Module_1:

Team Members:

Lakshya Raman, Zorawar Sandhu

Working towards a B.S. in BME (both of us)

Project Title:

Age and Sex influencers on the Progression of Dementia

The purpose of this project is to gather insight about how the progression of dementia changes by factor of age of initial diagnosis. This could be related to head injury, sex, schooling, etc.

Our Research Question:

Does the age of onset symptoms of dementia or the sex of the patient relate to the progression/duration of the disease? For example, diagnosis/onset of symptoms at a later age could mean a quicker progresson to death.

- Supplemental Ideas explored:
  - Cognitive Decline with CASI scores

How we came up with this question: From initial analysis of the data set and headers along with our background research, we found that the incidence of the disease simply increases with age. We grew curious on what this could mean about the progression of the disease, since biological changes continue to occur as time goes on, so we focused our analysis on finding the link between the initial onset of symptoms age and how this influences the progression of the disease. There is also a higher prevalence of the disease in women, so we wanted to extend our analysis into the male/female split of the progression of the disease. We then looked through the headers and the data values and grew curious about the cognitive assessments as they relate to cognitive decline rates, focusing in on CASI scores as they were recorded closer to the age of death, potentially providing us with a strong analysis of the cognitive decline rate by age of diagnosis.

Disease Background:

Fill in information about 11 bullets:

- Prevalence & incidence

    - There are aboiut 7.2 million Americans that live with Alzheimers. This figure is projected to rise to about 13 million by 2050. The majority of patients affected are 65+. Alzheimer's affects about 10% of all people ages 65 and older. Prevaelnce sharply increases with age. Additionally, Alzheimer's is more prevalent in women compared to men. There are about 500,000-900,000 new caes of alzheimer's that are diagnosed each year. Incidence also increases with age, meaning that older individuals are more likely to be diagnosed with alzheimer's.
    - Race and Ethnicity- Alzheimers has been found to affect more people of the races African American & Hispanic
- Economic burden
    - unpaid dementia caregiving market- 346.6 B in 2023
    - Shortages in demetia caregiving as rates of dementia increase
    - Total payments estimated in 2024 for 65+ dementia is 360B (healthcare, long term, and hospice services)
    - Estimation of total cost projection 321 B from 2022 to 1 trillion by 2050
    - [Paragraph Explanation] There is a harsh economic burden that is associated with Alzehemiers. In 2023, the unpaid dementia caregiving market was valued at 346.6 billion dollars. Additionally, there are shortages in dementia caregiving as rates of dementia increase. More workers are needed to support the demand for the rise of disease rate. For patients aged 65 or older that total payments are estimated to be 360 billion. This includes healhcare, long term care, and hospice services. By 2050, it is estimated that the total debt will be 1 trillion. On average, families pay 60,000-100,000 dollars annually for hospital/institutional care. Additionally, there is an economic burden put on the patients because they may be forced to retire early, missing out on income. Alzhemiers disease is one of the most expensive in the world, not only because of expensive treatments and hospital care, but also because patients can be effected for the long term.
- Risk factors (genetic, lifestyle)
    - The biggest risk factor of Alzheimer's is age. As a person gets older the brain begins to deteriorate, creating a higher chance of developing the disease. Another risk factor of Alzheimers is sex. There are double the amount of women over 65 that have alzheimer's then men. Genetic inheritance is also a risk factor of alzheimer's. This can include familial of risk genes. All three of these factors cannot be changed.
    - The risk factors that can be changed include, lifestyle and health conditions. Smoking, drinking alcohol, and not eating a balanced diet all contribute to the development of alzheimer's. Furthermore, keeping mentally and physical active help to prevent the disease. Protection from head injuries may also play a role in helping to prevent alzheimer's. Diseases such as diabetes, stroke, and heart problems can create a higher chance of developing alzheimer's.

- Societal determinants
  - Rheumatoid Arthritis, Diabetes, Depression, High homocysteine levels, Low folic acid correlations
  - 2x higher for people without high school diploma, college graduate correlation lowest rates of alzheimers, lower healthcare access correlates to less regular checkups
  - Education level has been linked to societal determinants of Alzheimer's. Lower education level has been linked to a higher chance of developing the disease, possibly because education builds congnitive strength that helps to deter the disease. Access to healthcare impacts the prevalance of the disease because oftentimes, early diagnosis can help to fight the disease. In communities with less access to preventative care, the disease may get to the later stages, making it harder for a patient to recover. A lack of communication with others can also be linked to developing Alzheimers. The environment a patient lives in can have some impact on development of the disease. Exposure to heavy metals by air pollution has been linked to cognitive decline. Black and Hispanic americans have higher rates of Alzheimers but also have less access to quality healthcare. Underdiagnosis and undertreatment occur more often in minority communities.
- Symptoms
  - Some of the early symptoms of alzheimers include memory loss, espeically for recent events. Also, patients may have a difficult time finding a word or using words correctly. Patient may feel confused of their location of time. Misplacing items frequently and mood swings are also symptoms of alzheimer's. As the disease progresses all of these symptoms get worse and eventually the person has a hard time completing day to day tasks.
- Diagnosis
  - There are many different ways that alzheimers can be diagnosed and most times it requires a comprehensive evaluation of a patient. For starters, doctors will gather information about cognitive capabilities/deterioration, changes in behavior, and family history of dementia. Additionally, doctors may conduct physical examinations to rule out other causes of cognitive decline, suck as Stroke or Parkinson's. Neurophysical tests are also used to more accuratly determine cognitive ability of a patient. This could include the Mini-Mental State exam or Montreal Congnitive Assesment. Lab tests can also be used to rule out other conditions such as vitamin B12 deficiency or thyroid disorders. Brain imagining scans can further be used to see what the brain looks like, to give a more accurate diagnosis. MRI and CT scans can be used to check for brain shrinkage, strokes, or tumors. PET scans can be used to check for amyloid plaques or tau tangles which are telling signs of AD. Emerging methods to diagnosis AD include different biomarker tests. Cerebrospinal fluid (CSF) tests

