North Weymouth Compressor Station Proximity in Relation to Residential Cardiopulmonary Health in the Fore River Basin Area

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Abstract

In the United States, the natural gas industry continues to expand as the country switches from coal to natural gas as its main source for electricity generation. As the need for natural gas rises, the infrastructure required to collect and deliver natural gas has begun to increase. This includes the building of new pipelines and compressor stations. One of these newer pipelines travels through the South Shore of Massachusetts, where a compressor station was also recently built in the town of Weymouth. Due to the negative implications of compressor stations releasing toxic pollutants that contribute to air pollution, it is of great concern for Weymouth residents as well as other surrounding towns. The presented study thus looks at the negative health effects the compressor station may have on residents, asking the question, "Since its opening in January of 2021, how has the North Weymouth Compressor Station Affected surrounding residential cardiopulmonary health through its influence over air quality?". With almost no research that pertains to proximities to compressor stations and human health in the academic literature, the study plans to address this gap through the use of a non-experimental correlational analysis that looks at proximity and occurrence of cardiopulmonary diseases.

Introduction

Over the past decade, the natural gas sector of the United States has expanded exponentially, supplying 35% of U.S. electricity generation today (Hendryx, 2020). Surpassing coal as the United State's number one energy source, newer technological advancements in fracking, favorable economics, and a lower contribution to air pollution have contributed to the rise in natural gas consumption (U.S. Department Of Energy, 2015). With greater natural gas demand, the United States has experienced an increased building of infrastructure used to extract, transport, distribute, and deliver natural gas (Mass.gov, 2019). Currently, there are 217,000 miles of interstate natural gas pipelines in the United States to deliver gas from extraction sites to end users, with more being built as the industry continues to expand (U.S. Department Of Energy, 2015). As natural gas moves along pipelines, distance, friction, and elevation differences slow the movement of the gas and reduce pressure (Penn State Extension, 2015). Without pressure, the natural gas within the pipelines cannot continue, and transportation is halted. To maintain the flow of natural gas, companies must build compressor stations along the transmission lines. Compressor stations are industrial facilities containing one or more compressor units that receive gas from a pipeline and repressurize it through compression, allowing for continued gas flow (Natural Gas Pipeline Network, 2008). Strategically placed at 25-100 mile intervals on transmission lines to maintain a constant flow, the United States contains about 1,650 compressor stations (Hendryx, 2020). One of these compressor stations includes the North Weymouth compressor station, located in the Fore River Basin at 54 Bridge Street, North Weymouth. Beginning to flow gas in January of 2021, the North Weymouth compressor station was built as a part of the "Atlantic Bridge Project" by Enbridge, one of North America's largest energy infrastructure companies focusing on natural gas (Enbridge, 2023)

(Refer to Appendix A for a picture of the compressor station). Since its opening, however, the North Weymouth compressor station has seen backlash from residents surrounding it as many fear the negative implications allegedly associated with them.

Literature Review

Compressor Stations and Air Pollution

Natural gas, while predominantly methane, contains an array of naturally occurring organic and inorganic compounds (Nordgaard, 2022). When combusted or leaked into the environment, the compounds within the natural gas can be transformed and released. Due to the nature of the compounds, the Environmental Protection Agency (EPA) and the World Health Organization (WHO) have labeled them as "pollutants", grouping them into four different categories. As stated by the EPA, these four categories include gaseous pollutants, persistent organic pollutants, heavy metals, and particulate matter (EPA,2016). In addition, the release of these pollutants into the atmosphere has been identified by the WHO to contribute to ambient air pollution, the contamination of the outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere (WHO, 2016).

Compressor stations, which are heavily linked to natural gas, have been identified by a large body of literature as ample sources of air pollutants. One study conducted by D.O. Carpenter, who focused on the release of pollutants from 18 compressor stations in New York, found that the compressor stations produced over 40.2 million pounds of 70 different identifiable chemical pollutants in a year (Carpenter, 2017) (For a comprehensive list of pollutants, please refer to Appendix B). The most prominent of the pollutants discussed included Nitrogen oxides (NO2), Carbon monoxide, Volatile organic compounds, PM 2.5-10, and Sulphur Dioxide (SO2)(Carpenter, 2017). Additionally, studies done by the EPA have discussed that compressor

stations are the biggest source of fugitive emissions, leaking a combined total of 50.7 billion cubic feet (Bcf) of methane emissions annually from U.S. compressor stations (EPA, 2016). Dr. Cynthia Walter, a retired biology professor who has worked on shale gas industry pollution since 2009, augments Carpenter's and the EPA's findings by exploring the exact place of emissions from compressor stations and the specific pollutants that are released from them. Beginning with the compressor station engine, used to power the compressor unit, Walters describes how the engine uses methane as a fuel source. Through the combustion of methane gas, Walters iterates how nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOCs), and hazardous air pollutants (HAP) are released (Walter, 2021). Subsequently, Walters discusses how the primary source of pollutants from compressor stations is emitted through the processes known as a "blowdown". A "blowdown" is when gas within the compressors and associated piping is manually or automatically vented into the atmosphere when taken offline for maintenance or during an emergency shutdown (EPA,2016). Walters discusses how blowdowns are typically released through a smokestack, releasing the most varied amount of pollutants (Walter, 2021). Lastly, Walters includes how pollutants are emitted through "non-compressor procedures". Along with compressing natural gas, compressor stations also include filtration equipment meant to filter out particulates, water, or other pollutants that may have built up as they traveled through the pipeline. The particles filtered from the pipeline are frequently released on-site, contributing to increased particulate emissions (Walter, 2021). Storage tanks are also built on compressor stations and are used to hold waste substances. The substances, as described by Walters, that are stored on-site release fumes. If leaked or released, these fumes emit toxic VOCs and other chemical substances (Walter, 2021).

A study by a company named "Trinity Consultants", conducted a dispersion model for the North Weymouth compressor station. In their study, the company discussed topics much similar to Walters; however, they looked at the specific components of the North Weymouth compressor station instead of compressor stations in General. Trinity Consultants included a detailed outline of the North Weymouth compressor station, which included a SolarTaurus 60-7802 natural gas-fired turbine-driven compressor unit, a natural gas-fire emergency generator, a natural gas-fired turbine compressor fuel gas heater, five natural gas-fired catalytic space heaters, a parts washer, a separator vessel, smoke stacks, and storage tanks (Trinity Consultants, 2018). While the North Weymouth compressor station is not exactly like the general one described by Walters, Trinity Consultants identifies similar key emission components as well as others. As the North Weymouth compressor Station releases emissions, it is imperative to consider its contribution to air pollution in the Fore River Basin (To view the sources of emissions, please refer to Appendix C, which includes an image).

Cardiopulmonary Diseases and Air Pollution

As mentioned in previous studies, pollutants emitted from anthropogenic sources, such as compressor stations, negatively affect our environment as they contribute to ambient air pollution. Like our environment, Air pollution can significantly impact humans, with extensive evidence linking exposure to outdoor air pollution and health effects (Abelsohn, 2011).

In both their respective studies, Abelsohn and Kampa discuss the adverse effects air pollution has on the human body, highlighting the development of cardiopulmonary diseases, the medical term used to describe a range of severe disorders that affect the heart ("cardio-") and lungs ("-pulmonary")(Kampa, 2007). Albelsohn describes how long and short-term exposure to ambient air pollution has been linked to the development, as well as exacerbation of both

cardiovascular and respiratory diseases (Abelsohn, 2011). Kampa expands on this idea by discussing how the inhalation of certain pollutants can result in the body's immune system weakening, leaving the body vulnerable to infections in the lungs and thus causing respiratory issues. Kampa also discusses how certain pollutants have also been found to impair organ function, with one of them, carbon monoxide (CO), inhibiting the flow of oxygen to major organs in the body (like the heart and brain) by binding to hemoglobin (Kampa, 2007). In the rest of their studies, Kamap and Abelsohn list several specific cardiopulmonary diseases attributed to air pollution, including lower and upper respiratory infections, asthma, COPD, ischemia, lung cancer, leukemia, bronchitis, and emphysema (Abelsohn, 2011; Kampa, 2007). In agreement with Kampa and Abelsohn, the Environmental Health Project also found that long-term exposure to air pollution contributes to the development of chronic cardiac and respiratory illnesses, like coronary heart disease, lung cancer, COPD, and asthma (Environmental Health Project, 2022).

