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Skin cancer and its associated factors using behavioral risk factor surveillance system data

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Abstract. Skin cancer is the most common cancer in the United States. The The Behavioral Risk Factor Surveillance System (BRFSS) surveyed 438,693 US participants aged 18 and above in 2021, providing valuable insight into skin cancer patterns and associated risk factors. Among the participants, 427,883 did not have any missing values, 9.44% had skin cancer. Exploratory association analysis of skin cancer was performed using a dataset with complete values, including five covariates: age, sex, BMI, race/ethnicity, and smoking status. Single-variant association analysis on these variables revealed significant associations with skin cancer for all covariates. Subsequently, multi-variant logistic regression analysis showed significant associations between skin cancer and age (5 year, beta=0.33 CI= (0.33, 0.34)), sex (female, beta=-0.19, CI= (-0.21, -0.16)), race/ethnicity (Black, beta= -2.68, CI= (-2.82, -2.55); Asian, beta= -2.30, CI=(-2.53, -2.08); American Indian/Alaskan Native, beta=-1.00, CI= (-1.14, -8.87); Hispanic, beta= -1.61, CI=(-1.71, -1.52)), and smoking status (current smokers, beta= -0.18, CI=(-0.22, -0.13); former smoker, beta=0.05, CI=(0.02, 0.07)). Additionally, two-way interactions among some of these factors were explored, and the interactions of age by BMI, age by sex (Female), and race/ethnicity (Hispanics) by current smoking were significantly associated with skin cancer, with p-values of <1 × 10-6, <1 × 10-6, and 2.63 × 10-6 respectively. Overall, our data validated the conclusion that age, sex, and race/ethnicity were the three most significantly-associated factors to skin cancer. This finding hints at possible guidance on how to identify groups that are at a greater risk of developing skin cancer, though further research is needed to control for covariates not examined here.

Keywords: skin cancer, association analysis, logistic regression, interaction analysis.

1. Introduction

Skin cancer is the most common form of cancer in the United States, and the fifth most common around the world [1]. The exact causes of cancer are not clear, but existing literatures already identified associations between skin cancer and many common factors. For example, Wu et al. found in their 2016 study found that a history of sunburns was a strong predictor for three types of skin cancers -Basal Cell Carcinoma, Squamous Cell Carcinoma, and melanoma- and that the location of the burns were likewise relevant [2]. This is an extensively documented association, yielding consistent results since the 1970s and establishing a strong causal association between sun-damage/lack of sunscreen usage and skin cancer [3, 4]. While these studies have studied this link, other contributing factors have been less studied; for example, Wu et al. found that skin cancer prediction varied by the location of the sun-damage and the sex, with men's predictor location being the trunk and women's the limbs, yet they did acknowledge that there has been a lack of studies that used sex alongside other variables to control for causality. Their reasoning for the disparity in their sex-based findings is "it is well known that sun exposure patterns differ between women and men, which may be responsible for the difference in patterns of melanoma distribution by body site between the sexes" [5]. Sex is not the only variable that is not disentangled as a causal factor in the incidence of skin cancer: skin color (ethnicity/race) is taken as a given in many studies, with the studies holding the assumption that darker skin color are less likely to develop skin cancer. However, such studies have focused on mortality rates, and health literacy rates by ethnic group instead of inquiring into the specifics and causal mechanisms for this discrepancy in skin cancer rates.

This paper aims to validate the common factors associated with skin cancer using the Behavioral Risk Factors Surveillance System (BRFSS) database to analyze different variables. The BRFSS is the "nation's premier system of health-related telephone surveys that collect state data about U.S. residents regarding their health-related risk behaviors, chronic health conditions, and use of preventive services" (CDC). It is a joint effort between the Center for Diseases Control (CDC) and all of the US states. Its goal is to gather data on health-care related issues such as: behaviors, chronic diseases, access to care, preventive healthcare measures, the most prevalent diseases in the US and the leading cause of death in the country. For that reason, it contains data about everything from the number of children in the household, to whether they have lived with anyone who has been to prison. Its core, however, is made up of data on health status and healthy days, exercise, hypertension and cholesterol awareness, chronic health conditions, arthritis, tobacco use, fruit and vegetable consumption, and health-care access. (CDC, BFRSS).

