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Effect of Insufficient Sleep on Activity Limitation: Results from the BRFSS 2022 Survey

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Abstract

Objective: To determine whether insufficient sleep (<7 hours per night) is associated with activity limitation (≥ 14 days of poor mental or physical health interfering with everyday activities) in the Behavioral Risk Factor Surveillance System (BRFSS) survey data from 2022. **Methods:** BRFSS is a nationally representative cross-sectional survey of non-incarcerated US adults. The exposure of interest was insufficient sleep, and the outcome of interest was activity limitation. Other demographic variables were used in a final weighted adjusted analysis and include age ≥ 65 years, race/ethnicity, gender, marital status, income, and total physical inactivity. **Results:** The weighted prevalence of insufficient sleep for US adults in 2022 was 36.1%, and activity limitation was 9.8%. A multiple logistic regression was performed, and insufficient sleep had a prevalence odds ratio of 2.05 (95% CI: 1.94, 2.16) for activity limitation. **Conclusion:** The prevalence of insufficient sleep for adults in the US remains high, and this risk factor has a significant association with activity limitation, after controlling for several demographic variables. Results from BRFSS 2022 support recommendations that adults should get 7 hours of sleep per night.

Introduction

Sleep is an important part of health. During sleep, our body recovers from exertion, and helps to form our memories.¹ Decreased sleep duration has been associated with health problems, such as hypertension, heart attack, and stroke.² Due to the health benefits of getting enough sleep, the American Academy of Sleep Medicine (AASM) and the Sleep Research Society (SRS) recommended in 2015 that “adults should sleep 7 or more hours per night on a regular basis to promote optimal health.”³ However, many people do not get this much sleep, with nearly 1 in 3 adults reporting they do not get as much sleep as recommended.⁴

Previous work using nationwide surveys has shown a link between getting less than 7 hours of sleep per night and frequent mental distress, a component of mental health.⁵ Regarding physical health, some studies have used very short sleep duration (5 or less hours of sleep per night) to support links with other health outcomes, such as obesity, high cholesterol, diabetes, hypertension, heart attack, and stroke.^{2,6} However, when insufficient sleep only (less than 7 hours of sleep per night) is used, only the association with obesity and high cholesterol remains.² Other research on this topic sometimes does not control for insufficient sleep as a risk factor. These findings, along with studies using measures of time asleep other than 7 hours a night, make additional study on sleep less than 7 hours a night important. This research can support claims of the benefit of sufficient sleep on overall health.

Additionally, physical activity has been associated with long-term physical health outcomes. Physical activity can improve sleep and has been linked directly to improved quality of life.⁷⁻⁹ Physical inactivity, on the other hand, is associated with poor health outcomes such as stroke and heart attack.^{10,11}

Physical health includes more than diagnosed conditions such as heart attack and stroke. Another important area of health is health related quality of life (HRQOL). This refers to both objective and subjective measures assessments of health and is particularly important in research on disability.^{12,13}

One measure of HRQOL is the four-item measure termed HRQOL-4, four questions whose responses have been collected since 1993 on the Behavioral Risk Factor Surveillance System (BRFSS) survey. One of these questions is: “During this 30 days, for about how many days did poor physical or mental health keep you from your usual activities, such as self-care, work, or recreation?”.¹³ Having 14 or more days of poor overall health as per the this question has been termed activity limitation, or “role disability”.¹⁴ Signifying poor health affecting activities for half or more of the days in a month, the prevalence of this condition is remarkably high. In 2007, 6.6% of adults in the United States reported an activity limitation, and it was associated with previous diagnosis of chronic diseases.¹⁴ Even among employed persons, the prevalence of activity limitation is high and surveys from 2017-2019 showed the prevalence of activity limitation to be 3.8% among employed persons. Activity limitation is prevalent in several populations, and the entire United States as a whole.

Another population where activity limitation is important is older adults, where this condition was linked to increased mortality in a nationwide survey of Medicare recipients. Older adults with the highest activity limitation reported (21-30 days) had increased hazard ratio for death over a follow-up of 2.5 years. This was a direct link with a poor health outcome, and added to previous literature describing health related quality of life data as a “valid and appropriate” indicator of service need and measuring intervention outcomes.¹² In fact, only older age and “poor” global self-rated health had a higher magnitude of the hazard ratio for mortality at 2.5 years in this analysis.¹⁵ Research on activity limitation can help show areas of need in populations, and activity limitation has been linked to poor long-term health outcomes, such as mortality.