With a well-developed basis for what health problems air pollution can incite, other works of literature, like the Massachusetts Bureau of Waste Prevention, began looking at the pollutants that caused them. Presented in their annual air quality report, the Massachusetts Department of Waste Prevention states how NO2 lowers resistance to respiratory infections as well as how SO2 can harm and aggravate the respiratory tract and diseases such as asthma and bronchitis (Bureau of Waste Prevention, 2012). The review also discusses CO and CO2-causing cardiovascular diseases and symptoms such as coughing, chest pain, and shortness of breath. As well as how O3 can permanently damage the lining in the lungs, causing asthma attacks, nasal congestion, throat irritation, and reducing resistance to infection (Bureau of Waste Prevention, 2012). With CO, NO2, and SO2 being one of the primary pollutants emitted from the North Weymouth compressor stations, the air pollution surrounding the Fore River basin is expected to

result in similar cardiopulmonary diseases and symptoms among its residents. However, an analysis has yet to be completed.

The Fore River Basin (A Fragile Community)

The Fore River Basin is a small bay in Eastern Massachusetts that connects surrounding Massachusetts towns such as Weymouth, Quincy, Braintree, Higham, and Hull. According to LaRocque, the residential communities within the basin have been surrounded by heavy industrial development, such as gas and oil storage tanks, a hazardous waste processing facility, a biofuel processing facility, a fertilizer processing/pelletizing plant, a municipal power plant, one of the largest gas and oil-fired power generating plants in the state, a metering and regulating station, and a sewage pumping station (LaRocque, 2019). Along with the area containing 3A, a major commuting route used by more than 30,000 vehicles each day, and a significant import of ships in the basin, residents within the Fore River Basin area have been long exposed to heavy air pollution (LaRocque, 2019). While the EPA has stated the area has not gone below its standard air quality, studies such as the Massachusetts Environmental Public Health Tracking (MEPHT) have found that 35% of all deaths in the state are responsible by cardiopulmonary diseases, as well as their being a much higher pediatric asthma average in the town of Weymouth compared to other towns (MEPHT, 2022). The Massachusetts Environmental Public Health Tracking study thus displays that while quality may not break regulations, there is still a significant disparity compared to other locations.

In his Community Analysis, Baker found that the Four River Basin was a densely populated area containing schools, elderly housing, nursing homes, mental health facilities, and lots of residential housing (Baker,2019). Within his analysis, Baker also discovered two environmental justice communities, including Quincy Point and Germantown in Quincy.

Considering these aspects, the Fore River Basin is described as a fragile community already impacted by the pre-existing industrial facilities built there. However, since the addition of the North Weymouth Compressor, concerns for the community have been further expressed. While the addition of another industrial source may not seem like a significant change within the community, compared to the facilities that pre-existed the compressor station, LaRocque found that the compressor station would release 350 times the pollutants as the next biggest source in the Fore River Basin (LaRocque, 2019). Carpenter augments the concern of the addition of the compressor station by discussing how compressor stations are almost always located in sparsely populated rural areas as it is believed fewer people are exposed to the release of pollutants as there are higher concentrations the closer someone is to the station (Carpenter, 2017). Being located within a suburban area, where it is directly next to residents, the North Weymouth compressor station's location is an exception. With a considerable increase in emissions within the Fore River Basin and its unique location, it was apparent that a study needed to be conducted to better understand its impact. However, no such literature has been found.

The Gap

Pre-existing research addressed within the literature review has proven that compressor stations release air pollutants and that those pollutants can cause cardiopulmonary health problems. Additionally, research has also discussed higher concentrations of these pollutants closer to compressor stations. Assumptions within the scholarly community have thus been made that the pollutants released from compressor stations cause cardiopulmonary health issues and the assumption that as a consequence of higher concentrations closer to the compressor stations, closer proximity would result in more occurrences of cardiopulmonary diseases (Hendryx,2020). However, as described by Hendryx and Martin, these are purely assumptions, with research on

the relationship between compressor stations' proximity and residential health effects being utterly absent from the literature (Hendryx, 2020; Vollet Martin, 2021). A study on compressor station proximity and residential cardiopulmonary health was thus apparent to fill this gap within the literature. Correspondingly, the research question: "Since its opening in January of 2021, how has the North Weymouth compressor station affected surrounding residential cardiopulmonary health through its influence over air quality?" was created.

With the North Weymouth compressor station's proximity to residents being diminutive, the area was an optimal location to conduct the study. In addition, compared to other compressor stations, the North Weymouth compressor station could provide more accurate data as it is one of the only locations that could account for residents directly next to it. With this in mind, as well as the pre-existing assumptions already made within the scholarly community, the study hypothesized there would be a relationship with increased proximity to the compressor station resulting in more cardiopulmonary health effects in residents.

Method

Pearson Correlation

To understand the relationship between the North Weymouth compressor station and its impact on residents near the Fore River Basin, a non-experimental study was conducted with a correlational method. Due to the relationship of the variables relative to the study being absent in the literature, a Pearson correlation was evident to establish prevalence and relationships among the variables by calculating an r-value (Curtis, 2016). The variables measured in the study included proximity to the compressor station and residential health.

Sampling

To gather data on the residents surrounding the North Weymouth compressor station, a survey was conducted. The survey, labeled "Compressor Station Health Assessment", encompassed a consent form that participants electronically signed, as well as the questions of inquiry. The survey was broken into three sections with a total of 29 questions. The first section pertained to general demographic information, asking for gender, race, age, the town of residency, zip code, and the street the participant lived on. This section served to find specifics about each respondent, as extensive literature had identified how air pollution affects age, gender, and race differently. Zip Code and the street name each participant lived on were also necessary to find each participant's proximity to the compressor station. The second section of the survey was related to general cardiopulmonary diseases identified in the previous literature. The section included 15 different "yes" and "no" questions asking the participant if they had been officially diagnosed with the disease listed in the question (To learn more about the diseases mentioned, please refer to Appendix D.). The "Disease" section of the survey was used to record any existing cardiopulmonary diseases within the population being studied to be later correlated with the participants' distance as they would represent the population's health. To prevent the data from being skewed, the participants were explicitly asked to only answer "yes" to a question only if a medical professional had officially diagnosed them. While this may have prevented some participants from reporting self-diagnoses, participants may have been influenced by subject bias, answering how they think the researcher wants them to rather than naturally. To further ensure the validity of the participant's responses, every question was prompted with "subsequent to January of 2021 have you been diagnosed with". The questions in this section were phrased this way as any cardiopulmonary disease developed before January 2021 would not

be significant to the study as the compressor station had not started flowing gas yet. Therefore not releasing any air pollutants that could affect residential health. The third section of the survey discussed symptoms relative to cardiopulmonary diseases. This section included 7 "yes" and "no" questions asking the participant if they have experienced different symptoms linked to certain cardiopulmonary diseases (To find information about the symptoms mentioned, please refer to Appendix D.). The "symptom" section of the survey was used to see if there was any development of cardiopulmonary diseases among the participants, as the development of certain cardiopulmonary diseases has been discussed to be dependent on short or long-term exposure to air pollution. With the compressor station only being opened for approximately two years as of 2023, it was necessary to accommodate for the short exposure time by looking at possible symptoms that are more likely to have developed in the time frame. This allowed the study to maintain relevance if no "disease" section results yielded was significant. A concern relative to the "symptom" section of the survey includes how the questions are opinion based. Due to most symptoms being subjective to the participant in question, the reliability of the data collected from the section is diminished. However, some of the symptoms asked, including blood pressure and heart attacks, are objective due to the nature of the symptom being evident to the patient and showing physical signs that are easily identifiable to a doctor. For the same reason as the second section labeled "diseases", the questions for the "symptom" section of the survey were phrased to start with the statement "subsequent to January of 2021" to only obtain data from after the compressor station was built (Please refer to Appendix E for the survey and its corresponding questions).

