PHYSICAL ACTIVITY TRENDS DURING THE COVID-19 PANDEMIC: A CARDIOVASCULAR CONFLICT

A Causal Impact Analysis

STAT-451

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Abstract:

As discussed in the initial systematic review, numerous PubMed studies suggest that physical activity including intensive aerobic exercise and resistance band training has a significant impact on the outlook of breast cancer patients and their quality of life. Note that certain aspects of existing studies are lacking, as a substantial amount of them do not factor in relevant variables such as age and prior activity levels, making it challenging to determine whether treatments disproportionately affect certain groups. To fill in this research gap, this causal impact analysis seeks to utilize data from the Institute for Health Metrics and Evaluation to explore whether age and U.S. state of residence influence the prevalence of cardiovascular disease in both men and women, which can be attributed to physical inactivity. Furthermore, through collecting independent samples from two distinct states that differ in lockdown restrictions, one can analyze how the cardiovascular disease prevalence and disability adjusted life year (DALYs) trends differ based on state stringency index. Through analyzing California and Florida, this report determined that the increase in the prevalence of cardiovascular diseases during the pandemic was statistically significant in Florida ($p=0.002$) and the downward trend in disability adjusted life years from cardiovascular diseases during the pandemic was statistically significant in California ($p=0.031$).

Link to Project 1:

The systematic review sought to gather meaningful insights from the literature about the impacts of physical exercise on the outlook and quality of life of breast cancer patients. Through analyzing twelve randomized controlled trials, the review found that a combination of consistent resistance band training and intensive aerobic exercise resulted in statistically significant improvements in sensory/physical cancer-related fatigue, pain symptoms, and emotional functioning. Note that a majority of the literature only studied broad samples of breast cancer patients, failing to factor in variables such as age and consider the impact of the COVID-19 pandemic. To fill in gaps from the systematic review, this study more closely examines young adult (ages 15-29) and elderly women (ages 70-79) in Florida and California, two states significantly differing in their lockdown protocols throughout the COVID-19 pandemic. Note that the stringency index quantifies the strictness of the lockdown protocols in each of these states, and we observe that in 2020, Florida averaged an index of 44.24 while California averaged an index of 55.77 (Gitis). As opposed to studying only breast cancer patients, this report examines changes in the prevalence of cardiovascular diseases throughout the COVID-19 pandemic, a disease linked to low physical activity levels, to determine how physical activity trends differed during this period.

Introduction:

Cardiovascular diseases account for 17.9 million deaths, which is approximately 32% of all deaths worldwide, encompassing conditions like coronary artery disease, heart attack, stroke, and heart failure (WHO). Many of the known risk factors of developing cardiovascular disease include having an unhealthy diet, a lack of physical exercise, smoking regularly, and excessive alcohol use (Cleveland Clinic). Hence, to link low physical activity levels to breast cancer patients, this study examines overall rates of cardiovascular diseases during and after the COVID-19 pandemic, relying on the assumption that these trends are consistent for the subset of current and former breast cancer patients. Thus, by examining the difference in rates at which individuals are diagnosed with cardiovascular diseases before and after the pandemic, one can gain insight into how the trends of physical activity levels differed during these periods, as physical inactivity is a key risk factor of developing this disease. By referencing the literature from the initial systematic review, one can also argue that low physical activity levels in breast cancer patients during this period influenced their quality of life. Hence, this study seeks to indirectly answer the question about to what degree physical exercise habits have changed between before and throughout the COVID-19 pandemic, using cardiovascular disease development rates as an indicator. Future research will extend the ideas from this analysis to conclude whether the quality of life of breast cancer patients declined during the pandemic as a result of physical inactivity. One supplementary question pertains to how the impact of the COVID-19 pandemic on the prevalence of cardiovascular diseases and disability-adjusted life years of cardiovascular patients differed in California and Florida, two states starkly contrasting in the strictness of their lockdown policies. A second supplementary question fills in a gap from the systematic review by factoring in age groups to examine differences in the prevalence of cardiovascular diseases and disability-adjusted life years of cardiovascular patients in the young adult (ages 15-29) and elderly (ages 70-79) women populations, exploring whether physical inactivity disproportionately decreases the quality of life of young adult and elderly breast cancer patients respectively.