The paper utilized BRFSS data to analyze the associations between skin cancer and common factors in our life, such as age, race, and gender, etc. Specifically, the single variant tests and multivariate logistics regression were implemented to test the associations. Also, the interation effects were further analyzed in our model.

2. Methods

2.1. Database

This paper will use statistical analysis to find any correlation between skin cancer and other behavioral risk factors found in BRFSS. This database is an optimal dataset as it includes many variables that a database exclusively centered on skin cancer would not, such as BMI, or tobacco use. The data is collected at the state and local level, via phone interviews. There is a close cooperation between the CDC and local governments as this allows the agency to provide better information on healthcare to policymakers. Indeed, this is one of its stated goals "working closely with state and federal partners to ensure that BRFSS continues to provide data that are useful for public health research and practice and for state and local health policy decisions." While the data it gathers is extensive and useful, there are some issues in how it is collected: the main way for the CDC to administer the survey is through "in-house interviewers or contract with telephone call centers or universities to administer the BRFSS surveys continuously through the year".

This clearly shows a possible downside to the database, since it is restricted to the sample of people that can be physically interviewed; that agreed to the survey over a landline; or, that were in a university where it was administered. However, it does give us important pieces of data regardless of these limitations to conduct our analysis.

2.2. The outcomes and related covariates

In our analysis, the outcome was a binary variable indicating whether the participant had skin cancer (value =1), or not (value =0). The covariates we chose were the age, sex, body-mass index (BMI), race/ethnicity, and smoking status. Some were categorical, namely: sex, which had male as the default category, alongside female; race/ ethnicity had six categories, which included, White non-Hispanic as the default, Black, Asian, Native American, Hispanic, and other races/ethnicities; finally, smoking status had three categories, including current smokers, former smokers, and never smokers. The remaining covariates were numerical variables: age with interquartile range (42, 68) and BMI with interquartile range (24.14, 31.75).

2.3. Single variable association analysis and multiple-variant logistic regulation analysis

With the outcome and selected covariates, we utilized both unadjusted methods and adjusted methods to analyze the associations between the outcome: skin cancer indicator and related covariates. In our analysis, only participants with no missing values are included because there are a sufficient number of participants in the BRFSS dataset. After removing missing values, 427,883 samples were included in our model.

For the unadjusted methods, we conducted single-variant association analysis for each covariates. Specifically, for continuous variables, the mean (inter-quartile range) was reported stratified by skin cancer indicator. Two sample t-test was carried out to compare whether skin cancer group and no skin cancer group had significant differences with respect to this variable. For categorical vairables, the count and percentage of each category was reported stratified by skin cancer indicactor. Unadjusted p-values wre calculated using chi-square tests of independence comparing the distributions of categorical variables between skin cancer and no skin cancer groups.

In addition, we further implemented adjusted methods to incorporate all covariates in the multi-variant logistic regression. Specifically, the outcome in the logistic regression was the binary skin cancer indicator with 0 representing no skin cancer and 1 representing skin cancer. The covariates in the logistic regression included age, sex, body-mass index (BMI), race/ethnicity, and smoking status. Beta estimate, standard error, P-value, and 95% confidence interval (CI) were reported in the final result.

In order to explore the associations between two-way interactions and skin cancer indicator, we also included all possible two-way interactions in the logistic regression model. The identified significant associations were reported using beta estimate, standard error, and p-value.

All our analyses were conducted using the software R with the version number 4.2.2 and its integrated development environment Rstudio with the version number 2023.03.0.

3. Results

3.1. Single-variable association analysis

In our sample of 427,883 respondents, 40,401 respondents were reported to have skin cancer, and 387,482 reponsdents were reported not to have skin cancer. The skin cancer incidence rate was around 9.44% in this dataset. By conducting single-variable association analysis, we found that allvariables that we considered was statistically significantly associated with skin cancer indicator, given that all had a p-value below than 1 × 10-6 (Table 1).

Table 1. Characteristics of 427,883 individuals with skin cancer data in BRFSS dataset, stratified by skin cancer result. Statistics presented are mean (inter-quartile range) for continuous variables and n (%) for categorical variables. Unadjusted p-values are reported for either two-sample t test (continuous) or chi-square tests of independence (categorical) comparing the distributions of each of these characteristics between testing groups.