Extensive literature within the medical field has shown the importance of using surveys to collect health and social science information within a population (NLM, 2019). In addition,

large organizations such as The Department of Health and Human Services (HHS), along with the U.S. Census Bureau, have used surveys in the past to gain a better understanding of larger populations within the U.S. (NLM,2019). Therefore, the researcher found the use of a survey appropriate for the study as the population being studied included five towns (Weymouth, Quincy, Braintree, Hingham, and Hull), with individual populations of each town ranging from about 10,000 to 100,000. Accompanying the ability to garner numerous responses, a survey also allowed for gathering large amounts of data from each participant, as surveys can ask multiple questions to obtain simple information. While the main drawback to using a survey includes the inability to get detailed information, the study did not require detailed responses from its participants, assisting the decision in choosing a survey.

The survey was sent out to the town's populations through a post created by the researcher on each of the town's most popular Facebook pages. These groups included "Everything Weymouth", "Quincy is Everything", "Braintree is Everything", "Hingham is Everything", and "Today in Hull, MA". Using each of the towns' Facebook pages allowed for the survey to be seen by a larger population, allowing more people to see and take the survey than if the researcher sent out individual survey forms.

GIS Mapping (Finding Proximity)

Succeeding the collection of participants' street addresses, a means to find the proximity of each participant's address was imperative. GIS, or "Geographical Information System", is a mapping software containing extensive geographical data that can be used to assess the proximity of vulnerable populations to environmental hazards (Chakraborty, 2010). As a medium to analyze proximity to the compressor station, an environmental hazard, it was evident that the study should use a GIS system, much like other health assessment studies, to find proximity.

With the GIS system, participants' street addresses collected through the survey were imputed into the system, where it calculated and mapped the distance between each street location and the North Weymouth compressor station. After finding their proximity to the station, the participants were classified according to distance from the compressor station in categories labeled 0-2 km, 2-4 km, 4-6 km, 6-8 km, and 8-10 km, as displayed in Figure 1 below. With the creation of distance groups, the participant's proximity to the station was better organized as they became nominal variables to conduct a correlation (Peter M. Rabinowitz, 2015). Proximity groups were also used to follow the procedures of a previous study by Chakraborty, who also used a GIS system to look at a population's proximity to an environmental hazard. The only difference from Chakraborty's study was the distance range used for each group, changing from 1 km to 2 km intervals due to the larger study area.

While a GIS system can accurately measure the distance between two points, the system does not account for elevation, only measuring in a straight line. As a result, the proximity of each resident could be off, leading to some residents being assigned to a group they were not meant to be in.

Group 1: 0-2 km

Group 2: 2-4 km

Group 3: 4-6 km

Group 4: 6-8 km

Group 5: 8-10 km

Figure 1: Proximity map

Proximity map, produced by the GIS system, of the Fore River Basin and the surrounding towns that participated in the study. Each colored ring represents the distance group with the corresponding color.

Data Analysis

Organizing the Data

From the surveys sent out to the five different town's Facebook groups, 318 responses were garnered. Of the 318 participants, only a certain number of participants' responses could be analyzed, as some answered only a portion of the questions within the allotted survey. The remaining participants' responses to the questions were transported onto Google Sheets to organize the findings better and transform all "no" and "yes" responses into nominal variables. Due to a Pearson correlation only being able to compute the relationship between numbers, it was essential to transform the responses to each participant's health questions into a number to

correlate them with the participants' proximity group. Regarding the nominal variables used during the computation, "no" was represented as 1, and "yes" was represented as 2. Before further analyses, the most significant of the twenty-two questions pertaining to if a participant had a specific cardiopulmonary disease or cardiopulmonary symptom was chosen. Many of the questions asked, including cardiopulmonary diseases like Leukemia and Lung Cancer, only got one or zero "yes" responses. Since an analysis of questions that were evidently inconsequential in the first place was superfluous, only questions that received a significant amount of yes responses were looked at. Ultimately, a high occurrence of a disease or symptom indicated something occurring within the community that should be looked at, while a low occurrence did not. Of the fifteen cardiopulmonary diseases and seven symptoms, an initial analysis of the most significant questions was thus conducted. These included cardiopulmonary diseases: bronchitis, asthma, upper respiratory infections (URTI), and lower respiratory infections, as well as cardiopulmonary symptoms: high blood pressure/heart attacks, dizziness, shortness of breath, wheezing, coughing, chest pain, and difficulty in strenuous activities. Within google sheets, the Pearson correlation function was then used to correlate the participants' answers to the question pertaining to the cardiopulmonary disease or symptom and their proximity (For access to the complete compilation of outcomes, please consult Appendix F).

Singular Disease and Symptom Results

Of the four cardiopulmonary diseases and seven symptom questions looked at in the initial analysis, three were chosen with the highest r-value from the Pearson's correlation to be further analyzed. These included two cardiopulmonary diseases, bronchitis and URTIs, and one cardiopulmonary symptom, heart attacks/high blood pressure. Due to the research trying to find a relationship between the proximity of the North Weymouth compressor station and health

effects, it was only necessary to further analyze the diseases and symptoms with the highest r-value as they would indicate if there was a relationship or not.

Bronchitis

For the first disease, bronchitis, 38 of the 297 participants who answered the question stated they had bronchitis from January 2021 to the time of response, and 259 people reported they did not, in accordance with Figure 2. Regarding the proximity groups, for group 1, 9 reported "yes", and 75 reported "no". For group 2, 13 reported "yes", and 117 reported "no". For group 3, 13 reported yes, and 35 reported no. For group 4, 2 reported "yes", and 17 reported "no". Finally, for group 5, 1 reported "yes", and 15 reported "no". With the reported data from each participant, a correlation of the occurrence of bronchitis in the population to proximity could occur, with the Pearson correlation coefficient for bronchitis being an r-value of about 0.057.

Bronchitis		
Proximity to Compressor Station	yes	no
1 (0-2 km)	9	75
2 (2-4 km)	13	117
3 (4-6 km)	13	35
4 (6-8 km)	2	17
5 (8-10 km)	1	15
Total:	38	259
Correlation Coefficient:	**0.05712455704**	

Figure 2: Bronchitis Data Table

Displayed in Figure 2 is a comprehensive data table that provides insights into bronchitis. The table presents the number of "yes" and "no" responses obtained from participants who reported having or not having bronchitis. These responses are grouped based on the proximity of the participants. Additionally, the table also includes the r-value located at the bottom.

URTI

As shown in Figure 3 for URTI, 55 of 298 participants who answered the question stated they had a URTI from January 2021 to the time of response, and 243 people reported they did not. Regarding the proximity groups, for group 1, 15 reported "yes", and 69 reported "no". For group 2, 19 reported "yes", and 111 reported "no". For group 3, 14 reported "yes", and 34 reported "no". For group 4,4 reported "yes", and 16 reported "no". Finally, for group 5, 3 reported "yes", and 13 reported "no". With the reported data from each participant, a correlation of the occurrence of URTIs in the population to proximity could occur, with the Pearson correlation coefficient for URTIs being an r-value of about 0.051.

URTI		
Proximity to Compressor Station	yes	no
1 (0-2 km)	15	69
2 (2-4 km)	19	111
3 (4-6 km)	14	34
4 (6-8 km)	4	16
5 (8-10 km)	3	13
Total:	55	243
Correlation Coefficient:	**0.05132952238**	

Figure 3: URTI Data Table

Displayed in Figure 3 is a comprehensive data table that provides insights into URTI. The table presents the number of "yes" and "no" responses obtained from participants who reported having or not having an URTI. These responses are grouped based on the proximity of the participants. Additionally, the table also includes the r-value located at the bottom.

High blood pressure/Heart attacks

Lastly, as reported by Figure 4 for high blood pressure/heart attacks, 53 of 299 participants answered yes to experiencing the symptom between January of 2021 and the time of response, and 243 people reported they did not. Regarding the proximity groups, for group 1, 15 reported "yes", and 68 reported "no". For group 2, 20 reported "yes", and 112 reported "no". For group 3, 10 reported yes, and 38 reported no. For group 4,4 reported "yes", and 16 reported "no". Finally, for group 5, 4 reported "yes", and 12 reported "no". With the reported data from each participant, a correlation of high blood pressure/heart attacks in the population to proximity could occur, with the Pearson correlation coefficient for URTI being an r-value of about 0.045.