can measure amyloid-beta and tau proteins. Blood tests detect abnormal amyloid or tau levels with increasing accuracy.

- Standard of care treatments (& reimbursement)
  - In mild to moderate stages of the disease, Cholinesterase inhibitors are used to target the cognitive decline associated with the disease. It targets the nerve cells and improves communication between them. Additionally, Memantine is used to treat the disease in more moderate and severe stages. Memantine regulates glutamine to protect against excitotoxicity (moderate-severe). Aducanumab is a newer disease modifying therapy. It invloves Monoclonal antibodies targeting beta-amyloid plaques and is used to slow down the disease progression not only symptoms of AD.
  - Medicare covers costs of most AD patients because they tend to be older adults. It covers Cholinesterase inhibitors and memantine. For Aducanumab, Medicare coverage is limited. Many perscription drugs are covered by insurance, however, many long term care facilities are payed for out-of-pocket by families. However, Medicaid covers the costs of long term care.
- Disease progression & progression
  - Alzheimers is a progressive disease that worsens over time. It can begin 10-20 years before any symptoms occur with changes in the brain, such as beta amyloid buildup or tau tangles. As the disease progresses, patients begin to experience mild cognitive impairment. This could include subtle memory issues beyond that of normal aging. The patient can still be independent in their life but they begin to act somewhat different. Next, it progresses to mild AD, where patient experiences memory lapses and could have difficulty planning. They may still be independent, however, they need more help with daily tasks. At the moderate AD stage, patients experience worsening memory loss, have difficulty recognizing people close to them, and have major behavorial changes. At this stage, patients require daily supervision and assistance. At the severe AD stage, patients tend to lose the ablity to eat, walk, talk, no control bladder. They become vulnerable to infections and require full time care.

On average, the life expectancy after diagnosis is about 4-8 years, while some are able to live 10-20. AD is the sixth leading cause of death in America, however, most patients die from complications rather than AD itself. The decline of the disease is gradual but relentless.

- Continuum of care providers
  - In the early stages of AD, primary care physicians give treatment and refer patients to more specialized care. Neurologists can also provide care in the early stages. This could include cognitive testing, and brain imaging to confirm a diagnosis. In moderate stages of AD, patients are taken to outpatient specialists that can monitor symptoms and provide/adjust medications as needed. Also, nurse practitioners can provide follow up care for patients. During

this stage physical therapists can also help patients maintain function and independence. Families may also consider adult day programs that provide structured activities and supervision for deteriorating patients. In severe cases, home health care providers can give skilled care directly to the patients home. They can help to give the patient medicine and also provide personal care for the patient. Palliative Care Teams can also help to advance care planning and also focus on symptom management to ensure the most comfort for patients. In the late/end-of-life stages of AD, nursing homes can provide 24 hour care for patients. More specifically, memory care units can help people with dementia specifically. Across all stages of the disease, the care of the family is very important. Oftentimes, AD can be very taxing on the loved ones of the patient and these support groups are important to ensure the highest rate of success. The continuum of care for AD is not linear, families often move back and forth between these providers as needs evolve. Ideally, care is integrated and coordinated to support both the patient and caregiver throughout the disease course.

- Biological mechanisms (anatomy, organ physiology, cell & molecular physiology)
  - The anatomy of the brain is impacted by AD.
  - The Cerebral Cortex is slowly damaged. This is responsible for the memory language and cognition centers.
  - The Hippocampus is important for memory formation and it is one of earliest regions that was impacted by AD.
  - The amygdala is responsible for emotional processing and behavioral responses. As AD impacts this region patients behavior changes and they begin to act differently than they normally would.
  - The brain and nervous system are impacted heavily by AD. AD causes imbalances in neurotransmitters. Acetylcholine (ACh) is decreased which results in memory and learning deficits. Additionally, glutamine signaling is altered which leads to excitotoxicity. A decrease in glucose utilization, also known as hypometabolism, in affected regions occurs. Furthermore, the blood-rain barrier becomes leaky causing the impairment of beta-amyloid clearance.
  - In cellular physiology, the Tau protein normally stabilizes microtubules, however in AD, Tau becomes hyperphosphorylated, forming neuro fibrillary tangles inside neurons. This blocks axonal transport and leads to cell death. Amyloid precursor protein is abnormally cleaved by beta-secertase and gamma-secertase. This produces AB42 peptides which are sticky, forming extracellular amyloid plaques. These plaques disrupt cell signaling and trigger inflammation.
  - Mitochondrial dysfunction leads to impaired ATP production, resulting in energy deficits.
  - Synaptic Failure: loss of dendritic spines and synapses precedes neuron death, usually results in the earliest cognitive symptoms.