Characteristic	Overall, N=427,883	Skin Cancers, N=40,401	No Skin Cancers N=387,482	p-values
Age	54.90 (42,67)	69.70 (62,77)	53.37(37,67)	$<1 \times 10^{-6}$
Body Mass Index	28.55 (24.14, 31.75)	27.79 (23.91, 30.62)	28.64 (24.20, 31.89)	$<1 \times 10^{-6}$

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Table 1. (continued).

Sex				$<1 \times 10^{-6}$
Male	198,860 (46.5%)	19,337 (47.9%)	179,523 (46.3%)	
Female	229,023 (53.5%)	21,064 (52.1%)	207,959 (53.7%)	
Race/Ethnicity				$<1 \times 10^{-6}$
White, Non-Hispanic	323,764 (75.7%)	38,517 (95.3%)	285,247 (73.6%)	
Black, Non-Hispanic	32,280 (7.5%)	267 (0.7%)	32,013 (8.3%)	
Asian, Non-Hispanic	11,211 (2.6%)	89 (0.2%)	11,122 (2.9%)	
American Indian/Alaskan Native, Non-Hispanic	7,229 (1.7%)	251(0.6%)	6,978 (1.8%)	
Hispanic	38,157 (8.9%)	520 (1.3%)	37,637 (9.7%)	
Other race, Non-Hispanic	15,242 (3.6%)	757 (1.9%)	14,485 (3.7%)	
Computed Smoking Status				$<1 \times 10^{-6}$
Current smoker	240,521(59.4%)	20,933 (54.1%)	219,588 (60.0%)	
Former smoker	53,021(13.1(%)	3,264(8.4%)	49,757(13.6%)	
Never smoked	111,191 (27.5%)	14,464 (37.4%)	96,727(26.4%)	

Specifically, the average age was 54.90 with the interquartile range (42, 67) among all the participants in our data. The average age of skin cancer group was 69.70 with the interquartile (62, 77), significantly higher than the average age of no skin cancer group (mean: 53.37 (37, 67)), which indicates that older people had higher risk to be diagnosed with the skin cancer. The average Body Mass Index was 28.55 for the overall group with the range (24.14, 31.75), the averge BMI of skin cancer group was 27.79 with (23.91, 30.62), it’s lower than the average BMI of no skin cancer group (mean: 28.64 (24.20, 31.89), which show that BMI lower people had risk in skin cancer. In terms of sex percentages, female individuals were 53.5% of the whole sample, while male individuals were 46.5%. Although the averages sex percentages of those with and without skin cancer were significantly different (p-value <1 × 10-6), the absolute difference was smaller than 2%. The male: female percentages are 47.9%:52.1% and 46.3%:53.7% for the skin cancer and no skin cancer groups, respectively. Regarding race/ethinicity, there were 6 categories in our BRFSS data: white (75.7%), black (7.5%), Asian (2.6%), Native-American (1.7%), Hispanic (8.9%), and other races (3.6%). Here we saw some gaps between ethnicities and their representation in the skin-cancer group: white individuals made up 75.7% of the sampled population, but they made up 95.3% of the cases of skin-cancer cancer; for every other race/ethnicity category, each was significantly underrepresented in the skin cancers group by a margin ranging from 1.5 to 10 times against the overall percentage of the population. For example, Black individuals made up 7.5% of the population, but only 0.7% of the skin cancer population; Asians were 2.6% of the overall, and 0.2% of the skin cancers; Native Americans were 1.7% overall and only 0.6% of the cancer cases; Hispanics were 8.9% of the population but only 1.3% of the cancer population; the remaining racial/ethnic groups were closer in their representation, with 3.6% of the total, 1.9% of the cancers, and 3.7% of the cancer-free people. Finally, the smoking status had three categories in our data: current smoker (59.4%), former smoker (13.1%), and never-smokers (27.5%). Two categories had very similar ratios between skin cancer group and no skin cancer group: Current smokers were 54.1% of the cancer cases, and 60% of the cancer-free group; former smokers were 8.4% of the cancers, and 13.6% of the cancer-free. The only category to show a noticeable gap are the never-smokers, who showed a more than 10% gap between the cancer-free and the cancer population: they represent 37.4% of the cancer group while 26.4% of the cancer free group.