HBP/Heart Attacks		
Proximity to Compressor Station	yes	no
1 (0-2 km)	15	68
2 (2-4 km)	20	112
3 (4-6 km)	10	38
4 (6-8 km)	4	16
5 (8-10 km)	4	12
Total:	53	246
Correlation Coefficient:	**0.04566071446**	

Figure 4: HBP and Heart Attacks Data Table

Displayed in Figure 4 is a comprehensive data table that provides insights into high blood pressure and heart attacks.. The table presents the number of "yes" and "no" responses obtained from participants who reported having or not having the symptom. These responses are grouped based on the proximity of the participants. Additionally, the table also includes the r-value located at the bottom.

Significance of r-values

For a correlation, the r-value represents the strength of the relationship between the two correlated variables. A positive or negative r-value between 0.7 and 1 indicates a high correlation and that the two variables are highly related. A negative or positive r-value of 0.5-0.7 indicates the variables are moderately correlated, while a positive or negative r-value between 0.3 and 0.5 indicates a low correlation. Finally, a positive or negative r-value between 0 and 0.3 means there is no correlation, and the two variables are independent of each other. Looking for a relationship between the proximity of the North Weymouth compressor station and residential health through

the occurrence of cardiopulmonary diseases and symptoms, the r-value calculated from the data would reveal if there was a relationship and how strong it was.

While bronchitis, URTIs, and high blood pressure/heart attacks had the highest r-values of all 22 health questions analyzed, the r-values for each were very close to a value of 0. Falling between the range of 0 and 0.3, the r-values from the Pearson correlation revealed no relationship between any individual cardiopulmonary disease or symptom (which represents residential health) with proximity to the North Weymouth compressor station. After seeing that there was no significance in each individual symptom and disease asked, a correlation was conducted for both the total amount of cardiopulmonary diseases and the total amount of cardiopulmonary symptoms in the population.

Total Disease and Symptom Results

Due to a singular cardiopulmonary disease or symptom not accurately representing the entire population's health, it was still necessary to look at cardiopulmonary diseases or symptoms as a whole. Each Cardiopulmonary disease and symptom looked at develops independently of each other. One could develop within an individual over another due to other factors. So, by looking at the total amount of each, it would more accurately represent and display the overall health of the participants and show if the North Weymouth compressor station and proximity truly affect residential health.

While significantly more people responded "yes" to both, according to Figures 5 and 6, with 100 people having any cardiopulmonary disease and 158 having any symptom within the total population studied, the r-values for both were not any higher than that of the individual correlations. With the reported data from all participants, a correlation of all cardiopulmonary diseases present within the population to proximity could occur, with the Pearson correlation

coefficient being an r-value of about 0.050. Likewise, with the reported data from all participants, a correlation of all cardiopulmonary symptoms present within the population to proximity could occur, with the Pearson correlation coefficient being an r-value of about 0.01.

All Cardiopulmonary Diseases		
Proximity to Compressor Station	yes	no
1 (0-2 km)	27	57
2 (2-4 km)	39	93
3 (4-6 km)	21	27
4 (6-8 km)	8	12
5 (8-10 km)	5	11
Total:	100	200
Correlation Coefficient:	**0.05040757644**	

Figure 5 : All Cardiopulmonary Diseases Data Table

All Cardiopulmonary Symptoms		
Proximity to Compressor Station	yes	no
1 (0-2 km)	47	37
2 (2-4 km)	66	66
3 (4-6 km)	23	25
4 (6-8 km)	13	7
5 (8-10 km)	9	7
Total:	158	142
Correlation Coefficient:	**0.01001510773**	

Figure 6: All Cardiopulmonary Symptoms Table

Displayed in Figure 5 is a comprehensive data table that provides insights into all cardiopulmonary diseases within the participants. The table presents the number of "yes" and "no" responses obtained from participants who reported having or not having a cardiopulmonary disease. These responses are grouped based on the

Displayed in Figure 6 is a comprehensive data table that provides insights into all cardiopulmonary symptoms within the participants. The table presents the number of "yes" and "no" responses obtained from participants who reported having or not having a symptom. These responses are grouped based on the proximity of the

Conclusion

As seen in the figures, the r-values for each correlation are between a value of 0 and 0.3. Falling in this range of r-values, with the highest r-value only reaching 0.05712455704, the study deduced that there is no correlation present in any manner. Therefore, since a correlation represents the presence of a relationship, with no correlation present between any of the diseases or symptoms, there is ultimately no relationship between proximity to the North Weymouth compressor station and residential cardiopulmonary health. The original research question is thus

answered with the North Weymouth compressor station not affecting people's cardiopulmonary health, and the hypothesis that increased proximity is related to an increase in cardiopulmonary health effects addressed earlier in the study is refuted.

Limitations

As stated in the previous literature, cardiopulmonary diseases and symptoms can be developed from short-term and long-term exposure to ambient air pollution. According to Mass.gov, most cardiopulmonary diseases and symptoms discussed in the paper have a long latency period, ranging between five to ten years (Mass.gov, 2019). Since the compressor station has only been in operation for two years, the residents surrounding the compressor station have yet to be exposed long enough to ambient air pollution to see an effect on their health. Respectively, this could explain why no correlation was found from the data, as residents have not yet developed or experienced the cardiopulmonary diseases or symptoms studied. In addition to the interval of time in which the study was conducted not being long enough, the specific period in which the study was analyzed could also have skewed the study's results. A major event that transpired from January of 2021 to the time the study was conducted included the Covid-19 pandemic. As warranted by Michos, Covid-19 had lasting adverse effects on many people, specifically people's cardiopulmonary systems. Damaging people's cardiopulmonary systems, Covid-19 has left many people susceptible to the development of cardiopulmonary diseases and symptoms (Michos, 2022). As a result, some of the cardiopulmonary disease recorded may have been caused by Covid-19, influencing the r-values of each correlation as it was no longer just an analysis of the compressor station's effects. Lastly, the study did not account for the participants' age or history of drug use. Due to the body's immune system weakening from old age and drug use such as smoking, residents could have developed certain

cardiopulmonary diseases from these outside factors rather than the compressor station itself. As a result, the reported data could have been skewed so that people who lived farther away from the station displayed more cardiopulmonary health problems, resulting in a lower r-value as it offset the number of people who could have had a cardiopulmonary disease from living closer to the compressor station.

Implications

The significance of the study is the discovery that there is no relationship between the North Weymouth compressor station and residential cardiopulmonary health. With this information, the residents surrounding the North Weymouth compressor station can quell their anxieties about the negative implications the compressor station may have on their cardiopulmonary health, as the conclusion disproves it would have any adverse effects. Moreover, Enbridge and other natural gas companies can also use the study's findings to defend the future building of compressor stations in residential areas. The main reason why compressor stations were not built in residential areas initially was due to the unknown human health effects they could cause. However, the study results indicated it is safe, as no relationship implies otherwise. As a result, natural gas companies can build more compressor stations in residential areas until further developments.

Ultimately, with the study finding no relationship for the North Weymouth compressor station, other researchers within the community of practice could also imply that there may not be a relationship present for compressor stations in general. While each compressor station may differ, the differences are not significant enough to completely dispel the argument. While residents' proximity and population density fluctuate for each station, the current study found that there was still no relationship even in a close, densely populated area where the

concentration was high. It is thus reasonable to infer that if there were no relationship where people were directly next to the compressor station and exposed to higher concentrations of pollutants, there would also be none where proximity was larger, as it has been proven by previous scholarly work that exposure to less amount of pollutants results in lower occurrences of cardiopulmonary health effects. Nonetheless, a study for each station should be conducted as a correlation is not able to prove causation and we cannot generalize the results.

Future Directions

Although the study concluded there was no relationship between the North Weymouth compressor station, monitoring the site to see if any changes have occurred is essential. Future studies could replicate the same method used within the study but conduct it ten years from now to address one of the limitations: there might not have been a significant relationship due to the latency period of the health effects. If another study was to be conducted ten years later, the amount of time should display a significant difference or confirm the current results.

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Appendices

Appendix A: Image of North Weymouth compressor station

The image presented is of the North Weymouth compressor station located in the Fore River Basin at 54 Bridge Street, North Weymouth (Enbridge, 2023).

Appendix B: Types of pollutants

The following tables were adapted from Carpenter's research on compressor stations in New York, where they identified 70 different types of chemical pollutants (Carpenter, 2017).