Exploratory Analysis:

Table 1:

Variable	**Description**
Years Lived with Disability (YLD)	The impact (in years) that cardiovascular diseases have on life expectancy per 100,000 people in the population.
Years of Life Lost (YLL)	The number of years deducted from life expectancy following an intervention, such as the COVID-19 pandemic, per 100,000 people in the population.
Disability-Adjusted Life Years (DALYs)	The total number of years deducted from life expectancy computed by accumulating the YLL and YLD per 100,000 people in the population.
Prevalence	The total number of cardiovascular disease cases in a given year per 100,000 people in the population.
Incidence	The number of new cases of cardiovascular disease per 100,000 people in a given year.
Health-Adjusted Life Expectancy (HALE)	The mean number of healthy years a person can expect to live, disregarding any disabilities, illnesses, or injuries.
Prospective DALYs (pDALYs)	A metric providing insights into how the DALYs rate is expected to change for new cases in a population, computed as the product of the DALYs per person (DALYs/prevalence), the incidence rate of the disease, and the HALE.
pDALYs Ratio	The ratio of the prospective DALYs between the elderly women and young adult populations, used for direct comparison of the respective impacts of the disease on these two populations.

Figure 1.1: The prevalence and DALYs per person trends of cardiovascular diseases in young adult women (ages 15-29) and elderly women (ages 70+). Both plots demonstrate that these variables are susceptible to massive changes over time with the elderly women population. With the DALYs rate, especially, there is a massive downward trend from 1998 to 2020 in this population, while in the younger population, there is lots of stability with the prevalence and a mild downward trend in the DALYs rate.

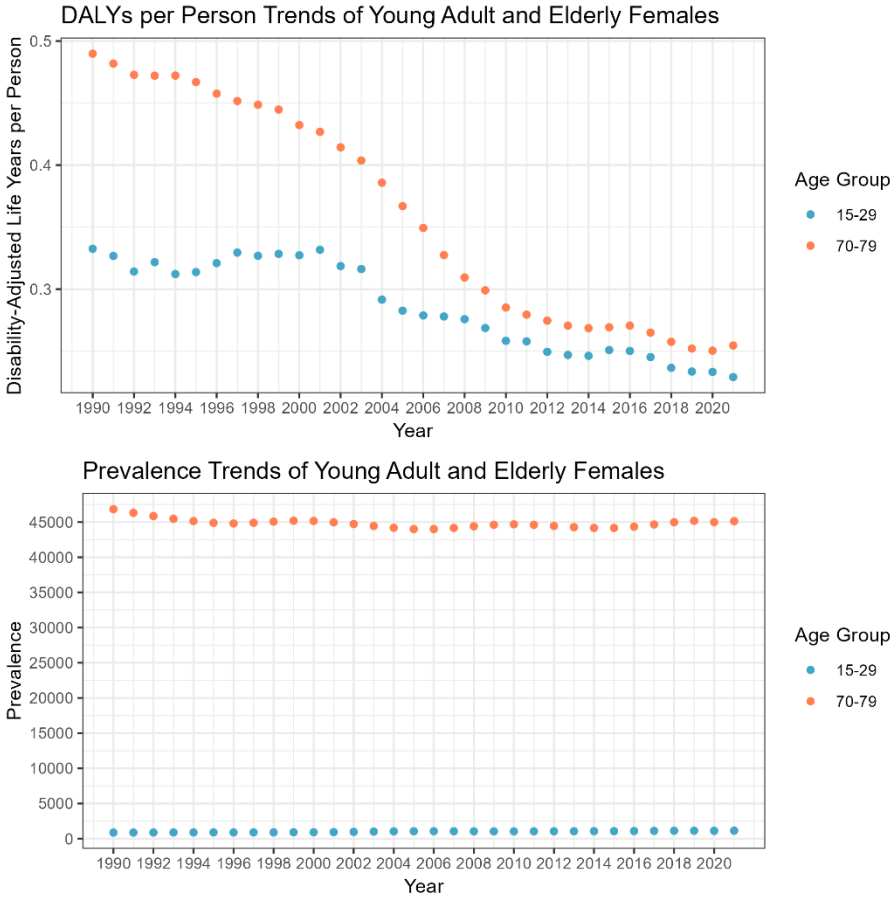


Figure 1.2: The prevalence and DALYs trends of cardiovascular diseases in samples from Florida and California. Observe that the trends in the DALYs remained consistent in both states up until 2008, when Florida began to trend upwards while California started to trend downwards. With the prevalence trends, it is evident that the total number of cases in Florida is significantly and consistently higher than that of California, but we see an uptick of cases in both states beginning at the start of the COVID-19 pandemic in 2020, with California having a larger increase in cardiovascular disease cases during this period.