3.2. *Multiple variant logistic regression analysis*

The results of single variant association analysis show that all the variables that we considered were significantly associated with the skin cancer indicator. We further explored these assoications using multiple-variant logistic regression model by including all the variables in the same model. Table 2 shows that the former smoker is 1.34 × 10-4 in p-value and other than that all the beta coefficients from the logistic regression model is significant as measured by the p-value less than 1 × 10-6. The beta-coefficient (called “Estimate” on our results table) for all of the variables was negative, with the exception of age (0.33) and former smokers (0.05), indicating that older people had a higher chance to be diagnosed as skin cancer than younger people and former smokers had a higher chance of skin cancer than never-smokers. BMI coefficient was -9.76 × 10-3 , suggesting people with higher BMI was less likely to be diagnosed with the skin cancer, however the absolute value of beta coefficients is small.The female coefficient was -0.19 compared to males as a reference group, showing that females were more protective from skin cancer than males. Compared with the White participants as the reference category, the beta coefficients were -2.68 for Black , -2.30 for Asians, -1.00 for American Indian/Alaskan Native, -1.61 for Hispanics, and -0.61 for other races, demonstrating that White people had the highest risk to have skin cancer among all race/ethnicity categories. Finally, compared to the never-smoking control group, current smokers had a coefficient of -0.18.

Table 2. Associations between skin cancer indicator and patient characteristics. Beta estimates, standard error, p-value and 95% confidence intervals are reported for each characteristic, fully adjusting for all other demographic and clinical characteristics in a logistic regression model, including age, BMI, sex, race/ethincity, and smoking status. CI: confidence interval.

	Estimate	**Std. Error**	**P-value**	**95% CI**
Age	0.33	2.43×10^{-3}	$<1 \times 10^{-6}$	(0.33, 0.34)
BMI	-9.76×10^{-3}	1.01×10^{-3}	$<1 \times 10^{-6}$	(-0.01, -0.01)
Sex (female)	-0.19	0.01	$<1 \times 10^{-6}$	(-0.21, -0.16)

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Table 2. (continued).

Black, Non-Hispanic	-2.68	0.07	$<1 \times 10^{-6}$	(-2.82, -2.55)
Asian, Non-Hispanic	-2.30	0.11	$<1 \times 10^{-6}$	(-2.53, -2.08)
American Indian/Alaskan Native, Non-Hispanic	-1.00	0.07	$<1 \times 10^{-6}$	(-1.14, -0.87)
Hispanic	-1.61	0.05	$<1 \times 10^{-6}$	(-1.71, -1.52)
Other race, Non-Hispanic	-0.61	0.04	$<1 \times 10^{-6}$	(-0.69, -0.53)
Current smoker	-0.18	0.04	$<1 \times 10^{-6}$	(-0.22, -0.13)
Former smoker	0.05	0.01	0.000314	(0.02, 0.07)

3.3. Multiple variant logistic regression analysis including two-way interactions

Within the same framework of logistic regression model, we further included two-way interactions between all the covariates. Table 3 shows the results from this model, including the beta coefficient, standard error, and P-value.

Table 3. Associations between skin cancer indicator and patient characteristics, including all two-way interactions of patient characteristics. Beta estimates, standard error, and p-value are reported for each characteristic, fully adjusting for all other demographic and clinical characteristics in a logistic regression model, including age, BMI, sex, race/ethnicity, smoking status, and all two way interactions.

	Estimate	**Std. Error**	**P-value**
Age	0.33	0.01	$<1 \times 10^{-6}$
BMI	-0.03	0.005	$<1 \times 10^{-6}$
Sex (female)	1.17	0.08285	$<1 \times 10^{-6}$
Black, Non-Hispanic	-2.43	0.42	$<1 \times 10^{-6}$
Asian, Non-Hispanic	-3.78	0.75	$<1 \times 10^{-6}$
American Indian/Alaskan Native, Non-Hispanic	-0.93	0.47	0.05
Hispanic	-1.89	0.29	$<1 \times 10^{-6}$
Other race, Non-Hispanic	-1.24	0.27	4.50×10^{-6}
Current smoker	-0.52	0.14	0.000119

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Table 3. (continued).