Rank		Pounds						
	Description	2008	2011	2014	3-Years	3-Yr-Avg	7 Years	%
1	Nitrogen oxides (NO2)	2,269,341	2,993,049	2,487,284	7,749,673	2,583,224	18,082,571	45.22
2	Carbon monoxide	1,415,996	2,030,629	1,850,403	5,297,028	1,765,676	12,359,731	30.91
3	Volatile organic compounds	374,277	831,915	902,548	2,108,741	702,914	4,920,396	12.31
4	Formaldehyde	110,334	229,882	220,928	561,144	187,048	1,309,336	3.27
5	PM10 Primary (Filt + Cond)	107,946	242,279	189,665	539,890	179,963	1,259,744	3.15
6	PM 2.5 Primary (Filt + Cond)	92,595	220,983	160,507	474,085	158,028	1,106,198	2.77
7	PM Condensable	43,227	109,501	78,815	231,543	77,181	540,267	1.35
8	Sulfur dioxide	7,587	14,174	58,287	80,048	26,683	186,778	0.47
9	Acetaldehyde	4,385	15,091	8,797	28,272	9,424	65,969	0.16
10	Acrolein	3,226	11,742	7,628	22,596	7,532	52,723	0.13
11	Benzene	2,029	3,876	3,199	9,103	3,034	21,241	0.05
12	Methanol	1,381	4,324	2,580	8,286	2,762	19,333	0.05
13	Toluene	1,267	3,633	3,375	8,275	2,758	19,308	0.05
14	Hexane, n-	1,939	1,780	1,502	5,222	1,741	12,184	0.03
15	Xylene (mixed isomers)	360	1,460	1,777	3,598	1,199	8,394	0.02
16	Butadiene, 1,3-	273	999	751	2,022	674	4,719	0.01
17	Trimethylpentane, 2,2,4-	238	931	735	1,905	635	4,445	0.01
18	Ethyl benzene	155	577	466	1,198	399	2,794	0.01
19	Ammonia	262	238	174	674	225	1,573	0.00
20	Phenol	33	149	121	303	101	706	0.00
21	Naphthalene	50	154	94	298	99	696	0.00
22	Nickel	169	21	107	296	99	692	0.00
23	Biphenyl	68	178	49	296	99	690	0.00
24	Methane dichloride [1910.1052]	31	118	120	269	90	629	0.00
25	Propylene oxide	7	115	142	263	88	615	0.00
26	Manganese	104	0	47	150	50	350	0.00
27	Ethylene dibromide	29	71	49	149	50	347	0.00
28	Tetrachloroethane, 1,1,2,2-	26	64	42	132	44	309	0.00
29	Carbon tetrachloride	24	59	38	121	40	282	0.00
30	Trichloroethane, 1,1,2-	21	52	33	106	35	247	0.00
31	Styrene	18	49	33	100	33	234	0.00
32	Chloroform	18	45	19	83	28	193	0.00
33	Methylnaphthalene, 2-	15	55	12	82	27	191	0.00
34	Chlorobenzene	19	36	19	74	25	172	0.00
35	Propylene dichloride	17	35	18	70	23	164	0.00
36	Dichloropropene, 1,3	17	34	18	69	23	161	0.00
37	Ethylene dichloride	16	32	17	65	22	151	0.00
38	Ethylidene dichloride	15	31	16	62	21	144	0.00
39	Vinyl chloride	10	24	12	46	15	107	0.00
40	Mercury	17	7	6	30	10	70	0.00
41	Chromium (III) compounds (as Cr)	16	0	7	24	8	56	0.00
42	Phenanthrene	4	14	2	21	7	48	0.00
43	Polycyclic aromatic hydrocarbons, total (PAHs Total)		0	15	15	5	35	0.00
44	Cadmium	9	0	4	13	4	30	0.00
45	Fluorene	2	8	1	12	4	28	0.00
46	Benz[a]anthracene	4	2	2	8	3	19	0.00
47	Benzo(j,k)fluorene	2	2	1	5	2	11	0.00

Rank	Description	Pounds 2008	2011	2014	3-Years	3-Yr-Avg	7 Years	%
48	Anthracene	0	4	0	4	1	10	0.00
49	Perchloroethylene [PERC PCE, Tetrachloroethylene]	1	2	1	4	1	9	0.00
50	Acenaphthene	1	2	1	4	1	8	0.00
51	Pyrene	1	2	0	3	1	7	0.00
52	Ethyl chloride (Chloroethane)	1	2	0	3	1	6	0.00
53	Acenaphthylene	2		-	2	1	5	0.00
54	Chrysene	0	1	0	2	1	4	0.00
55	Chromium (VI) & inorganic Cr6+ compounds	1	0	0	1	0	2.3	0.00
56	Benzo[g,h,i]perylene	0	1	0	1	0	1.7	0.00
57	Benzo[b]fluoranthene	0	0	0	0	0	0.7	0.00
58	Lead	0	0	0	0	0	0.6	0.00
59	Benzo[e]pyrene	0			0	0	0.09	0.00
60	Arsenic	0	0	0	0	0	0.06	0.00
61	Cobalt	0	0	0	0	0	0.03	0.00
62	Indeno[1,2,3-cd]pyrene	0	0	0	0	0	0.02	0.00
63	Benzo[a]pyrene	0	0	0	0	0	0.01	0.00
64	Selenium	0	0	0	0	0	0.01	0.00
65	Perylene	0			0	0	0.00	0.00
66	Beryllium	0	0	0	0	0	0.00	0.00
67	Dimethylbenz[a]anthracene, 7,12-		0	0	0	0	0.00	0.00
68	Benzo[k]fluoranthene	0			0	0	0.00	0.00
69	Methylcholanthrene, 3-		0	-	0	0	0.00	0.00
70	Dibenz[a,h]anthracene	0			0	0	0.00	0.00

Appendix C: Emission sources

The figure presented below is of the North Weymouth compressor station. The structures shown within the figure are the components within the North Weymouth compressor station that have been identified to release pollutants. The structure labeled “A” is the smoke stack where blowdowns occur. The structure labeled as “B” is the pipeline liquid condensate tank that stores the natural gas, which primarily releases pollutants through fugitive emissions. Finally, the structure labeled “C” is the compressor unit that volatilizes liquid to a gaseous state as it moves from high pipeline pressure to atmospheric pressure (Nordgaard, 2022).

Appendix D: Types of pollutants

The following tables include a list of Cardiopulmonary disease and symptoms asked in the survey. Within the table the definition for each of the disease and symptoms are given (Mayo Clinic, 2022).

Cardiopulmonary Disease:	**Definition:**
Chronic Obstructive Pulmonary Disease	"Chronic obstructive pulmonary disease (COPD) is a chronic inflammatory lung disease that causes obstructed airflow from the lungs. Symptoms include breathing difficulty, cough, mucus (sputum) production and wheezing. It's typically caused by long-term exposure to irritating gasses or particulate matter, most often from cigarette smoke. People with COPD are at increased risk of developing heart disease, lung cancer and a variety of other conditions."
Bronchitis	"Bronchitis is an inflammation of the lining of your bronchial tubes, which carry air to and from your lungs. People who have bronchitis often cough up thickened mucus, which can be discolored. Bronchitis may be either acute or chronic."
Emphysema	"Emphysema is a lung condition that causes shortness of breath. In people with emphysema, the air sacs in the lungs (alveoli) are damaged. Over time, the inner walls of the air sacs weaken and rupture, creating larger air spaces instead of many small ones. This reduces the surface area of the lungs and, in turn, the amount of oxygen that reaches your bloodstream."
Peripheral arterial disease	"Peripheral artery disease (also called peripheral arterial disease) is a common condition in which narrowed arteries reduce blood flow to the arms or legs."
Aortic disease	"Aortic disease is a range of disorders of the aorta-the main artery that supplies blood from

	the heart.”
Lung cancer	“Lung cancer is a type of cancer that begins in the lungs. Your lungs are two spongy organs in your chest that take in oxygen when you inhale and release carbon dioxide when you exhale.”
Leukemia	“Leukemia is cancer of the body's blood-forming tissues, including the bone marrow and the lymphatic system.”
Cardio cerebrovascular disease	“The term cerebrovascular disease includes all disorders in which an area of the brain is temporarily or permanently affected by ischemia or bleeding and one or more of the cerebral blood vessels are involved in the pathological process.”
Coronary heart disease	“Coronary heart disease is a common heart condition. The major blood vessels that supply the heart (coronary arteries) struggle to send enough blood, oxygen and nutrients to the heart muscle.”
Stroke	“A stroke occurs when the blood supply to part of the brain is interrupted or reduced, preventing brain tissue from getting oxygen and nutrients. Brain cells begin to die in minutes.”
Upper respiratory infection	“A viral infection of your nose and throat (upper respiratory tract). It's usually harmless, although it might not feel that way.”
Lower respiratory infection	“An infection that inflames the air sacs in one or both lungs. The air sacs may fill with fluid or pus (purulent material), causing cough with phlegm or pus, fever, chills, and difficulty breathing.”