    - Genetic risk factors also exist. APOE e4 allele reduces the clearance of beta-amyloid.
- Clinical Trials/next-gen therapies
    - Donanemab - This treatment is already approved and has begun to be put into practice. Donanemab is an IV antibody that helps the immune system remove amyloid plaques in early stages of AD. This is a very promising treatment because in a large trial, people on donanemab declined about 32–35 percent more slowly than the placebo group over 18 months. In 2025 the FDA okayed a gentler dose-titration that aims to cut ARIA (brain-swelling) risk which was a significant side effect. The downside of this is this brain swelling side effect, which is more prevalent in individuals with the APOE4 gene.
    - Remternetug - Antibody designed by Lilly that is designed for stronger plaque removal in early AD. This is a promising treatment because multiple Phase 3 studies are underway now. It could offer faster or more complete plaque clearance with dosing designed from prior mAb lessons. If the trials hit, this could be the next approved anti-amyloid. However, it also has similar side effects to Donanemab which could cause brain swelling.
    - ACU193 - An antibody that ignores big plaques and instead targets small, soluble amyloid oligomers. These forms are considered by many scientists to be more toxic to synapses. This drug is promising because the Phase 2 trial finished enrollment in 2025. It's the leading test of a genuinely different amyloid target that might help even when plaques are already present. The results are expected after 2025.
    - BIIB080 - An antisense oligonucleotide that lowers production of tau. This treatment is promosing because it's in Phase 2 with FDA Fast Track. If lowering tau translates to slower decline, this would be the first disease-modifier beyond amyloid, and potentially combinable with amyloid drugs.

Data-Set:

(Describe the data set(s) you will analyze. Cite the source(s) of the data.)

- How was the data set aquired?
    - This data was aquired by using multiomics, spatial genomics, and reference atlases from BRAIN initiative. Researchers used these to study middle temporal gyrus cell types in 84 donors. The 84 donors were made up by 33 male donors and 51 female donors, with an average age of death of 88 years.
- When was it aquired?
    - The data was published on October 14, 2024.
- Who was it aquired by?
    - The data was aquired by researchers at the University of Washington and the Allen Institute for Brain Science in Seattle, Washington. The main researchers

behind the study were Mariano I. Gibitto and Kyle J. Travaglini.

- What is the data being used for?
  - The data was used to focus in on the different cell types in the brain and their ageing progression at different disease stages, the location and pathology of disease based on cell type, finding new early treatments and diagnosis, etc.
- What techniques were used to measure the data?
  - quantitative neuropathophysiological measurement system, single nucleus RNA sequencing, single-nucleus assay for transposase-accessible chromatin with sequencing, single-nucleus multiome, and cellularly resolved spatial transcriptomics were used to measure and gather data to populate the dataset.
- What units is the data in?
  - The data uses multiple units per type of data recorded, with the single nucleus RNA sequencing units as number per 10000 reads, transcriptometrics as counts per spot, neuropathophysiology reads as cell density, etc.
- How was the data obtained? (Study design & methodology)
  - The SEA-AD project is a large-scale brain atlas study. It was designed as a cross-sectional postmortem study. Researchers collected donated human brain tissue from individuals who had Alzheimer's disease and from healthy controls. They applied single-nucleus RNA sequencing (snRNA-seq), spatial transcriptomics, ATAC-seq (chromatin accessibility), and other advanced "multi-omics" methods to profile cells. They also combined these molecular data with neuropathological assessments and clinical metadata (like age of onset, cognitive status, etc.).
- What subjects was the data obtained from?
  - Human brain tissue samples donated from individuals diagnosed with Alzheimer's disease at varying stages of progression. Also, control individuals without AD pathology. Samples were taken from specific brain regions vulnerable in AD (e.g., entorhinal cortex, hippocampus, prefrontal cortex).
- What physiological/pathological process the data describes:
  - The dataset captures how brain cells change at the molecular level during the course of Alzheimer's. It describes Amyloid-β accumulation and tau pathology. Cell-type–specific gene expression changes linked to disease progression. Synaptic dysfunction, neuroinflammation, and cell death pathways that underlie dementia.
- Potential bias sources:
  - Only people who donated their brains were represented. This can underrepresent certain demographics (age, ethnicity, socioeconomic background). Also, focused on particular brain regions most relevant to AD, so not the whole brain. Additionally, relies on medical history and diagnosis accuracy before death, which may not be uniform.
  - This was also not a longitudinal study, making any analysis of the data limited in application. For example, CASI scores and other cognitive assessments could

have been provided by interval, with multiple scores over time per patient for additional data verification

- Limitations and assumptions in the dataset:
  - Since data is from brains after death, we can't track real-time progression in the same individuals. Also there were sampling limitations such as, number of samples is large compared to past brain atlases, but still small compared to population diversity.
  - Assumption of representativeness: Researchers assume that these samples and cell states reflect generalizable AD biology—but brain donation bias (more severe or unusual cases, or mostly certain demographics) could limit that.
  - Data integration challenges: Combining transcriptomics, epigenomics, and pathology assumes that different data layers align well across individuals.

Data Analyis:

(Describe how you analyzed the data. This is where you should intersperse your Python code so that anyone reading this can run your code to perform the analysis that you did, generate your figures, etc.)