When considering the entire adult US population, is insufficient sleep associated with activity limitation? Review of this subject matter has not uncovered this specific association. Sleep is an important subject since it is an essential part of health and linked with many health effects. An analysis of BRFSS data from 2022 for insufficient sleep (and not extremely short sleep duration) may be helpful

to characterize its effects. Similarly, activity limitation is a valid, appropriate measure of health-related quality of life. Analysis of these variables in a large, nationally representative cohort from the most recent BRFSS survey may uncover a meaningful association. Additionally, it would help promote efforts to increase adequate sleep in the general population through additional data, and subsequent promotion efforts.

Methods

Study Design

Publicly available data from the Behavioral Risk Factor Surveillance System (BRFSS) performed in 2022 was used. This data is obtained from a national telephone survey.¹⁶ The data is obtained for all non-incarcerated US adults in 50 states, the District of Columbia, three territories, and is a nationally representative sample. It is weighted by age, sex, ethnicity, regions, and additional variables. This is a telephonic, cross-sectional survey done yearly and performed through the Centers for Disease Control and Prevention (CDC).

Ethical approval

Since this data is de-identified public health surveillance data, it is therefore not subject to IRB oversight.

Sample

For this analysis, all non-missing data were included. In BRFSS 2022, there were 445,132 adult surveys completed in total. Responses such as “do not know”, “unsure”, or refusals for the variables studied were not included in analysis. The sample is adults, 18 years of age or older, living in all US states and territories during 2022 who completed the survey.

Outcome Variable: Activity Limitation

Activity limitation was the outcome variable, as defined as 14 or more days in response to the following question: “During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?”¹⁷ This cutoff has been used in previous work, including nationwide surveys of the general American public, and employed persons.^{14,18} It is also termed “role disability” in some literature due to the nature of not being able to fulfill one’s chosen role at work, home, or in recreation. Responses included numerical values from 1 to 30, as well as “none”, “don’t know/not sure”, refused or missing. There were many missing responses. However, as per the notes on this variable available from CDC,¹⁹ missing data included persons who responded “none” to two previous questions, labelled: the “Number of Days Physical Health Not Good”; and the “Number of Days Mental Health Not Good”. If both conditions were met, then it was recoded into a new variable indicating no activity limitation. For other values of “poor physical or mental health”, 14 days and above of poor health was coded as having activity limitation, and values less than 14 days were coded as having no activity limitation.

Exposure of Interest: Insufficient Sleep

Sleep time (<7 hours) was the exposure of interest. This was queried using the following question: “On average, how many hours of sleep do you get in a 24-hour period?” Allowed responses were numerical, from 1-24, “missing”, or “refused”. The reported sleep time was dichotomized- sufficient sleep was greater than or equal to 7 hours, and insufficient sleep was less than 7 hours.

Other Variables

Age was used to examine the effect of age on the relationship between sleep and activity limitation. The calculated variable for two-level age category was used. The effect of age was examined on this relationship by comparing age greater than or equal to 65 compared to those 18 years of age to 64.

Race and ethnicity were examined using four categories of race/ethnicity combined. The variable for “computed race groups for internet prevalence tables”, is included directly in BRFSS and derived from self-reported race/ethnicity data. It includes seven categories. For this analysis, four groups were used due to low percent prevalence (<10%) in some racial/ethnic categories. The categories used were: White, non-Hispanic; Black, non-Hispanic, Hispanic only, and other race/ethnicity. Other race/ethnicity combined “Asian only, non-Hispanic”, “American Indian/ Alaska Native only, non-Hispanic”, and “Multiracial, non-Hispanic categories” from the “computed race groups...” variable.

Income was compared using three categories, as previously described.²⁰ Income categories used in analysis were less than \$25,000; \$25,000 to less than \$75,000; and \$75,000 or more. Income has a complicated relationship with health outcomes,¹⁸ but it is a reliable measure of socio-economic status and predictive of some health outcomes.²¹ I also examined social support (as measured by marital status), and employment, as had been performed in previous work.¹⁸ For marital status, those who were married (not separated), or in an exclusive non-married relationship were “coupled”. Being coupled is a positive marker for having social support. For employment, only those who were employed for wages or self-employed were “employed”. Those who were, out of work, a “homemaker”, student, retired, or unable to work were “unemployed”.