Former smoker	0.04	0.09	0.68
Age x BMI	2.38×10^{-3}	4.10×10^{-4}	$<1 \times 10^{-6}$
Age x Sex Female	-0.12	4.98×10^{-3}	$<1 \times 10^{-6}$
Age x Black, Non-Hispanic	-0.07	0.03	0.004587
Age x Asian, Non-Hispanic	0.01	0.04	0.72
Age x American Indian/Alaskan Native, Non-Hispanic	-0.02	0.03	0.53
Age x Hispanic	-3.88×10^{-3}	0.02	0.81
Age x Other race, Non-Hispanic	0.03	0.02	0.11
Age x Current smoker	-0.01	8.50 × 10-3	0.08
Age x Former smoker	-4.75 × 10-3	5.51×10^{-3}	0.39
BMI x Sex (female)	-5.99 × 10-3	2.08×10^{-3}	0.003930
BMI x Black, Non-Hispanic	2.05×10^{-2}	0.01	0.04
BMI x Asian, Non-Hispanic	3.47×10^{-2}	2.31×10^{-2}	0.13
BMI x American Indian/Alaskan Native, Non-Hispanic	2.12×10^{-3}	1.11×10^{-2}	0.85
BMI x Hispanic	6.99×10^{-3}	7.77×10^{-3}	0.37
BMI x Other race, Non-Hispanic	7.91×10^{-3}	6.59×10^{-3}	0.23
BMI x Current smoker	1.47×10^{-2}	3.37×10^{-2}	1.24×10^{-5}
BMI x Former smoker	-9.01×10^{-4}	2.21×10^{-3}	0.68
Sex (female) x Black, Non-Hispanic	-0.27	0.14	0.05
Sex (female) x Asian, Non-Hispanic	0.59	0.24	0.01
Sex (female) x American Indian/Alaskan Native, Non-Hispanic	-7.94×10^{-3}	0.14	0.95

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Table 3. (continued).

Sex (female) x Hispanic	-0.09	0.10	0.38
Sex (female) x Other race, Non-Hispanic	0.05	0.08	0.57
Sex (female) x Current smoker	0.10	0.04	0.01
Sex (female) x Former smoker	0.11	0.03	2.77×10^{-5}
Black, Non-Hispanic x Current smoker	0.23	0.20	0.26
Asian, Non-Hispanic x Current smoker	0.47	0.48	0.32
American Indian/Alaskan Native, Non-Hispanic x Current smoker	7.49×10^{-3}	0.19	0.97
Hispanic x Current smoker	0.68	0.14	2.63×10^{-6}
Other race, Non-Hispanic x Current smoker	0.41	0.12	0.000563
Black, Non-Hispanic x Former smoker	-0.02	0.16	0.88
Asian, Non-Hispanic x Former smoker	0.46	0.26	0.08
American Indian/Alaskan Native, Non-Hispanic x Former smoker	0.08	0.16	0.59
Hispanic x Former smoker	0.28	0.11	0.01
Other race, Non-Hispanic x Former smoker	0.21	0.09	0.02

Among all possible two-way interactions, three significant interactions were identified: age by BMI (beta: 2.38×10-3, p-value: <1×10-6) and age by sex female (beta: -0.12, p-value: <1×10-6), and Hispanic ethnicity by current smoker (beta: 0.68, p-value: 2.63×10-6). Here in order to avoid false positives due to multiple testing, we use a more stringent p-value cutoff 1×10-5. It shows that these common risk factors not only have main effects on the skin cancer indicator, but might have the interaction effects on the skin cancer. For example, according to our model results, the interaction between age and BMI will increase the risk of being diagnosed with skin cancer. Females have less risk of getting skin cancer than males when getting old because the beta coefficient of age by sex female is

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significantly negative. For Hipanic ethnicities, the current smoker has a higher risk of getting skin cancer than current smokers of non-Hipanic ethnicities. With these interactions, it can help us better quantify the skin cancer risk using common risk factors.