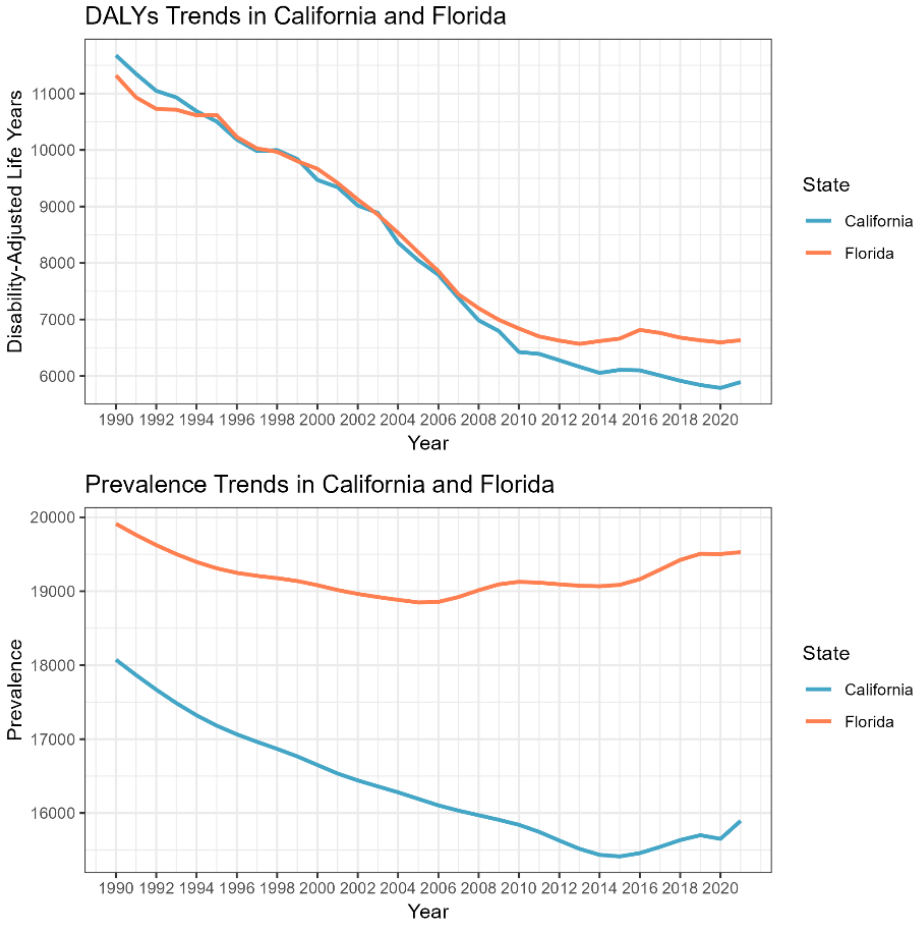


Figure 1.3: The prevalence and DALYs trends of cardiovascular diseases before and after the COVID-19 Pandemic. Note that the lack of variability in the box plots for the post-COVID-19 period is indicative of the low sample size of three years (2019-2021). With the DALYs box plots, however, we see an overall lower mean in the post-period, which is likely due to greater technological and medicinal advancements, helping to improve life expectancy. As with the cardiovascular disease prevalence trends in the age groups, there is some fluctuation over time with the mean prevalence not changing significantly despite the pandemic.