Given the link between physical activity, sleep, and chronic health outcomes, this will be examined as a potential confounder in the relationship between sleep and poor physical or mental health.

Specifically, total physical inactivity (reporting no physical activity during leisure time the last month) versus at least some physical activity will be used to test this relationship.^{10,11}

Variables which were considered, but not used in this analysis, were other health outcomes, specifically two “Healthy Days” measures.^{12,13} These questions are like the question for activity limitation, which is the third (of three) “Healthy Days” measures. These were: “Now thinking about your mental health, which includes stress, depression, and problems with emotions, how many days during the past 30 days was your mental health not good?”; and: “Now thinking about your physical health, which includes illness and injury, how many days during the past 30 days was your mental health not good?”. Mental health specifically has been examined in relation to insufficient sleep before.⁵

Statistical Analysis

For this analysis, SAS® OnDemand for Academics: Studio (SAS) was used. This consisted of a preliminary analysis of the data with respect to the variables of interest, including descriptive analysis to determine frequencies of selected variables. Unadjusted prevalence odds ratios (pORs) were also calculated using `proc surveyfreq` and `proc surveylogistic` commands with weighting provided in code obtained at BRFSS website. Next, multiple logistic regression was performed for the effect of insufficient sleep (<7 hours sleep) on activity limitation (≥ 14 days of poor physical or mental health), when controlling for older age, race/ethnicity, gender, marital status, income, and employment.

The variables for other health outcomes, including- poor physical health; poor mental health- were considered to be outcomes that were collinear with activity limitation (poor physical or mental health) and were excluded from this adjusted analysis. The variables for chronic health conditions- which may be confounders in this analysis- were excluded as they are not extensive in this dataset, and some previous work has not corrected for these chronic health conditions. Specifically, past diagnosis of arthritis, current asthma, COPD/chronic lung disease, deafness, or heart disease was not included due to

these concerns. Moreover, review of literature regarding sleep and sleep quality focuses on other factors rather than chronic disease which may affect the benefits of sleep.^{1,5}

Results

The median survey response rate for BRFSS 2022 was 45.1% and ranged from 22.8% to 66.8%.²² Selected characteristics of the survey is presented in Table 1. Among respondents, the adjusted prevalence of insufficient sleep (sleep less than 7 hours per night) was 36.1%, and the adjusted prevalence of activity limitation (poor physical or mental health limiting everyday activities for 14 or more days in the last 30 days) was 9.8%. These numbers are weighted according to survey weights and represent the prevalence of the general adult US population.

Other demographic factors are also listed and reported as the number of respondents and the adjusted prevalence. Most of the sample was female (51%), “White only, non-Hispanic” (59.2%), employed (for wages or self-employed) (57.7%), and coupled (married, or in a mutually exclusive relationship (55.2%). Finally, the prevalence of total physical inactivity (no recreational physical activity the previous 30 days) was 23.9%, and the prevalence of income over \$75,000 was 28.7%.

Next, a bivariate analysis of the data was performed to examine the relationship between the exposure of interest (insufficient sleep), and activity limitation. Table 2 shows the unadjusted prevalence odds ratios between insufficient sleep, and other demographic variables, to the outcome activity limitation. A respondent with insufficient sleep has 2.13 times higher odds of having activity limitation (95% CI: 2.03, 2.22) compared to a person who gets sufficient sleep. There is also increased prevalence odds ratio for female gender, age over 65 years, unemployment, not being in a couple, physical inactivity, and income less than \$75,000 (<\$25,000, or \$25,000 to <\$75,000), indicating these conditions make it more likely that a respondent will report activity limitation. There were no differences between the different racial/ ethnic groups seen.

Adjusted prevalence odds ratios for sleep, age, gender, race/ethnicity, employment, married status, physical activity, and income on activity limitation of 14 days or more are reported (Table 3). In the adjusted model, there was a prevalence odds ratio of 2.05 (95% CI: 1.94, 2.16) for activity limitation due to insufficient sleep. There remained a significant association between sleep and activity limitation after adjustment. The magnitude of this relationship remained within 10% of the reported crude odds ratio after adjustment for several potential confounders.

