prevention and early detection in the U.S. population, given the nationally representative sample for the HINTS survey.

It is unclear why belief about the importance of genetics for early detection of cancer, but not cancer prevention, was associated with cancer genetic testing. Genetic fatalism may partly explain why belief about the importance of genetics for cancer prevention was not associated with genetic testing, but whether and how respondents distinguish between cancer prevention and early detection remains inconclusive. There are few genetically-informed strategies that can prevent cancer with a complete degree of certainty – in vitro fertilization coupled with prenatal genetic diagnosis is perhaps one such strategy. Other strategies reduce cancer risk to varying degrees. For example, there remains a 1–2% residual level of cancer risk from any inadvertently missed breast tissue following risk-reducing mastectomy for *BRCA1* mutation carriers (Domchek et al., 2010). It is possible that the general public may understand that ‘cancer prevention’ generally comprises approaches to reduce cancer risk rather than completely eliminating risk of cancer occurrence. The public's views and opinions may be shaped by how information about cancer prevention and early detection is presented in various information sources, including the mainstream media, Web and social media (Johnson et al., 2021). Trustworthy sources such as Centers for Disease Control and Prevention and National Cancer Institute do not appear to distinguish between the meaning of the terms ‘cancer prevention’ and ‘early detection’ in their public-facing information on cancer genetic testing; and there is limited data on laypersons' use of these information sources. The heuristics people use to think about the role of genetics in cancer prevention and early detection need to be better explored using qualitative methodology.

Another possible explanation is that clinicians and genetic counselors preferentially use one term over another, and thus survey respondents favorably endorse early detection over prevention. There is generally low population awareness of cancer susceptibility genetic testing (Krakow et al., 2017), which suggests that most people don't have *a priori* exposure to these concepts. However, genetic counselors likely use these terms interchangeably to facilitate communication, and in fact may even favor the more technically accurate term of risk-reduction over prevention or early detection (personal communication). The seeming disconnect between attitude and behavior in cancer genetic testing and cancer prevention beliefs aligns with results from a prior population survey from our group. Specifically, respondents who believed that inherited predispositions cause cancer were less likely to discuss genetic testing with a healthcare provider compared to those who did not believe that inherited cancer predispositions cause cancer (Makhnoon et al., 2021). This may indicate an interaction between fatalism and limited knowledge of the potential preventive benefits of genetic testing, however additional research to better understand the general public's beliefs about the role of genetics in cancer prevention is warranted.

The rate of high-risk cancer genetic testing from data collected in 2020 and reported here (5.24%) is greater than a previous report from 2015 (1.64%), which included all types of genetic tests in addition to tests for high-risk cancer susceptibility (Allen et al., 2019). This increase is likely a combined product of increased awareness of genetic testing among laypersons, patients, and healthcare providers; more inclusive genetic testing guidelines, and improved access to genetic testing services. Particularly encouraging is the cancer genetic testing among unaffected individuals with family history of cancer, which is critical for cancer prevention. The higher odds of testing among breast/ovarian/colorectal cancer patients suggests that most individuals are undergoing guideline concordant testing. Notably, family history of cancer was not associated with testing – even though significant family history of cancer is a key indication for testing – and may be explained by the way family history was measured within HINTS. The survey measured family history of any cancer, regardless of age of onset, cancer type, or degree of

Table 2
Factors associated with high risk cancer genetic testing (N = 2265, representing 158,364,845 in weighted).