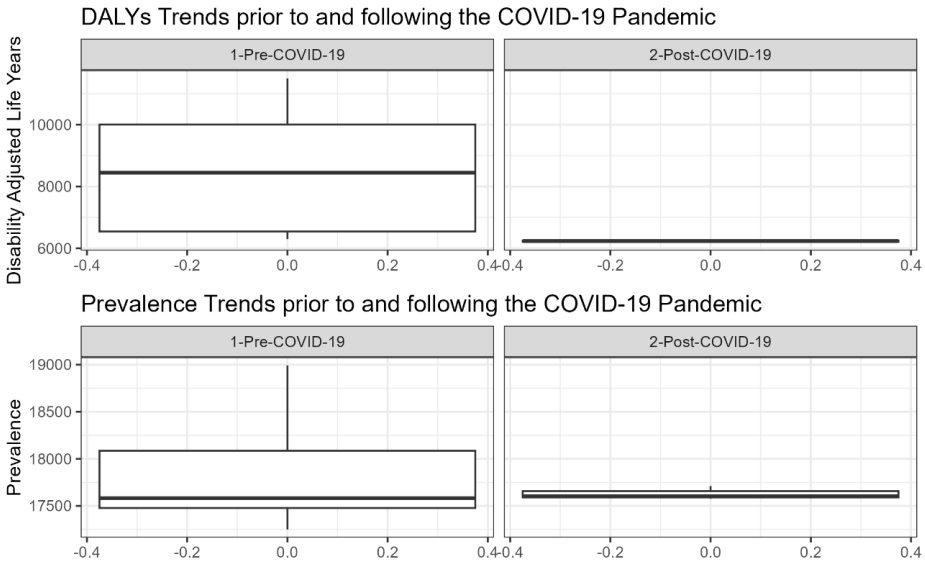
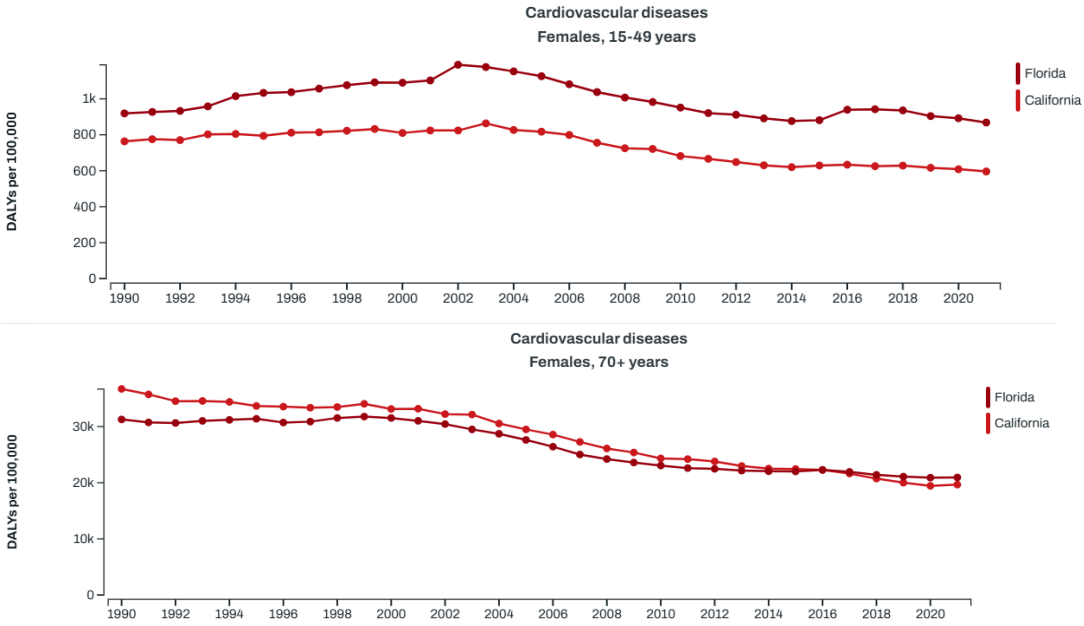


Figure 2: A plot generated through GBD tools displaying state-wide yearly trends in the disability-adjusted life years (DALYs) rates in cardiovascular patients aged 15-49 and 70+ years respectively.



Causal Impact Analysis:

Figure 3.1: A causal impact plot of the Disability Adjusted Life Years (DALYs) for cardiovascular diseases in the state of California. The BSTS model uses California's surface temperature and rainfall data to predict the DALYs following the intervention of COVID-19. Based on the fitted values of the model, the DALYs would fluctuate during this period if not for the pandemic.

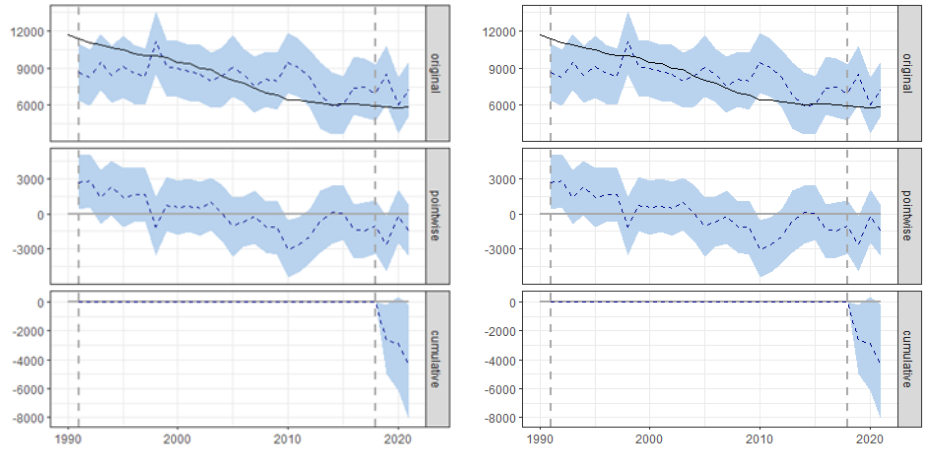


Figure 3.2: A causal impact plot of the Disability Adjusted Life Years (DALYs) for cardiovascular diseases in the state of Florida. The underlying BSTS model uses Florida's surface temperature and average rainfall from 1990 to 2018 to predict the DALYs following the start of the COVID-19 pandemic. Note that the fitted values of the model have a period trend, which continues into the start of the pandemic. The fluctuations of the predicted DALYs during this period, however, are less extreme relative to those in the causal impact analysis of the DALYs in California.