After adjustment, variables which were significant in the unadjusted model remained statistically significant predictors for activity limitation. There were two exceptions, which are listed below. For age of 65 or greater, this was no longer positively associated with the outcome of activity limitation and in fact became significantly negatively associated with activity limitation. The adjusted prevalence odds ratio was 0.52 (95% confidence interval: 0.49, 0.56) indicating those 65 or older are 48% less likely to report activity limitation than adults under 65 when adjusting for the variables listed in Table 3.

The relationship between sex (female or male) and activity limitation weakened after adjustment. Unadjusted analysis shows a pOR of 1.35 for activity limitation among women compared to men, however after adjustment, this pOR decreases to 1.10 (95% CI: 1.05, 1.16).

Discussion

Insufficient sleep and activity limitation remain prevalent for adults in the United States. For adults in the United States during 2022, over 1 in 3 reported insufficient sleep, and is slightly increased from previous years.² Regarding activity limitation, or disability of 14 days or more per month, there has been a trend of increasing activity limitation noted in review of survey research. The prevalence in our analysis is nearly 50% higher than results from the early 2000s. Using the same definition of activity limitation (poor health of 14 or more days interfering with everyday activities), this prevalence increased

from 6.6% in 2009, to 9.8% in 2022.¹⁴ This is a worrisome result, indicating this measure of overall health may be worsening nationwide.

The pOR reported here for the relationship between insufficient sleep and activity limitation is similar to that reported for insufficient sleep and “frequent mental distress” of 14 days or more. In BRFSS 2018, the pOR for frequent mental distress given insufficient sleep was 2.5,⁵ similar in magnitude and direction to the pOR of 2.05 for activity limitation given insufficient sleep reported here. This is an important association and may be important for future research on disability.

Regarding potential confounders, several demographic variables were assessed for confounding, including age, gender, employment, physical activity status, and income. Interestingly, the relationship between activity limitation and age of 65 years or older switched during the adjusted analysis. The relationship between disability and age 65 or greater was negative, with older adults reporting less disability after controlling for the above demographic variables. This result may have two explanations. One, the effect of insufficient sleep may be modified by age, or, two: there are other variables confounding this relationship. For future research, one can consider analyzing these two populations separately, or using more granular data on age to study this relationship. In general, there exists a large literature on health in older adults, and there may be specific risk factors unique to this population when considering measures of health.

Other demographic variables, such as income, marital support, and employment status, followed expected trends. After adjustment, race and ethnicity did not emerge as a significant risk factor for disability in this analysis.

We directly compared inadequate sleep of less than 7 hours with activity limitation. This differs from other research which uses measures other than under 7 hours a night, such as under 5 hours per night or over 9 hours of sleep per night.^{2,6} Because of this, a more direct comparison between not getting the

recommended amount of sleep and this poor health outcomes was made. This is important, as it more directly supports the claim made that adults in the United States should get 7 or more hours of sleep per night.

Limitations of this work is that this is data from a cross-sectional survey which may be prone to recall bias and social desirability bias. Additionally, these results cannot prove causation between the predictors and outcomes studied. The population studied is only non-institutionalized United States adults and results may not be applicable to other populations, such as those in assisted living communities or nursing homes who may have higher prevalence of adverse health conditions and activity limitations. Strengths of this analysis include it that the BRFSS survey data collected during 2022 was a large sample and was weighted appropriately. It is also the most recently completed BRFSS survey. Future work can include the analysis of insufficient sleep on other outcomes, including mortality or hospitalizations, which would be accomplished by linking other data sets with BRFSS data.

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Table 1. Self-Reported Activity Limitation by Selected Demographic Measures and Variables of Interest, Including Sleep Time: 2022 Behavioral Risk Factor Surveillance System Data.