Variable	Categories	Unadjusted model			Adjusted model		
		OR	95% CI	P	OR	95% CI	P
Cancer worry ¹	Not at all or Slightly	ref					
	Somewhat	2.72	1.47–5.01	0.002	2.37	1.12–5.01	0.025
Perceived genetic susceptibility ²	Extremely or Moderately	5.84	2.87–11.86	less than0.001	4.78	2.19–10.43	less than0.001
	A little or Not at all	ref					
Importance of genetics for cancer prevention ³	A lot or Somewhat	3.81	0.86–16.80	0.076	2.38	0.55–10.24	0.239
	A little or Not at all	ref					
Importance of genetics for early detection of cancer ³	Very or Somewhat	2.86	0.82–9.98	0.097	0.78	0.19–3.29	0.735
	A little or Not at all	ref					
Fatalistic belief ⁴	Very or Somewhat	8.26	1.65–41.25	0.011	18.03	4.07–79.79	less than0.001
	Strongly/Somewhat disagree	ref					
Prevention not possible ⁵	Strongly/Somewhat agree	0.83	0.43–1.59	0.572	0.82	0.41–1.63	0.564
	Strongly/Somewhat disagree	ref					
Too many recommendations ⁶	Strongly/Somewhat agree	0.68	0.35–1.35	0.265	0.68	0.27–1.72	0.403
	Strongly/Somewhat disagree	ref					
Self-efficacy ⁷	Strongly/Somewhat agree	0.98	0.52–1.86	0.943	0.82	0.36–1.89	0.639
	Strongly/Somewhat disagree	ref					
Desire to know about mutation status ⁸	Strongly/Somewhat agree	0.69	0.29–1.67	0.405	0.45	0.17–1.18	0.102
	A little or Not at all	ref					
Personal history of cancer	A lot or Somewhat	2.36	0.89–6.30	0.084	1.85	0.77–4.43	0.165
	No	ref					
Family history of cancer	Breast/ovarian/Colorectal cancer	52.20	24.16–112.80	less than0.001	28.38	10.19–79.04	less than0.001
	Other cancer	1.30	0.63–2.68	0.469	0.69	0.31–1.52	0.346
Age	No/Not sure	ref					
	Yes	3.59	1.46–8.81	0.006	2.43	0.77–7.64	0.127
Sex	Age	1.02	1.01–1.03	0.002	1.02	1.00–1.03	0.085
	Male	ref					
Race/Ethnicity	Female	4.14	2.23–7.70	less than0.001	2.97	1.41–6.26	0.005
	NH White	ref					
Education	NH Black	0.63	0.25–1.54	0.302	0.75	0.19–3.02	0.679
	Hispanic	0.39	0.18–0.82	0.014	0.37	0.16–0.86	0.022
Income	NH Asian	0.12	0.01–2.43	0.162	0.12	0.04–0.33	less than0.001
	NH Other	0.79	0.22–2.81	0.705	1.30	0.21–8.17	0.775
Education	Less than high school	ref					
	12 years or completed high school	0.78	0.22–2.76	0.688	0.38	0.08–1.80	0.218
Income	Some college	0.78	0.25–2.49	0.674	0.33	0.08–1.42	0.133
	College graduate or higher	0.70	0.28–1.76	0.436	0.33	0.09–1.23	0.098
Income	Less than 20,000	ref					
	20,000 to less than 35,000	0.33	0.11–0.98	0.046	0.31	0.07–1.37	0.120
Income	35,000 to less than 50,000	0.86	0.26–2.83	0.799	0.83	0.18–3.82	0.809
	50,000 to less than 75,000	1.38	0.51–3.73	0.524	1.76	0.60–5.21	0.300
Income	75,000 or more	1.02	0.46–2.24	0.962	1.27	0.41–3.88	0.673

OR: Odds ratio; NH: Non-Hispanic; ¹How worried are you about getting cancer?; ²How much do you think genes that are inherited determine whether or not a person will develop [cancer]?; ³How important is knowing a person's genetic information for: a) preventing cancer; and, b) detecting cancer early; ⁴It seems like everything causes cancer; ⁵There's not much you can do to lower your chances of getting cancer; ⁶There are so many different recommendations about preventing cancer, it's hard to know which ones to follow; ⁷If I found out from a genetic test that I was at high risk of cancer, I would change my behaviors such as diet, exercise and getting routine medical tests; ⁸How much would you want to know if you have a genetic change that increases your chances of getting cancer?

relatedness, thus not everyone with family history had a significant family history of cancer. The increased odds of testing among females found in this study confirms previous reports (Roberts et al., 2019) and is unsurprising as a large proportion of all cancer genetic testing occurs within breast and ovarian cancers, which are more common among females. In addition, the well-established gender differences in perceptions of cancer – particularly the fact that men are more likely to identify behavioral factors as important in cancer whereas women are more likely to rate heredity as important (Murray and McMillan, 1993), may also partly explain the higher odds of cancer genetic testing among females.