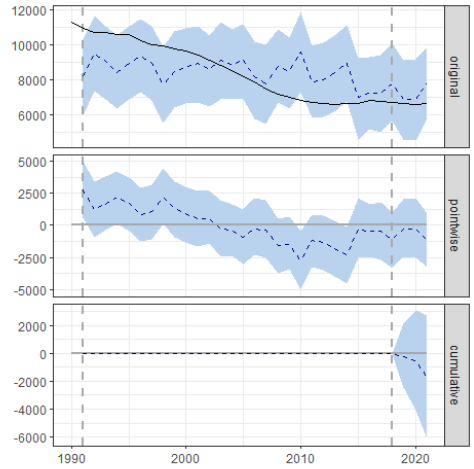


Figure 4.1: A causal impact plot of the prevalence of cardiovascular diseases in the state of California. It is evident that the BSTS model underestimates the prevalence of the disease in the late 1990's yet overestimates it from 2010 to 2020. Overall, however, the results are not statistically significant, implying that the pandemic alone most likely did not have a strong impact on the prevalence of cardiovascular diseases.

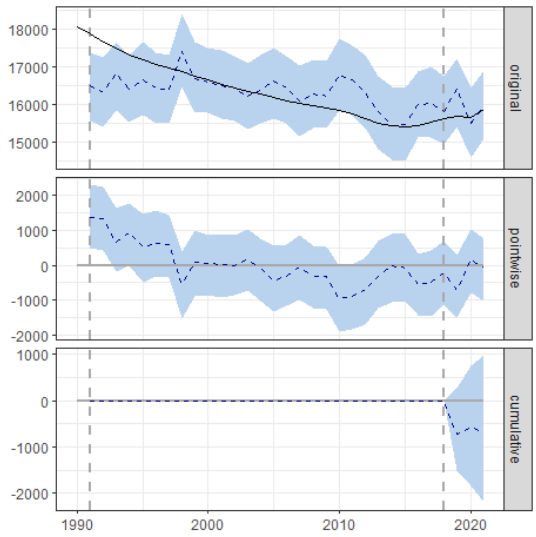


Figure 4.2: A causal impact plot of the prevalence of cardiovascular diseases in the state of Florida. Unlike the results in the causal impact analysis of the prevalence in California, it is clear that the BSTS model significantly underestimates the true prevalence during the observed years of the pandemic (2019-2021). Note that this difference in the observed prevalence and fitted prevalence from the model is substantial enough for the effect of the pandemic on the prevalence to be considered statistically significant.

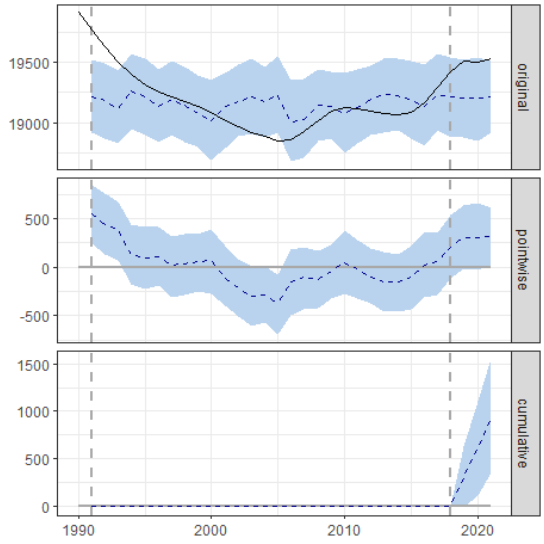


Figure 5.1: A causal impact plot of the prospective DALYs for cardiovascular diseases in the state of California for the young adult women population (ages 15-29). The underlying BSTS model uses California's rainfall and mean ground temperature for prediction of the pDALYs. Note that the decline in the prospective DALYs throughout the pandemic is statistically significant, implying that it is unlikely to have occurred by chance.

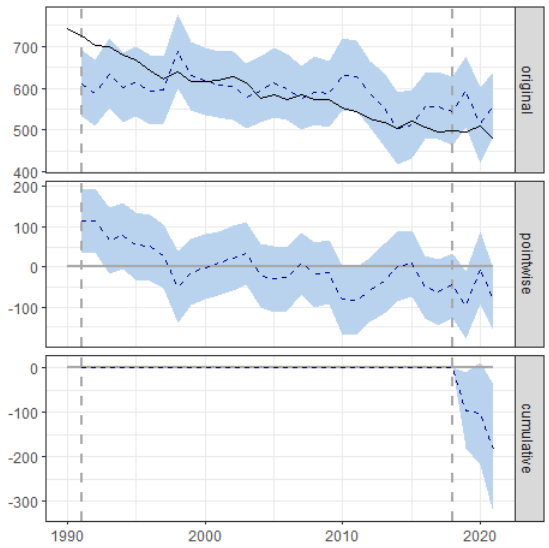


Figure 5.2: A causal impact plot of the prospective DALYs for cardiovascular diseases in the state of California for the elderly women population (ages 70-79). The fluctuation occurring during the period of the pandemic (2019-2021) is considered statistically significant, implying that these observations of the prospective DALYs during the years of the pandemic are unlikely to have occurred by chance.