Learning about the dataset: We started off by counting all the rows (# of patients) and columns (# of metrics) to get a better idea of our dataset. We also searched up all unknown terms as they relate to our question, such as CASI score, MMSE score, etc.

In [88]:
```
#all imports
import pandas as pd
import numpy
import matplotlib.pyplot as plt
import csv
import warnings
import matplotlib.pyplot as plt

import csv

file_path = "UpdatedMetaData.csv"

def rows_and_headers(file_path): #Copied from ChatGPT
    with open(file_path, newline="") as f:
        reader = csv.reader(f)
        headers = next(reader)   # first row
        row_count = sum(1 for _ in reader)  # count remaining rows
    return row_count, headers

# Number of Rows and Columns
x, headers = count_csv_rows_len(file_path)
y = len(headers)

print(f"There are {x} patients and {y} metrics in the dataset.")
```

```
#All headers
for h in headers:
    print(h)
```

```
There are 84 patients and 66 metrics in the dataset.
Donor ID
Primary Study Name
Secondary Study Name
Age at Death
Sex
Race (choice=White)
Race (choice=Black/ African American)
Race (choice=Asian)
Race (choice=American Indian/ Alaska Native)
Race (choice=Native Hawaiian or Pacific Islander)
Race (choice=Unknown or unreported)
Race (choice=Other)
specify other race
Hispanic/Latino
Highest level of education
Years of education
APOE Genotype
Cognitive Status
Age of onset cognitive symptoms
Age of Dementia diagnosis
Known head injury
Have they had neuroimaging
Consensus Clinical Dx (choice=Alzheimers disease)
Consensus Clinical Dx (choice=Alzheimers Possible/ Probable)
Consensus Clinical Dx (choice=Ataxia)
Consensus Clinical Dx (choice=Corticobasal Degeneration)
Consensus Clinical Dx (choice=Control)
Consensus Clinical Dx (choice=Dementia with Lewy Bodies/ Lewy Body Disease)
Consensus Clinical Dx (choice=Frontotemporal lobar degeneration)
Consensus Clinical Dx (choice=Huntingtons disease)
Consensus Clinical Dx (choice=Motor Neuron disease)
Consensus Clinical Dx (choice=Multiple System Atrophy)
Consensus Clinical Dx (choice=Parkinsons disease)
Consensus Clinical Dx (choice=Parkinsons Cognitive Impairment - no dementia)
Consensus Clinical Dx (choice=Parkinsons Disease Dementia)
Consensus Clinical Dx (choice=Prion)
Consensus Clinical Dx (choice=Progressive Supranuclear Palsy)
Consensus Clinical Dx (choice=Taupathy)
Consensus Clinical Dx (choice=Vascular Dementia)
Consensus Clinical Dx (choice=Unknown)
Consensus Clinical Dx (choice=Other)
If other Consensus dx, describe
Last CASI Score
Interval from last CASI in months
Last MMSE Score
Interval from last MMSE in months
Last MOCA Score
Interval from last MOCA in months
PMI
Rapid Frozen Tissue Type
Ex Vivo Imaging
Fresh Brain Weight
Brain pH
Overall AD neuropathological Change
Thal
```

```
Braak
CERAD score
Overall CAA Score
Highest Lewy Body Disease
Total Microinfarcts (not observed grossly)
Total microinfarcts in screening sections
Atherosclerosis
Arteriolosclerosis
LATE
RIN
Severely Affected Donor
```

Into the data analysis! We began by creating a patient class (edited the original) to include the metrics of casi score, moca score, mmse score, and progression years. Our final 'patient' will return the data of sex, cognitive status, symptoms to death progression, death age, diagnosis age, symptom onset age, CASI score, MOCA score, and MMSE score. We do not end up using all these metrics, however. At the beginning of the project, we felt it necessary to compare all 3 scores but we only end up using the CASI score for additional comparisons.

Dealing with null values in the data was a big issue, as we were looking to subtract age at death minus age of diagnosis to get the "symptoms to death progression" metric. To do so, we asked Claude for help of formatting the conditional (specified in a comment below). We end up using this conditional multiple times throughout the analysis to filter out the null values when creating our graphs. This metric is necessary and can be used to directly answer our question of whether the age of diagnosis of dementia relates to the age of death.