Variable	Prevalence (weighted %)
<i>Activity Limitation</i>	
≥ 14 days	42,444 (9.8%)
< 14 days	396,210 (90.2%)
<i>Sleep</i>	
< 7 hours	114,398 (36.1%)
≥ 7 hours	295,281 (63.9%)
<i>Age</i>	
18-64 years	276,713 (76.9%)
≥ 65 years	159,340 (23.1%)
<i>Gender</i>	
Male	209,239 (48.7%)
Female	235,893 (51.3%)
<i>Race/ Ethnicity</i>	
White, non-Hispanic	333,514 (59.2%)
Black, non-Hispanic	35,876 (11.6%)
Other, non-Hispanic	32,765 (10.9%)
Hispanic	42,977 (18.3%)
<i>Employment</i>	
Not employed	209,120 (42.3%)
Employed	224,772 (57.7%)
<i>Married Status</i>	
Not Coupled	194,238 (44.8%)
Coupled	246,092 (55.2%)
<i>Physical Activity</i>	
Physical Inactivity	106,480 (23.9%)
No Physical Inactivity	337,559 (76.1%)
<i>Income</i>	
<\$25k /year	56,015 (17.1%)
\$25k-<\$75k/year	196,709 (54.2%)
≥\$75k/year	96,361 (28.7%)

Abbreviations: k, thousand (used in income variable section).

Table 2: Association of Activity Limitation and Selected Demographic Variables and Other Variables of Interest, Including Sleep Time: 2022 Behavioral Risk Factor Surveillance System Data.

Variable	Activity Limitation n (%)	No Activity Limitation n (%)	pOR (CI)
<i>Sleep</i>			
< 7 hours	20,263 (52.5%)	121,824 (34.2%)	2.13 (2.03, 2.22)
≥7 hours	21,236 (47.5%)	270,519 (65.8%)	ref
<i>Age</i>			
18-64 years	26,704 (75.9%)	246,784 (77.2%)	ref
≥ 65 years	15,086 (24.1%)	141,310 (22.8%)	1.08 (1.02, 1.13)
<i>Gender</i>			
Male	17,521 (41.9%)	188,879 (49.5%)	ref
Female	24,923 (58.1%)	207,331 (50.5%)	1.35 (1.30, 1.41)
<i>Race/ Ethnicity</i>			
White, non-Hispanic	31,272 (59.2%)	297,916 (59.5%)	ref
Black, non-Hispanic	3,604 (12.1%)	31,610 (11.6%)	1.05 (0.99, 1.1)
Other, non-Hispanic	3,374 (10.6%)	28,866 (10.9%)	0.98 (0.90, 1.06)
Hispanic	4,194 (18.1%)	37,818 (18.1%)	1.01 (0.94, 1.08)
<i>Employment</i>			
Not employed	30,373 (68.6%)	174,513 (39.1%)	3.40 (3.25, 3.56)
Employed	11,111 (31.4%)	211,869 (60.9%)	ref
<i>Married Status</i>			
Not Coupled	24163 (57.1%)	166396 (43.3%)	1.75 (1.67, 1.82)
Coupled	17860 (42.9%)	225660 (56.7%)	ref
<i>Physical Activity</i>			
Physical Inactivity	21,085 (46.1%)	82,797 (21.3%)	3.17 (3.03, 3.31)
No Physical Inactivity	21,192 (53.9%)	312,653 (78.7%)	ref
<i>Income</i>			
<\$25k /year	12218 (36.7%)	42375 (14.7%)	5.95 (5.48, 6.46)
\$25k-<\$75k/year	17354 (50.4%)	177410 (54.7%)	2.19 (2.03, 2.37)
≥\$75k/year	3975 (12.8%)	91885 (30.6%)	ref

Abbreviations: %, column percent; pOR, prevalence Odds Ratio; p-value, probability of obtaining a value at least as extreme as the one obtained under the null hypothesis; k, thousand (used in income variable section).

Table 3. Adjusted Analysis of Activity Limitation Predicted by Selected Demographic Variables and Sleep Time: 2022 Behavioral Risk Factor Surveillance System Data.