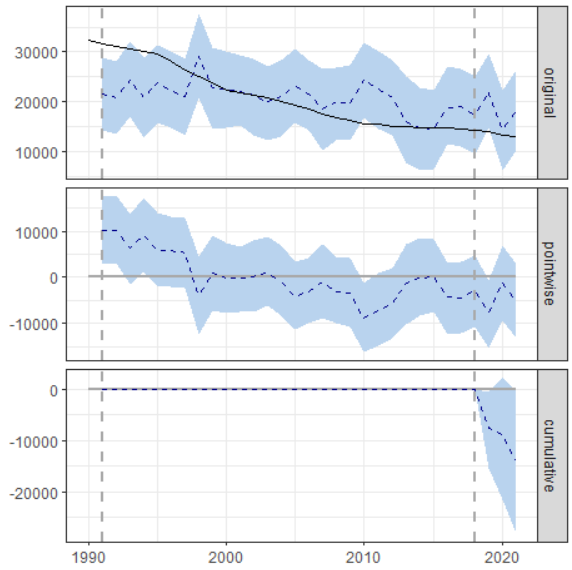


Figure 5.3: A causal impact plot of the prospective DALYs for cardiovascular diseases in the state of Florida for the young adult women population (ages 15-29). The underlying BSTS model uses Florida's mean rainfall and surface temperature data for prediction of the pDALYs.The drastic decline of the prospective DALYs during the years of the pandemic is statistically significant when compared to the fitted prospective DALYs from the BSTS model.

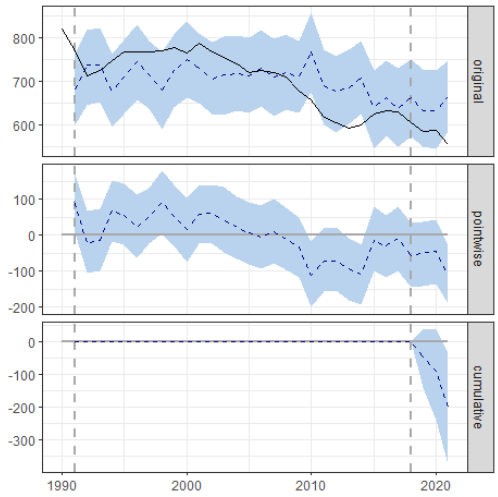


Figure 5.4: A causal impact plot of the prospective DALYs for cardiovascular diseases in the state of Florida for the elderly women population (ages 70-79). While the prospective DALYs mildly declines during the observed years of the pandemic, the difference between the fitted values of the BSTS model during this period and the observed prospective DALYs is not considered statistically significant.

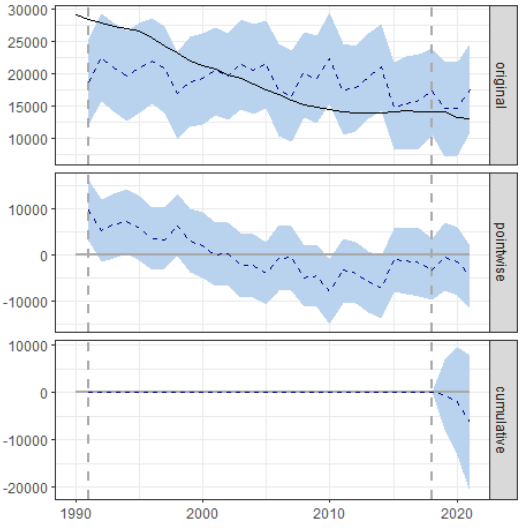


Figure 6.1: A causal impact of the ratio of the prospective DALYs between the elderly and young adult women populations in California. There is a statistically significant mild decrease in the ratio at the start of the pandemic followed by a slight uptick in the later months of 2020, aligning with the more extreme decrease in the prospective DALYs with young adult women compared to elderly women in California.