In [89]:
```
#all imports
import pandas as pd
import numpy
import matplotlib.pyplot as plt

#Building the class by combining the two CSV's of data

import csv
import warnings
import matplotlib.pyplot as plt

class Patient:

    all_patients = []

    death_age = []

    education_lvl = {}

    def __init__(self, DonorID, ABeta40: float , ABeta42: float, tTau: float

        self.DonorID = DonorID
        self.ABeta40 = ABeta40
        self.ABeta42 = ABeta42
```

```
        self.tTau = tTau
        self.pTau = pTau
        self.sex = None
        self.death_age = None
        self.cog_stat = None
        self.age_symp_on = None
        self.age_diag = None
        self.head_inj = None
        self.thal_score = None
        #added metrics for our own data analysis purposes
        self.casi_score = None
        self.moca_score = None
        self.mmse_score = None
        self.progression_years = None
        Patient.all_patients.append(self)

    def __repr__(self):
        return f"{self.DonorID} | Sex: {self.sex} | Cognitive Status: {self.

    def get_id(self):
        return self.DonorID

    def get_ABeta42(self):
        return self.ABeta42


    def get_death_age(self):
        return self.death_age

    #all new add ons

    def get_casi_score(self):
        return self.casi_score

    def get_moca_score(self):
        return self.moca_score

    def get_mmse_score(self):
        return self.mmse_score

    def get_age_diag(self):
        return self.age_diag

    def get_age_symp_on(self):
        return self.age_symp_on

    def get_cog_stat(self):
        return self.cog_stat

    def get_progression_years(self):
        return self.progression_years
```

```
    @classmethod
    def combine_data(cls, filename: str):
            with open(filename, encoding="utf8") as f:
                reader = csv.DictReader(f)
                rows_of_patients = list(reader)
                #for line in csv create object
                for row in range(len(rows_of_patients)):
                    if Patient.all_patients[row].DonorID == rows_of_patients
                        if rows_of_patients[row]["Sex"] != "":
                            Patient.all_patients[row].sex = rows_of_patients

                        if rows_of_patients[row]["Age at Death"] != "":
                            Patient.all_patients[row].death_age = int(rows_o

                        if rows_of_patients[row]["Cognitive Status"] != "":
                            Patient.all_patients[row].cog_stat = rows_of_pat

                        if rows_of_patients[row]["Age of onset cognitive sym
                            Patient.all_patients[row].age_symp_on = int(rows

                        if rows_of_patients[row]["Age of Dementia diagnosis"
                            Patient.all_patients[row].age_diag = int(rows_of

                        if rows_of_patients[row]["Known head injury"] != "":
                            Patient.all_patients[row].head_inj = rows_of_pat

                        if rows_of_patients[row]["Thal"] != "":
                            Patient.all_patients[row].thal_score = int(rows_
                        #####

                        if rows_of_patients[row]["Last CASI Score"] != "":
                            Patient.all_patients[row].casi_score = rows_of_p

                        if rows_of_patients[row]["Last MOCA Score"] != "":
                            Patient.all_patients[row].moca_score = rows_of_p

                        if rows_of_patients[row]["Last MMSE Score"] != "":
                            Patient.all_patients[row].mmse_score = rows_of_p


                        #Asked Claude to filter out Nonetype in code to calc
                        patient = Patient.all_patients[row]
                        if patient.death_age is not None and patient.age_dia
                            patient.progression_years = patient.death_age -
                        else:
                            patient.progression_years= None

                    else:
                        warnings.warn("IDs do not match.")

    @classmethod
    def instantiate_from_csv(cls, filename: str, other_file: str):
    #open csv and create list of all rows
        with open(filename, encoding="utf8") as f:
            reader = csv.DictReader(f)
            rows_of_patients = list(reader)
```

```
            #for line in csv create object
            for row in rows_of_patients:
                Patient(
                    DonorID = row['Donor ID'],
                    ABeta40 = float(row['ABeta40 pg/ug']),
                    ABeta42 = float(row['ABeta42 pg/ug']),
                    tTau = float(row['tTAU pg/ug']),
                    pTau = float(row['pTAU pg/ug'])
                )
            Patient.all_patients.sort(key = Patient.get_id)
            Patient.combine_data(other_file)
```

To verify we have the right metrics for each patient, we printed out the list of patients.

In [90]:
```
#PRINT OUR LIST OF PATIENTS

Patient.instantiate_from_csv('UpdatedLuminex.csv', 'UpdatedMetaData.csv')

for patient in Patient.all_patients:
    print(patient)
```