Cardiopulmonary Symptom:	**Definition:**
Heart attack/High blood pressure	“High blood pressure is a common condition that affects the body's arteries. It's also called

	hypertension. If you have high blood pressure, the force of the blood pushing against the artery walls is consistently too high. The heart has to work harder to pump blood." "A heart attack occurs when the flow of blood to the heart is severely reduced or blocked. The blockage is usually due to a buildup of fat, cholesterol and other substances in the heart (coronary) arteries. The fatty, cholesterol-containing deposits are called plaques. The process of plaque buildup is called atherosclerosis."
Dizziness	"Dizziness is a term used to describe a range of sensations, such as feeling faint, woozy, weak or unsteady. Dizziness that creates the false sense that you or your surroundings are spinning or moving is called vertigo."
Chest Pain	"Chest pain appears in many forms, ranging from a sharp stab to a dull ache. Sometimes chest pain feels crushing or burning. In certain cases, the pain travels up the neck and into the jaw and then spreads to the back or down one or both arms."
Shortness of breath	"Shortness of breath — known medically as dyspnea — is often described as an intense tightening in the chest, air hunger, difficulty breathing, breathlessness or a feeling of suffocation."
Wheezing	"Wheezing is a high-pitched whistling sound made while breathing. It's often associated with difficulty breathing. Wheezing may occur during breathing out (expiration) or breathing in (inspiration)."
Cough	"A cough is your body's way of responding when something irritates your throat or airways. An irritant stimulates nerves that send a message to your brain. The brain then

	tells muscles in your chest and abdomen to push air out of your lungs to force out the irritant.”
Difficulty in strenuous activities	“Finding activities that may have been easy to be more difficult. Examples of strenuous activities include exercise, cleaning, sports, ect. “

Appendix E: Survey

The survey contains a consent form and 27 different questions. The questions either pertain to the general demographics of the participant or are about the cardiopulmonary disease and symptoms that were identified in the literature

Compressor Station Health Assessment

Informed Consent

You are being asked to participate in a research project entitled "**The Impact of the North Weymouth Compressor Station on Residential Health**". This research is being conducted by an AP Research student in Weymouth, Massachusetts. As a participant in this project you will be asked to answer the following questions to the best of your ability. The entire research process will take approximately **[5-10]** minutes to complete.

Your participation in this study is completely voluntary. As a participant in this study, you have the right to refuse participation or opt out at any time without penalty if you feel uncomfortable.You are free to decline to answer any particular question or questions that you do not wish to answer for any reason without penalty.

Benefits of Participation

You will receive no direct benefits from participating in this research study. However, your responses may help the researcher learn more about **a potential correlation between the North Weymouth Compressor Station and an increase in cardiopulmonary diseases among the residents of Weymouth.**

Risks of Participation

The possible risks or discomforts associated with this research study are minimal to none.

Confidentiality

The Researcher has made every effort to safeguard the confidentiality of the information that you provide. The **"Compressor Station Health Assessment" survey** is anonymous, and, therefore, will not collect identifying information including your **name, email address, or IP Address.** Any and all data obtained from this study that can be identified with you will remain confidential and will not be released without your additional consent. Additionally, only the researcher directly involved in this study and their teacher will have access to the data collected.

Contact

If at any time, you would like additional information concerning the study, you may contact the researcher's teacher, Ms. Paquette, directly at sarah.paquette@weymouthps.org

* Indicates required question

1. **Electronic Consent** *

Check all that apply.

- [ ] I have read the above information
- [ ] I voluntarily consent to participate in this research
- [ ] I acknowledge that at any time I may opt out of this study without penalty
- [ ] I acknowledge that at any time I may refuse to answer any question without penalty
- [ ] I have, to the best of my knowledge and belief, no physical or mental impairments that would be adversely affected by my participation in this study
- [ ] I am at least 18 years of age, or
- [ ] If I am under 18 years of age, my parent/guardian is also consenting to my participation

General Demographics

In this section I will be inquiring general information regarding the respondents gender, race, age, town, zip code, and the street they live on. The latter is only to be used to display proximity of the respondent to the compressor station as it is a necessary component of the researchers study.

2. What gender do you identify with?
(If other, please specify in the space provided)

Mark only one oval.

- ◯ Male
- ◯ Female
- ◯ Non-binary
- ◯ Other: _____

3. Which race or ethnicity do you identify with?
(If other, please specify in the space provided)

Mark only one oval.

- ◯ Native American or Alaskan Native
- ◯ Asian/Asian Pacific Islander
- ◯ Black or African American
- ◯ White/Caucasian
- ◯ Hispanic
- ◯ Native Hawaiian
- ◯ Other: _____

4. What is your age?

_____

5. Are you a Weymouth resident?

Mark only one oval.

- ◯ Yes
- ◯ No

6. If no to the above question, what town are you a current resident of?
(respond with town name)

_____

7. What is your ZIP code?
(If zip code is not listed please specify in the "other" option)

Mark only one oval.

- ◯ 02188
- ◯ 02189
- ◯ 02190
- ◯ 02191
- ◯ 02018
- ◯ 02025
- ◯ 02043
- ◯ 02044
- ◯ 02066
- ◯ 02122
- ◯ 02169
- ◯ 02170
- ◯ 02171
- ◯ 02184
- ◯ 02186
- ◯ 02269
- ◯ 02368
- ◯ 02185
- ◯ 02045
- ◯ Other: _____

8. What street do you live on?
(Only used to find proximity to the compressor station)

_____

Diseases

This section serves to collect any diagnoses for cardiopulmonary and other diseases related to air pollution. Please do not report any diseases before January of 2021 as that is the date before the North Weymouth Compressor Stations opening. Also, please only report official medical diagnoses, not self diagnoses.

9. Subsequent to January of 2021, have you been diagnosed with any type of heart disease?

   Mark only one oval.

   ( ) Yes

   ( ) No

10. Subsequent to January of 2021, have you been diagnosed with any respiratory disease?

    Mark only one oval.

    ( ) Yes

    ( ) No

11. Subsequent to January of 2021, have you been diagnosed with chronic obstructive pulmonary disease (COPD)?

    Mark only one oval.

    ( ) Yes

    ( ) No

12. Subsequent to January of 2021, have you been diagnosed with bronchitis?

Mark only one oval.

- ◯ Yes
- ◯ No

13. Subsequent to January of 2021, have you been diagnosed with emphysema?

Mark only one oval.

- ◯ Yes
- ◯ No

14. Subsequent to January of 2021, have you been diagnosed with peripheral arterial disease?

Mark only one oval.

- ◯ Yes
- ◯ No

15. Subsequent to January of 2021, have you been diagnosed with aortic disease?

Mark only one oval.

- ◯ Yes
- ◯ No

16. Subsequent to January of 2021, have you been diagnosed with asthma?

Mark only one oval.

- Yes
- No

17. Subsequent to January of 2021, have you been diagnosed with lung cancer?

Mark only one oval.

- Yes
- No

18. Subsequent to January of 2021, have you been diagnosed with leukemia?

Mark only one oval.

- Yes
- No

19. Subsequent to January of 2021, have you been diagnosed with cardio cerebrovascular disease (CCVD)?

Mark only one oval.

- Yes
- No

20. Subsequent to January of 2021, have you been diagnosed with ischaemic heart disease or coronary heart disease (CAD)?

Mark only one oval.

- ◯ Yes
- ◯ No

21. Subsequent to January of 2021, have you been diagnosed with a stroke?

Mark only one oval.

- ◯ Yes
- ◯ No

22. Subsequent to January of 2021, have you been diagnosed with a upper respiratory tract infection (URTI)?

Mark only one oval.