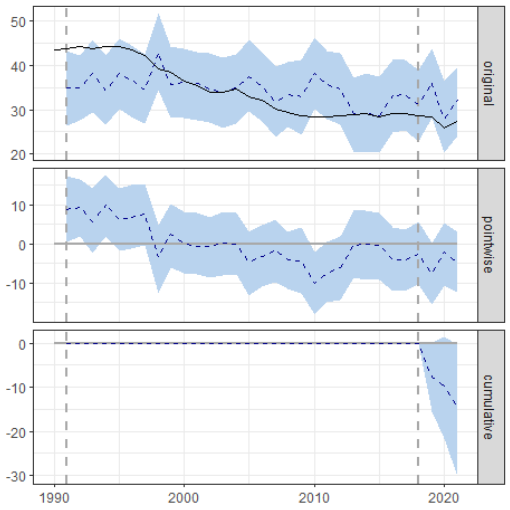
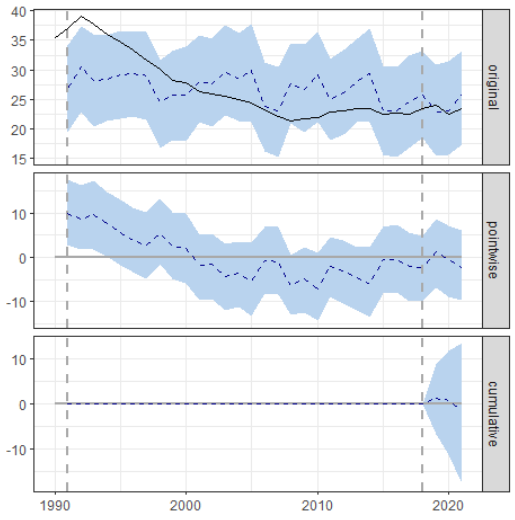


Figure 6.2: A causal impact of the ratio of the prospective DALYs between the elderly and young adult women populations in Florida. It appears that the ratio remained stable throughout the years of the pandemic, aligning with the expected values of the ratio from the underlying BSTS model.



Prospective DALYs Insights:

The prospective DALYs is computed annually as the product of the per person DALYs rate, the incidence of cardiovascular disease, and the health-adjusted life expectancy, standardizing the DALYs rate for comparison between different groups. Essentially, it provides important insights into how the DALYs rate is projected to change based on its rate per person and the number of new cardiovascular cases. In other words, the prospective DALYs forecasts the number of healthy years lost per every 100,000 new cardiovascular patients in a given year. For example, in the elder and young adult populations in California, the prospective DALYs for 2021 were 32,400.24 and 743.0795 respectively, demonstrating that in this state, the data projects a cardiovascular disease burden in the elderly women population approximately 44 times the magnitude of that of the young adult population. Given the new cases in California in 2021, it is expected that the elderly and young adult women populations will respectively lose a total of 32,400 and 743 healthy years per 100,000 people, suggesting that the risk factors for cardiovascular diseases are more present in the elderly women population as opposed to the young adult women population. Ultimately, this new metric sheds light on the impact of cardiovascular diseases on the remaining healthy years of certain populations.

Analyzing the causal impact plots for the prospective DALYs, most of the meaningful insights can be gathered from the young women populations in both states. In Florida, there is a drastic decline in the prospective DALYs for this age group. Based on the fitted values of the BSTS model, it is extremely unlikely that these results occurred by chance ($p=0.008$). Likewise, in California, the prospective DALYs plummets during the observed years of the pandemic, differing significantly from the fitted values of the BSTS model in this period ($p=0.01$). In the elderly women population, the prospective DALYs mildly declined in both states, but there is a statistically significant result in California ($p=0.024$). Despite similar trends occurring in Florida, there is no statistically significant deviation from the fitted values of the prospective DALYs from the BSTS model ($p=0.197$). When comparing both the young adult and elderly women populations, there is ultimately a much milder decrease in the prospective DALYs during the period of the pandemic with the elderly women population. The reasoning for the disparities between the young adult and elderly women populations can be due to several factors but is likely attributed to the fact that the older population was more susceptible to COVID-19 and thus prioritized quarantining over leaving the home to walk or exercise. On the contrast, as the younger population had a lower mortality rate from the virus, a majority of them were significantly less hesitant to continue engaging in their routine activities such as outdoor exercise, causing the prospective DALYs to decrease more drastically for this group during the pandemic.

To more directly compare changes in the prospective DALYs between young adult and elderly women in both states, this study conducted causal impact analyses on the prospective

DALYs ratios between these populations in their respective states. Recall that in California, the change in the prospective DALYs in the young adult women population was only slightly milder compared to that of the elderly women population (Figures 5.1, 5.2). Interestingly, however, in this state, there is a mild decline in the ratio in the initial months of the pandemic followed by a sudden increase in the later months of 2020 (Figure 6.1). Observing trends in Figure 5.1, there is a sharp decrease in the prospective DALYs around this time, mirroring the sudden increase in the ratio. Note that these changes in the ratio are statistically significant ($p=0.024$), suggesting that factors from the pandemic may be responsible for this deviation in the ratio. Recall that in Florida, the prospective DALYs in the young adult women population declined more drastically during the years of the pandemic compared to the elderly women population (Figure 5.3, 5.4). Overall, however, the ratio only slightly increases throughout the years of the pandemic, which is a peculiar result without any statistical significance ($p=0.433$) (Figure 6.2). The discrepancies between these two states may be a result of their differences in lockdown protocols, as California has a significantly higher stringency index compared to Florida. To elaborate, the less strict protocols in Florida may be correlated with the stability of the ratio, while the highly strict protocols in California may be leading to fluctuations in the ratio during the years of the pandemic.