H19.33.004 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 80 | Diagnosis Age None | Symptom Onset Age None | CASI Score 85 | MOCA Score None | MMSE Score 25
H20.33.001 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 82 | Diagnosis Age None | Symptom Onset Age None | CASI Score 97 | MOCA Score None | MMSE Score 28
H20.33.002 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 97 | Diagnosis Age None | Symptom Onset Age None | CASI Score 93 | MOCA Score None | MMSE Score 33
H20.33.004 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 5 | Death Age 86 | Diagnosis Age 81 | Symptom Onset Age 80 | CASI Score 80 | MOCA Score None | MMSE Score 25
H20.33.005 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 99 | Diagnosis Age None | Symptom Onset Age None | CASI Score 94 | MOCA Score None | MMSE Score 29
H20.33.008 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 92 | Diagnosis Age None | Symptom Onset Age None | CASI Score 92 | MOCA Score None | MMSE Score 29
H20.33.011 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 1 | Death Age 93 | Diagnosis Age 92 | Symptom Onset Age 87 | CASI Score 79 | MOCA Score None | MMSE Score 21
H20.33.012 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 91 | Diagnosis Age None | Symptom Onset Age None | CASI Score 98 | MOCA Score None | MMSE Score 29
H20.33.013 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 94 | Diagnosis Age None | Symptom Onset Age None | CASI Score 93 | MOCA Score None | MMSE Score 25
H20.33.014 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 82 | Diagnosis Age None | Symptom Onset Age None | CASI Score None | MOCA Score 25 | MMSE Score None
H20.33.015 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 4 | Death Age 88 | Diagnosis Age 84 | Symptom Onset Age 83 | CASI Score 88 | MOCA Score None | MMSE Score 27
H20.33.016 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 9 | Death Age 93 | Diagnosis Age 84 | Symptom Onset Age 84 | CASI Score None | MOCA Score None | MMSE Score 25
H20.33.017 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 2 | Death Age 69 | Diagnosis Age 67 | Symptom Onset Age 64 | CASI Score None | MOCA Score None | MMSE Score None
H20.33.018 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 7 | Death Age 81 | Diagnosis Age 74 | Symptom Onset Age 71 | CASI Score 71 | MOCA Score None | MMSE Score 21
H20.33.019 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 87 | Diagnosis Age None | Symptom Onset Age None | CASI Score 98 | MOCA Score None | MMSE Score 30
H20.33.020 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age 81 | Diagnosis Age None | Symptom Onset Age 64 | CASI Score None | MOCA Score 4 | MMSE Score 14
H20.33.024 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 90 | Diagnosis Age None | Symptom Onset Age None | CASI Score 94 | MOCA Score None | MMSE Score 28
H20.33.025 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 94 | Diagnosis Age None | Symptom Onset Age None | CASI Score 94 | MOCA Score None | MMSE Score 22
H20.33.026 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age 75 | Diagnosis Age None | Symptom Onset Age 64 |

```
CASI Score None | MOCA Score None | MMSE Score None
H20.33.027 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death
Progression None | Death Age 99 | Diagnosis Age None | Symptom Onset Age Non
e | CASI Score 88 | MOCA Score None | MMSE Score 23
H20.33.028 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 0 | Death Age 94 | Diagnosis Age 94 | Symptom Onset Age 92 | CASI
Score 75 | MOCA Score 21 | MMSE Score 22
H20.33.029 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 2 | Death Age 91 | Diagnosis Age 89 | Symptom Onset Age 88 | CASI
Score 77 | MOCA Score None | MMSE Score 23
H20.33.030 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death
Progression None | Death Age 86 | Diagnosis Age None | Symptom Onset Age Non
e | CASI Score 74 | MOCA Score None | MMSE Score 25
H20.33.031 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 1 | Death Age 87 | Diagnosis Age 86 | Symptom Onset Age 84 | CASI
Score 79 | MOCA Score None | MMSE Score 26
H20.33.032 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 98 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 91 | MOCA Score None | MMSE Score 27
H20.33.033 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Prog
ression 8 | Death Age 68 | Diagnosis Age 60 | Symptom Onset Age 54 | CASI Sc
ore None | MOCA Score 7 | MMSE Score 25
H20.33.034 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death
Progression None | Death Age 85 | Diagnosis Age None | Symptom Onset Age Non
e | CASI Score 99 | MOCA Score None | MMSE Score 30
H20.33.035 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death
Progression None | Death Age 99 | Diagnosis Age None | Symptom Onset Age Non
e | CASI Score 92 | MOCA Score None | MMSE Score 24
H20.33.036 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death
Progression None | Death Age 100 | Diagnosis Age None | Symptom Onset Age 94
| CASI Score None | MOCA Score None | MMSE Score 29
H20.33.037 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 2 | Death Age 96 | Diagnosis Age 94 | Symptom Onset Age 92 | CASI
Score 70 | MOCA Score None | MMSE Score 18
H20.33.038 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 4 | Death Age 90 | Diagnosis Age 86 | Symptom Onset Age 85 | CASI
Score 83 | MOCA Score None | MMSE Score 23
H20.33.039 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death
Progression None | Death Age 96 | Diagnosis Age None | Symptom Onset Age Non
e | CASI Score 91 | MOCA Score 21 | MMSE Score 26
H20.33.040 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Prog
ression None | Death Age 98 | Diagnosis Age None | Symptom Onset Age None |
CASI Score 93 | MOCA Score None | MMSE Score 27
H20.33.041 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression None | Death Age 91 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 86 | MOCA Score None | MMSE Score 25
H20.33.043 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 85 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 95 | MOCA Score None | MMSE Score 26
H20.33.044 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 81 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 88 | MOCA Score None | MMSE Score 24
H20.33.045 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 12 | Death Age 77 | Diagnosis Age 65 | Symptom Onset Age 63 | CASI
Score None | MOCA Score None | MMSE Score 6
H20.33.046 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Prog
```

```
ression 3 | Death Age 94 | Diagnosis Age 91 | Symptom Onset Age 88 | CASI Sc
ore 68 | MOCA Score 20 | MMSE Score 18
H21.33.001 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Prog
ression 2 | Death Age 80 | Diagnosis Age 78 | Symptom Onset Age None | CASI
Score 89 | MOCA Score None | MMSE Score 25
H21.33.002 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 5 | Death Age 70 | Diagnosis Age 65 | Symptom Onset Age 61 | CASI
Score None | MOCA Score 17 | MMSE Score None
H21.33.003 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 78 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 95 | MOCA Score None | MMSE Score 27
H21.33.004 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 93 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 89 | MOCA Score None | MMSE Score 27
H21.33.005 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Prog
ression 4 | Death Age 95 | Diagnosis Age 91 | Symptom Onset Age 89 | CASI Sc
ore 98 | MOCA Score None | MMSE Score 30
H21.33.006 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 97 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 88 | MOCA Score None | MMSE Score 24
H21.33.007 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 2 | Death Age 86 | Diagnosis Age 84 | Symptom Onset Age 80 | CASI
Score 86 | MOCA Score None | MMSE Score 26
H21.33.008 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 8 | Death Age 91 | Diagnosis Age 83 | Symptom Onset Age 82 | CASI
Score 67 | MOCA Score None | MMSE Score 21
H21.33.009 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 12 | Death Age 65 | Diagnosis Age 53 | Symptom Onset Age 53 | CASI
Score None | MOCA Score None | MMSE Score 11
H21.33.010 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 4 | Death Age 93 | Diagnosis Age 89 | Symptom Onset Age 88 | CASI
Score 87 | MOCA Score None | MMSE Score 27
H21.33.011 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death
Progression None | Death Age 83 | Diagnosis Age None | Symptom Onset Age Non
e | CASI Score 91 | MOCA Score None | MMSE Score 25
H21.33.012 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 3 | Death Age 93 | Diagnosis Age 90 | Symptom Onset Age 88 | CASI
Score 98 | MOCA Score None | MMSE Score 30
H21.33.013 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 10 | Death Age 94 | Diagnosis Age 84 | Symptom Onset Age 82 | CASI
Score 80 | MOCA Score None | MMSE Score 23
H21.33.014 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 92 | Diagnosis Age None | Symptom Onset Age None
| CASI Score None | MOCA Score 25 | MMSE Score 28
H21.33.015 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 98 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 84 | MOCA Score None | MMSE Score 24
H21.33.016 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 1 | Death Age 94 | Diagnosis Age 93 | Symptom Onset Age 92 | CASI
Score 80 | MOCA Score 16 | MMSE Score 22
H21.33.017 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 0 | Death Age 92 | Diagnosis Age 92 | Symptom Onset Age 90 | CASI
Score 78 | MOCA Score None | MMSE Score 19
H21.33.018 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 0 | Death Age 89 | Diagnosis Age 89 | Symptom Onset Age 86 | CASI
Score 92 | MOCA Score None | MMSE Score 23
```