It is important to note that the population prevalence of cancer genetic testing and related health beliefs reported in this study do not support or oppose ongoing population genetic screening efforts, but rather may be useful in shaping health messaging for these efforts. If associations between belief and testing from this cross-sectional study are confirmed and found to be predictive in future longitudinal studies, the results could inform health messaging for population screening. In particular, motivations for undergoing genetic testing between those

with and without personal history of cancer may be different (as shown in Supplementary Table S1) suggesting the need to target different mechanisms to improve test uptake in these populations. Comprehensive genetic counseling will still be necessary to communicate the clinical implications and limitations of clinical cancer genetic testing.

Hispanic and NH Asian participants were less likely to undergo high-risk cancer genetic testing than NH White participants in this study which aligns well with existing literature on racial/ethnic disparity in use of genetic testing for hereditary cancers (Childers et al., 2018; Hall et al., 2009; Manriquez et al., 2017). This disparity in testing persisted even after adjustment for relevant psychosocial and attitudinal covariates that are known to vary among racial/ethnic groups (Canedo et al., 2019) and impact test uptake. In contrast to previous reports that demonstrated lower use of genetic services among Blacks (Armstrong et al., 2005; Lerman et al., 1999), we found no significant difference in test uptake between NH Blacks and NH Whites. Racism, a critical driver for racial health inequity, may potentially underlie these observed differences. The mechanism by which it may be operating in this situation include unmeasured structural barriers that limit access to genetic

testing among racial/ethnic minorities, e.g., lack of testing recommendation from physicians, insurance (Modell et al., 2021) and high genetic testing cost (Cragun et al., 2019). Awareness of genetic testing or acculturation that have been previously shown to influence test uptake among Latino participants (Vadaparampil et al., 2006; Hamilton et al., 2016) may also explain some of the observed differences. However, these interpersonal and institutional factors were not measured in this version of the HINTS survey and thus not included in our analyses. The specific underlying reason notwithstanding, this persistent racial/ethnic disparity in genetic testing use is a barrier to realizing the promise of precision cancer prevention and multilevel targeted interventions are needed to ensure equitable access to genetic services among minority populations. Future studies should explore the impact of rural/urban residency as potential surrogates for geographic barrier to access, potential language and cultural barriers to testing, and attempt to identify the form by which racism may be operating in genetic testing.

The present study benefits from the use of data from a large nationally representative survey to estimate the prevalence of high-risk cancer genetic testing and beliefs regarding the importance of genetics for cancer prevention and early detection. Our analytic strategy focused on high-risk cancer genetic testing and removed other types of direct-to-consumer and ancestry genetic testing; this enabled us to accurately define the study outcome and focus on clinically relevant genetic testing for cancer. The unique cross-sectional data along with large sample size provided the ability to identify factors associated with high-risk cancer genetic testing. Despite these strengths, this study is not without its limitations. Self-reported data is subject to individual interpretation and response bias but we used weights to make the survey responses population representative. As with any cross-sectional study, this study cannot determine temporality. Nuanced examination of these cancer genetic beliefs in future research could shed light on why they are differently associated with genetic testing.

In conclusion, this study showed that over 5% of the US population has undergone high-risk cancer genetic testing and cancer prevention is the likely motivation behind many of these tests. However racial and ethnic disparities in use of genetic testing persists. Belief about the importance of genetics for early detection of cancer, but not cancer prevention, is associated with testing, which is a surprising finding that warrants further research. Better understanding of these beliefs and their potential impact on test uptake may inform population genetic testing efforts.

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CRedit authorship contribution statement

Sukh Makhnoon: Conceptualization, Writing – original draft, Writing – review & editing. **Kristin G. Maki:** Conceptualization, Writing – review & editing. **Robert Yu:** Formal analysis, Writing – review & editing. **Susan K. Peterson:** Writing – review & editing. **Sanjay Shete:** Resources, Supervision, 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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2022.101781>.

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