- ◯ Yes
- ◯ No

23. Subsequent to January of 2021, have you been diagnosed with a lower respiratory tract infection (LRTI)?

Mark only one oval.

- ◯ Yes
- ◯ No

Symptoms

This section serves to collect any long-term symptoms the respondent may be experiencing relative to air pollution. Please do not report any long-term symptoms before January of 2021 as that is the date before the North Weymouth Compressor Stations opening. However, if any previous symptom listed has worsened following the opening of the station please still specify.

24. Subsequent to January of 2021, have you experienced a recurring high blood pressure or heart attacks?

Mark only one oval.

- ◯ Yes
- ◯ No

25. Subsequent to January of 2021, have you experienced recurring dizziness or lightheadedness?

Mark only one oval.

- ◯ Yes
- ◯ No

26. Subsequent to January of 2021, have you experienced any recurring chest pain?

Mark only one oval.

- ◯ Yes
- ◯ No

27. Subsequent to January of 2021, have you experienced a recurring shortness of breath?

Mark only one oval.

- Yes
- No

28. Subsequent to January of 2021, have you experienced any recurring wheezing or difficulty breathing?

Mark only one oval.

- Yes
- No

29. Subsequent to January of 2021, have you experienced any recurring coughing?

Mark only one oval.

- Yes
- No

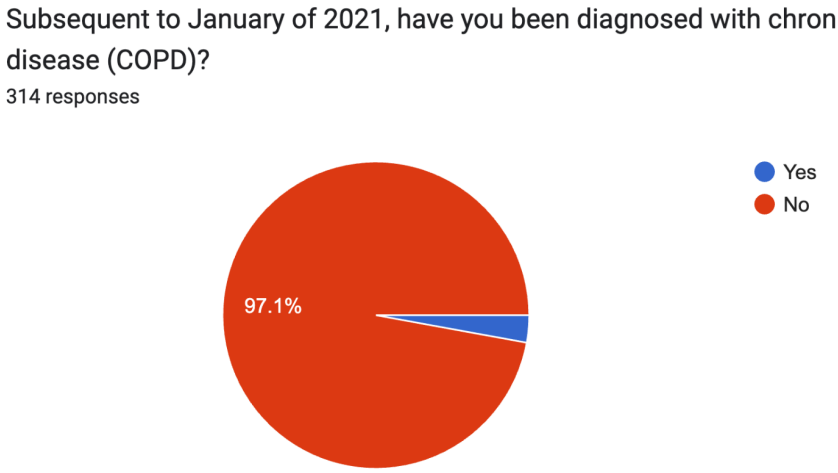
30. Subsequent to January of 2021, have you experienced any unusual recurring difficulty in strenuous activities? (e.g. sports)

Mark only one oval.

- Yes
- No

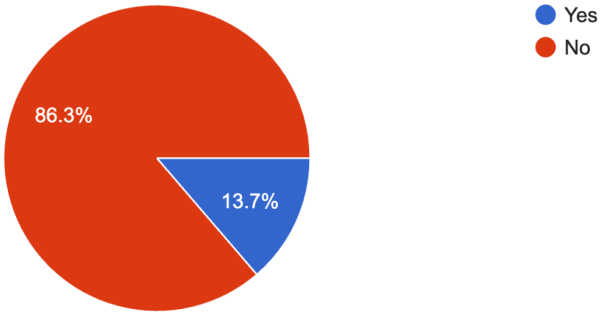
Appendix F: Raw survey data

Includes the pie charts google forms provides, along with the percentage of each of the answers.



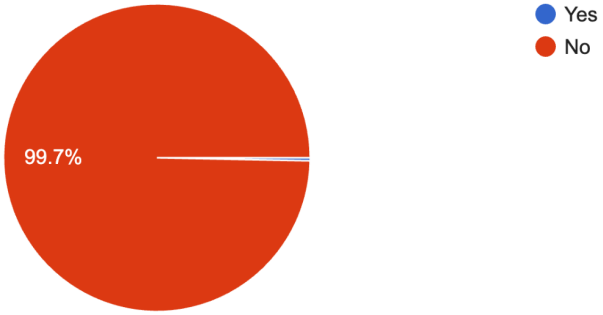
Subsequent to January of 2021, have you been diagnosed with bronchitis?

314 responses



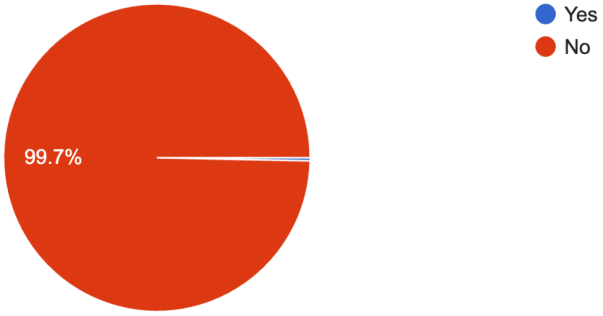
Subsequent to January of 2021, have you been diagnosed with emphysema?

312 responses



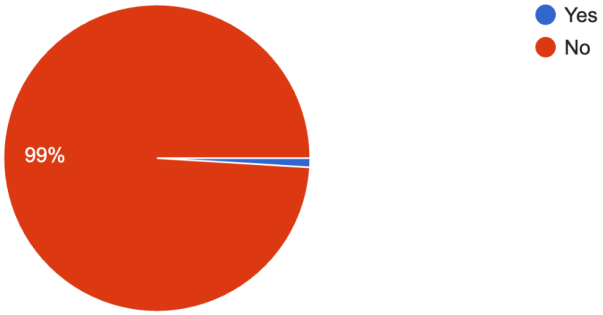
Subsequent to January of 2021, have you been diagnosed with peripheral arterial disease?

310 responses



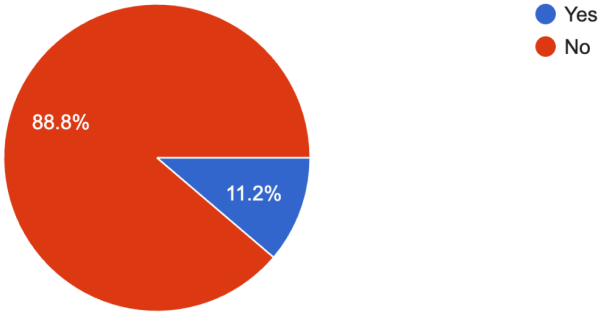
Subsequent to January of 2021, have you been diagnosed with aortic disease?

314 responses



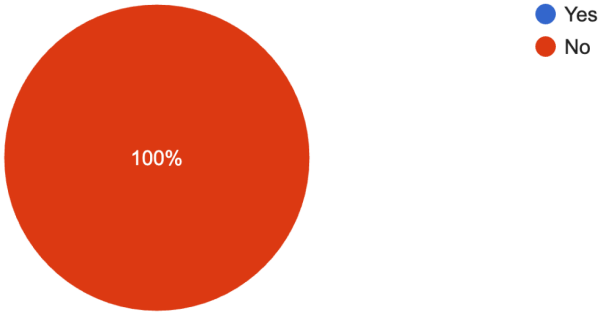
Subsequent to January of 2021, have you been diagnosed with asthma?

312 responses



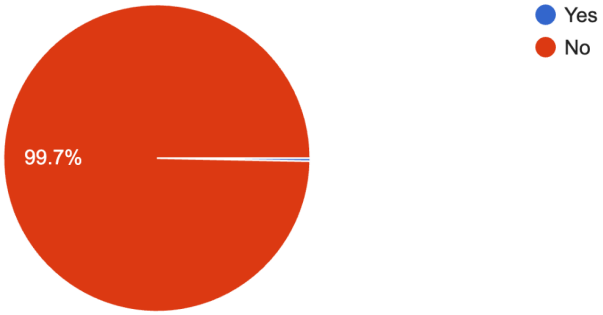
Subsequent to January of 2021, have you been diagnosed with lung cancer?