Conclusions, Discussion, and Future Considerations:

An initial exploration of the IHME data indicates that the rate (per 100,000 people) of the prevalence of cardiovascular diseases is disproportionately higher in the elderly women population (age 70-79), suggesting that elderly women are more susceptible to developing cardiovascular diseases compared to young adult women (age 15-29) (Figure 1.1). Note that while this relationship holds for the rate of the DALYs, the prevalence of the disease is factored into the calculation of the DALYs through the Years Lived with Disability (YLD), leading to incomparable results. Upon standardizing the DALYs to account for this, it is evident that since the start of the pandemic, the total number of years deducted from life expectancy mildly increased in the elderly women population, with the opposite effect occurring in the young adult women population. Examining state-wide prevalence rates, Florida clearly has a much higher prevalence rate of cardiovascular diseases per 100,000 people compared to California (Figure 1.2). Observing the rates of change at the start of the pandemic, however, it is clear that the prevalence of cardiovascular diseases had a sharp uptick in California without much change occurring in Florida, which is likely due to California's high stringency index. This exact relationship holds when examining the DALYs trends in Florida and California, likely due to the positive correlation between the DALYs and the prevalence. Figure 1.3 demonstrates that the rates for the prevalence and DALYs remained consistent throughout the pandemic without much variability, but this is likely due to a low sample size of three years (2019-2021). In addition, technological and medicinal advancements are most likely responsible for the differences in the DALYs trends before and during the pandemic. Finally, using GBD comparison tools available through the Institute for Health Metrics and Evaluation (IHME) to create a visualization factored by age and state, it is evident that the trend in the DALYs rate is mostly consistent between California and Florida for both the respective 15-49 and 70+ year old age groups, but there is a mild increase in the DALYs rate in California for 70+ year old women at the start of the pandemic in 2020, which is supporting evidence for the claim that a higher stringency index is correlated with higher prevalence and DALYs rates for cardiovascular diseases (Figure 2).

Through conducting causal impact analyses on the prevalence of cardiovascular diseases and DALYs of cardiovascular patients in Florida and California respectively, one can gain insight into how the differences in their policies influenced the risk factors for developing this disease such as physical activity. For example, Florida had a statistically significant increase in the prevalence of the disease during the pandemic ($p=0.002$) (Figure 3.1), while in California, the change in the prevalence of the disease was not statistically significant during this period ($p=0.21$) (Figure 4.1). Interestingly, the decrease in the DALYs in Florida during the pandemic was not statistically significant ($p=0.218$), implying that these observations could have occurred by chance (Figure 3.2). In California, however, the decrease in the DALYs during the pandemic was statistically significant ($p=0.031$), suggesting that the intervention of the pandemic has a significant effect on the DALYs in this state (Figure 4.2).

Overall, the increased prevalence of the disease in Florida suggests elevated risk factors in their residents, which may indicate that physical activity declined despite the loose restrictions throughout the pandemic. In California, the decline in the DALYs during the period of the pandemic suggests that on average, cardiovascular disease had a reduced impact on the life expectancies of their residents. The stabilization of the prevalence in this state, however, may suggest that physical activity levels of residents did not change significantly during this period. To tie these insights back to the sample of breast cancer patients, these trends suggest that during the pandemic, breast cancer patients living in Florida may have significantly reduced physical activity levels, causing their quality of life to decline. Based on the exploratory analysis, it is evident that with the two age groups, the respective prevalences remained relatively stable throughout the period of the COVID-19 pandemic, but there is a consistently higher prevalence of the disease in elderly women as opposed to young adult women, suggesting that on average, elderly women may have lower physical activity levels compared to young adult women (Figure 1.1).

One drawback of this study is that it indirectly answers the research question through linking cases of cardiovascular diseases to physical inactivity and tying that back into the initial systematic review that discussed how rates of physical activity influence the outlook and quality of life of breast cancer patients. While this process is not ideal and has several flaws, it is the most compatible with the IHME database so that one can connect the prevalence of cardiovascular diseases to rates of physical activity. A disclaimer of this study is that there are many confounding variables that can result in diagnoses of cardiovascular diseases such as smoking habits, high blood pressure, and high cholesterol, implying that physical inactivity may not be a sole cause of developing this disease (Cleveland Clinic). To remedy this, one can either explore additional ideas that utilize data from the IHME database or consult external data that directly describes physical activity trends prior to and during the COVID-19 pandemic. Furthermore, it would be the most ideal to examine physical activity trends in a sample of women that are current and former breast cancer patients as opposed to conducting the analysis on a broad population of young and elderly women.

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