4. Discussion

In this study, we analyzed the associations between common risk factors and the binary skin cancer indicators. Both single-variant association tests and multi-variant logistic regression models show that age, sex, BMI, race/ethnicity, and smoking status were significantly associated with skin cancer indicators. When we included the two-way interactions in the logistic model, we found the interactions of age by BMI, age by sex (Female), and race/ethnicity (Hispanics) by current smoking were the top three most significant interactions associated with skin cancer, having p-values of <1 × 10-6, <1 × 10-6, and 2.63 × 10-6 respectively. Overall, our data validated the conclusion that age, sex, and race/ethnicity were the three most significantly-associated factors to skin cancer. This finding provided guidance on how to identify groups that are at a greater risk of developing skin cancer.

Among the single varian comparisons between the cancer versus non-cancer groups, the more than 20% gap between the percentage of White-non-Hispanic individuals in the cancer group and non-cancer group is already a strong indicator of an association -if not a causal link- that has strong health-care and policy implications; likewise, the more than fifteen years gap between the average age of the skin cancer group and group and non-cancer group is also a strong indicator of a link that might be causal and carry policy implications.

Adjusted multiple variant analysis gave us interesting results: almost all of the variables are below 1 ×10-6 and only age and former smoker have positive beta-coefficients while all other beta coefficients are negative. This finding is inconsistent with the results from the paper of Rollison et al. which claims that smoking have higher risk of getting skin cancer [6]. This discrepency might be due to different study regions and study years. Another possible reason is that the data we used are cross-sectional data, which might cause misleading associations and we further explained it in the limitation section. In addition, Cassano et al. did comprehensive literature review on the link between obesity and melanoma prognosis and found further studies were needed to conclude the association [7]. Our result shows within BRFSS dataset, people with higher BMI have lower risk of getting skin cancer while the interaction between age and BMI will cause higher risk of getting skin cancer. Furthermore, we find that smoking is not an independent risk factor for skin cancer, unlike what De Hertog et al. had found [8]. Instead, just like the papers of Leonardi-Bee et al. we find that smoking is associated with skin cancer, particularly among women [9]. We also find that current smokers were less likely to get skin cancer than non-smokers, a result consistent with Song et al. [10]. In the paper of Gloster and Neal, they demonstrated that skin cancers pose a significant risk in skin of color [11]. Our results validate their results by identifying the whites have the highest risk of getting skin cancers compared to other race/ethnicity groups.

There are several limitations in our study. First, the BRFSS data we used are cross-sectional study without follow-up period, which means that the significant associations in our results don't necessarily imply the casual effects. For example, it is likely that a person who was diagnosed with skin cancer before might reduce/ quit smoking, which may lead to the beta coefficient of current smoker to become negative. It means based on the cross-sectional obersevations, we might conclude smokers have less chance to get skin cancer. If this assumption holds true, it also explains why the beta coefficient of former smoker was positive, which means former smokers had higher chances to getting skin cancer compared to non-smokers. The concern can be addressed with a more detailed questionnaire or continuous follow-ups with these participants. Second, the number of covariates we used is limited. In the future analyses, we might consider include more covariates and they might explain more variations of the skin cancer indictor, such as the time exposed to the sun, which is already known as the most common risk factor of the skin cancer, if more data are available in the future. Lastly, we only considered the linear effect of risk factors. However, this assumption may not hold for all risk factors, such as age and BMI. Non-linear effect model can be further explored in the future analyses.

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To summarize, our findings validate age, sex, and race/ethnicity were the three most significantly-associated factors to skin cancer among all the factors that we considered. This finding provided guidance on how to identify high risk groups of developing skin cancer.

5. Conclusion

The Behavioral Risk Factor Surveillance System (BRFSS) surveyed 438,693 US participants in 2021, finding that 9.44% had skin cancer. The study found significant associations between age, sex, BMI, race/ethnicity, and smoking status. Age by BMI, age by sex, and race/ethnicity by current smoking were also significantly associated with skin cancer. These findings suggest that age, sex, and race/ethnicity are the three most significantly associated factors to skin cancer. Further research is needed to control for non-examined covariates.

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