313 responses



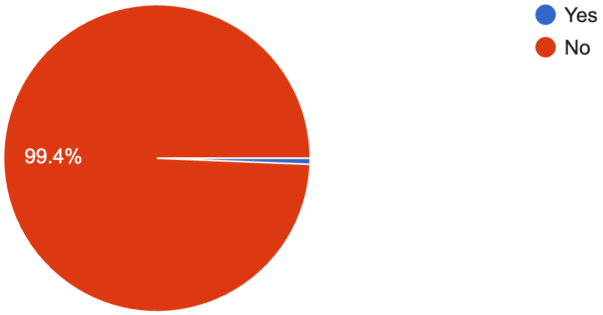
Subsequent to January of 2021, have you been diagnosed with leukemia?

312 responses



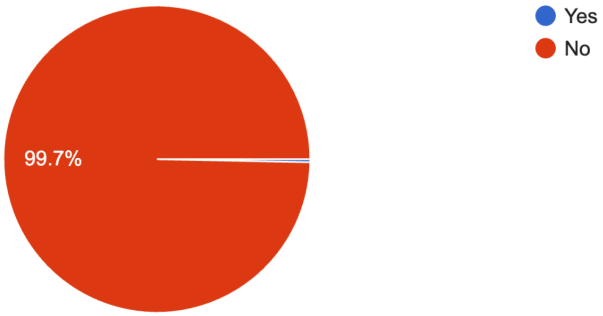
Subsequent to January of 2021, have you been diagnosed with cardio cerebrovascular disease (CCVD)?

312 responses



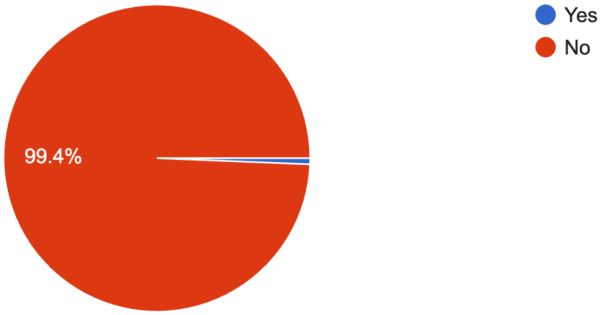
Subsequent to January of 2021, have you been diagnosed with ischaemic heart disease or coronary heart disease (CAD)?

314 responses



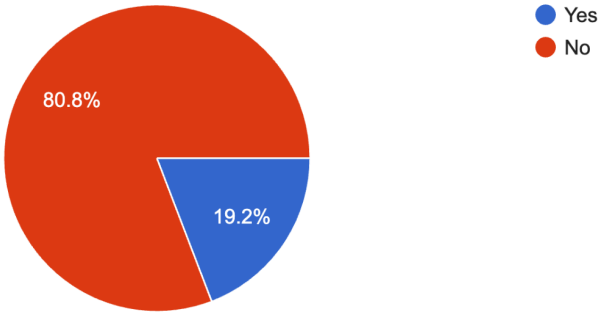
Subsequent to January of 2021, have you been diagnosed with a stroke?

310 responses



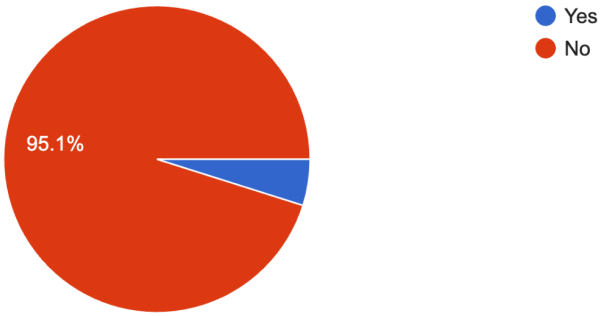
Subsequent to January of 2021, have you been diagnosed with a upper respiratory tract infection (URTI)?

313 responses



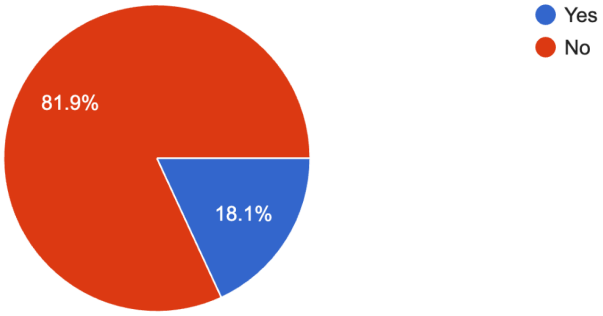
Subsequent to January of 2021, have you been diagnosed with a lower respiratory tract infection (LRTI)?

308 responses



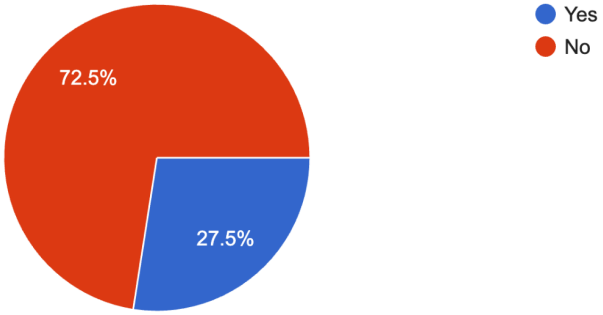
Subsequent to January of 2021, have you experienced a recurring high blood pressure or heart attacks?

315 responses



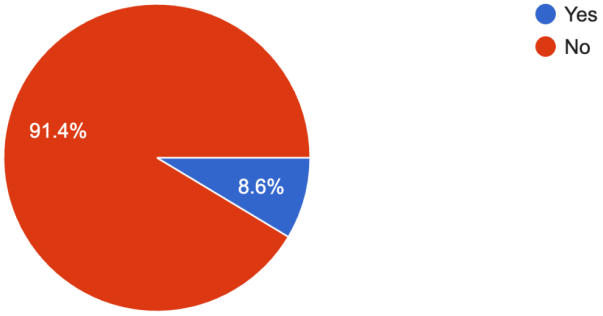
Subsequent to January of 2021, have you experienced recurring dizziness or lightheadedness?

313 responses



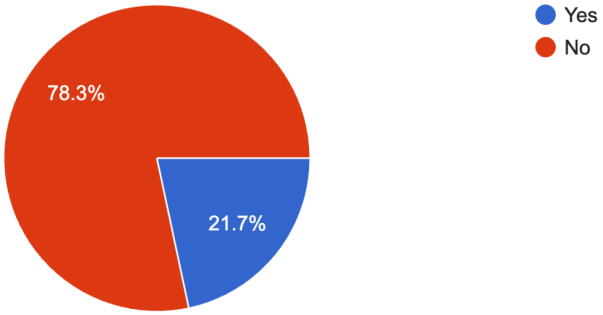
Subsequent to January of 2021, have you experienced any recurring chest pain?

314 responses



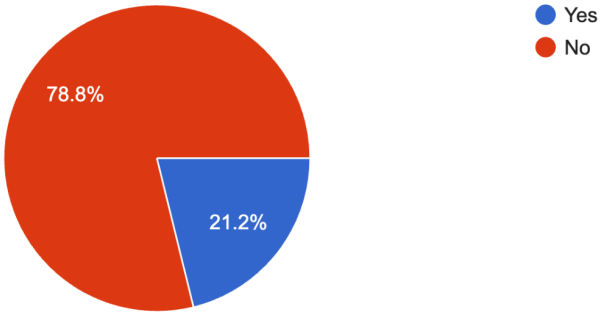
Subsequent to January of 2021, have you experienced a recurring shortness of breath?

314 responses



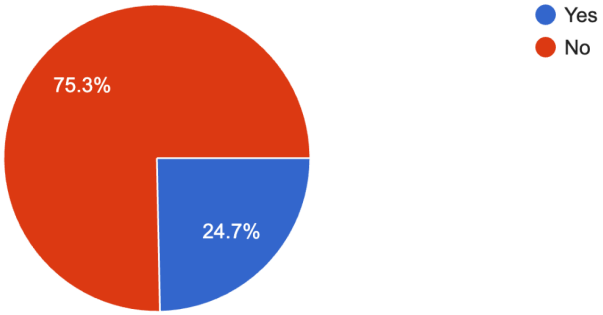
Subsequent to January of 2021, have you experienced any recurring wheezing or difficulty breathing?

312 responses



Subsequent to January of 2021, have you experienced any recurring coughing?

312 responses



Subsequent to January of 2021, have you experienced any unusual recurring difficulty in strenuous activities? (e.g. sports)

313 responses