H21.33.019 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 75 | Diagnosis Age None | Symptom Onset Age None | CASI Score 97 | MOCA Score None | MMSE Score 28
H21.33.020 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 1 | Death Age 82 | Diagnosis Age 81 | Symptom Onset Age 79 | CASI Score 77 | MOCA Score 14 | MMSE Score 23
H21.33.021 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 2 | Death Age 99 | Diagnosis Age 97 | Symptom Onset Age 93 | CASI Score 86 | MOCA Score None | MMSE Score 24
H21.33.022 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 82 | Diagnosis Age None | Symptom Onset Age None | CASI Score 97 | MOCA Score 25 | MMSE Score 30
H21.33.023 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 102 | Diagnosis Age None | Symptom Onset Age None | CASI Score 86 | MOCA Score 19 | MMSE Score 24
H21.33.025 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 88 | Diagnosis Age None | Symptom Onset Age None | CASI Score 94 | MOCA Score None | MMSE Score 29
H21.33.026 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 90 | Diagnosis Age None | Symptom Onset Age None | CASI Score None | MOCA Score None | MMSE Score 30
H21.33.027 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age 92 | Diagnosis Age None | Symptom Onset Age None | CASI Score 71 | MOCA Score None | MMSE Score 22
H21.33.028 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 72 | Diagnosis Age None | Symptom Onset Age None | CASI Score 99 | MOCA Score None | MMSE Score 29
H21.33.029 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 6 | Death Age 89 | Diagnosis Age 83 | Symptom Onset Age 82 | CASI Score 88 | MOCA Score None | MMSE Score 26
H21.33.030 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 89 | Diagnosis Age None | Symptom Onset Age None | CASI Score 99 | MOCA Score None | MMSE Score 27
H21.33.031 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age 84 | Diagnosis Age None | Symptom Onset Age 72 | CASI Score None | MOCA Score 16 | MMSE Score 27
H21.33.032 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 98 | Diagnosis Age None | Symptom Onset Age None | CASI Score None | MOCA Score 21 | MMSE Score 30
H21.33.033 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 83 | Diagnosis Age None | Symptom Onset Age None | CASI Score 96 | MOCA Score None | MMSE Score 27
H21.33.034 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 4 | Death Age 90 | Diagnosis Age 86 | Symptom Onset Age None | CASI Score 66 | MOCA Score None | MMSE Score 18
H21.33.035 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 97 | Diagnosis Age None | Symptom Onset Age None | CASI Score 97 | MOCA Score None | MMSE Score 27
H21.33.036 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 93 | Diagnosis Age None | Symptom Onset Age None | CASI Score 84 | MOCA Score None | MMSE Score 21
H21.33.037 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 88 | Diagnosis Age None | Symptom Onset Age None | CASI Score 96 | MOCA Score None | MMSE Score 26
H21.33.038 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death Progression None | Death Age 84 | Diagnosis Age None | Symptom Onset Age Non

```
e | CASI Score 97 | MOCA Score None | MMSE Score 27
H21.33.039 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 2 | Death Age 88 | Diagnosis Age 86 | Symptom Onset Age 84 | CASI
Score 70 | MOCA Score None | MMSE Score 20
H21.33.040 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 83 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 91 | MOCA Score 23 | MMSE Score 22
H21.33.041 | Sex: Female | Cognitive Status: No dementia | Symptoms to Death
Progression None | Death Age 98 | Diagnosis Age None | Symptom Onset Age Non
e | CASI Score 98 | MOCA Score None | MMSE Score 29
H21.33.042 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 2 | Death Age 91 | Diagnosis Age 89 | Symptom Onset Age 88 | CASI
Score 80 | MOCA Score None | MMSE Score 21
H21.33.043 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 1 | Death Age 95 | Diagnosis Age 94 | Symptom Onset Age 93 | CASI
Score 97 | MOCA Score None | MMSE Score 29
H21.33.044 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 0 | Death Age 88 | Diagnosis Age 88 | Symptom Onset Age 87 | CASI
Score 81 | MOCA Score None | MMSE Score 21
H21.33.045 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Pr
ogression 16 | Death Age 94 | Diagnosis Age 78 | Symptom Onset Age 78 | CASI
Score None | MOCA Score None | MMSE Score 17
H21.33.046 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Prog
ression 3 | Death Age 97 | Diagnosis Age 94 | Symptom Onset Age 94 | CASI Sc
ore 81 | MOCA Score None | MMSE Score 22
H21.33.047 | Sex: Male | Cognitive Status: No dementia | Symptoms to Death P
rogression None | Death Age 90 | Diagnosis Age None | Symptom Onset Age None
| CASI Score 90 | MOCA Score None | MMSE Score 26
```