Variable	Crude pOR (CI)	Adjusted pOR (CI)
<i>Sleep</i>		
< 7 hours	2.13 (2.03, 2.22)	2.05 (1.94, 2.16)
≥7 hours	ref	ref
<i>Age</i>		
18-64 years	ref	ref
≥ 65 years	1.08 (1.02, 1.13)	0.52 (0.49, 0.56)
<i>Gender</i>		
Male	ref	ref
Female	1.35 (1.30, 1.41)	1.10 (1.05, 1.16)
<i>Race/ Ethnicity</i>		
White, non-Hispanic	ref	ref
Black, non-Hispanic	1.05 (0.99, 1.1)	0.75 (0.69, 0.82)
Other, non-Hispanic	0.98 (0.90, 1.06)	0.92 (0.82, 1.02)
Hispanic	1.01 (0.94, 1.08)	0.74 (0.67, 0.80)
<i>Employment</i>		
Not employed	3.40 (3.25, 3.56)	3.39 (3.19, 3.61)
Employed	ref	ref
<i>Married Status</i>		
Not Coupled	1.75 (1.67, 1.82)	1.24 (1.17, 1.31)
Coupled	ref	ref
<i>Physical Activity</i>		
Physical Inactivity	3.17 (3.03, 3.31)	2.65 (2.51, 2.80)
No Physical Inactivity	ref	ref
<i>Income</i>		
<\$25,000/year	5.95 (5.48, 6.46)	2.59 (2.34, 2.87)
\$25,000-<\$75,000/year	2.19 (2.03, 2.37)	1.54 (1.42,1.67)
≥\$75,000/year	ref	ref

Abbreviations: pOR, prevalence Odds Ratio; CI, 95% Confidence Interval.

Appendix 1.

OMB No. 0925-0001 and 0925-0002 (Rev. 10/2021 Approved Through 01/31/2026)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Meyer, Jonathan C.

eRA COMMONS USER NAME (credential, e.g., agency login):

POSITION TITLE: Resident Physician

EDUCATION/TRAINING (*Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.*)

INSTITUTION AND LOCATION	DEGREE (if applicable)	Completion Date MM/YYYY	FIELD OF STUDY
University of St. Thomas, St. Paul, MN	BS	05/2010	Chemistry
University of Nebraska Medical Center, Omaha, NE	MD	05/2017	Medicine
University of Nevada Las Vegas, Las Vegas, NV		07/2018	Pediatrics/ Medical Internship
University of Nebraska Medical Center, Omaha, NE	MPH	05/2024	Epidemiology
University of New Mexico, Albuquerque, NM		07/2025	Preventive Medicine/ Residency

A. Personal Statement

I am a resident physician working at the University of New Mexico, studying General Preventive Medicine. I work on campus in the employee health clinic and participate in research and clinical practice with the Department of Health in the state of New Mexico. I am interested in health disparities in both occupational health and in the field of public health. I am passionate about finding ways to make our healthcare system more efficient, and more equitable.

My background is in medicine, and I have been practicing medicine since graduation from medical school in 2017. I am currently pursuing more training in general preventive medicine through the University of New Mexico to build my expertise in this area. General preventive medicine involves care of occupational health concerns, lifestyle medicine, addiction medicine, and the medicine of public health. Regarding research, I am most interested in studying social determinants of health, especially in relation to actionable recommendations that organizations within the United States can use to improve population health.

My career goal is to practice preventive medicine and occupational medicine while researching health disparities in public health. I have published before in the field of medicine as a contributing author:

1. *Later Diagnosis of Cystic Fibrosis with Negative Newborn Screen: Importance of The Clinical Picture.* Batocki, Galvis, Pescon, Meyer, Nakamura; Archives of Clinical and Medical Case Reports; **2019**
2. *M1759 Efficacy of Dimethylacetothetin, An Analog of Betaine, in the Treatment of Alcoholic Liver Injury.* Ward, Meyer, Tuma, Kharbanda, Hulce; Gastroenterology Vol. 134; **2008**

B. Positions, Scientific Appointments, and Honors

Resident Physician, University of New Mexico, General Preventive Medicine- July 2023- current

Physician, private practice, Omaha, NE- July 2020- June 2023

Resident Physician, University of Nevada Las Vegas, Pediatrics- July 2018- June 2020

C. Contributions to Science

Medical care- During my current training at UNM in general preventive medicine, I practice in an employee health clinic where I take care of patients who need diagnosis or treatment for injuries or conditions that affect them at the workplace.

Epidemiology- I am training in Epidemiology at UNMC in Nebraska. I have written and presented on important and ongoing epidemiological problems, including COVID outbreaks and investigation.