At this point, we created a filter to pull out specific values when necessary to create our graphs. We edited the base filter code (added casi score, moca score, mmse score, and progression years.

In [91]:
```
#MAKE A FILTER TO PULL OUT PATIENTS WITH SPECIIFC ATTRIBUTES

@classmethod
def filter(cls, list, ABeta40:float ="any", thal_score:int = "any", ABeta42:
        all_patients = list
        remove_list = []
        attr_list = (
                    ABeta40,
                    ABeta42,
                    tTau,
                    pTau,
                    sex,
                    death_age,
                    ed_lvl,
                    cog_stat,
                    age_symp_on,
                    age_diag,
                    head_inj,
                    thal_score,
                #added measures
                    casi_score,
                    moca_score,
```

```
                    mmse_score,
                    progression_years
                    )
        attr_name = (
                    "ABeta40",
                    "ABeta42",
                    "tTau",
                    "pTau",
                    "sex",
                    "death_age",
                    "ed_lvl",
                    "cog_stat",
                    "age_symp_on",
                    "age_diag",
                    "head_inj",
                    "thal_score",
                    "casi_score",
                    "moca_score",
                    "mmse_score",
                    "progression_years"
                    )
        for attr in range(len(attr_list)):
            if attr_list[attr] != "any":
                for patient in all_patients:
                    if getattr(patient,attr_name[attr]) != attr_list[attr]:
                        remove_list.append(patient)
                all_patients = [patient for patient in all_patients if patie
                remove_list.clear()

        return all_patients
Patient.filter = filter #initiate the filter
```

Our main goal with the filter was to get rid of all null values and metrics that were incomplete with the healthy patients, as our analysis was with the diseased patients anyway. We checked this by calling just the diseased patients with the filter and verifying there were not many null values as with the non-diseased patients.

In [92]:
```
#check if all values are present for dementia with filter
diseased_patients = Patient.filter(Patient.all_patients, cog_stat = "Dementi
print(diseased_patients)
```

[H20.33.004 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 5 | Death Age 86 | Diagnosis Age 81 | Symptom Onset Age 80 | CASI Score 80 | MOCA Score None | MMSE Score 25, H20.33.011 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 1 | Death Age 93 | Diagnosis Age 92 | Symptom Onset Age 87 | CASI Score 79 | MOCA Score None | MMSE Score 21, H20.33.015 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 4 | Death Age 88 | Diagnosis Age 84 | Symptom Onset Age 83 | CASI Score 88 | MOCA Score None | MMSE Score 27, H20.33.016 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 9 | Death Age 93 | Diagnosis Age 84 | Symptom Onset Age 84 | CASI Score None | MOCA Score None | MMSE Score 25, H20.33.017 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 2 | Death Age 69 | Diagnosis Age 67 | Symptom Onset Age 64 | CASI Score None | MOCA Score None | MMSE Score None, H20.33.018 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 7 | Death Age 81 | Diagnosis Age 74 | Symptom Onset Age 71 | CASI Score 71 | MOCA Score None | MMSE Score 21, H20.33.020 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age 81 | Diagnosis Age None | Symptom Onset Age 64 | CASI Score None | MOCA Score 4 | MMSE Score 14, H20.33.026 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age 75 | Diagnosis Age None | Symptom Onset Age 64 | CASI Score None | MOCA Score None | MMSE Score None, H20.33.028 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 0 | Death Age 94 | Diagnosis Age 94 | Symptom Onset Age 92 | CASI Score 75 | MOCA Score 21 | MMSE Score 22, H20.33.029 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 2 | Death Age 91 | Diagnosis Age 89 | Symptom Onset Age 88 | CASI Score 77 | MOCA Score None | MMSE Score 23, H20.33.031 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 1 | Death Age 87 | Diagnosis Age 86 | Symptom Onset Age 84 | CASI Score 79 | MOCA Score None | MMSE Score 26, H20.33.033 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 8 | Death Age 68 | Diagnosis Age 60 | Symptom Onset Age 54 | CASI Score None | MOCA Score 7 | MMSE Score 25, H20.33.037 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 2 | Death Age 96 | Diagnosis Age 94 | Symptom Onset Age 92 | CASI Score 70 | MOCA Score None | MMSE Score 18, H20.33.038 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 4 | Death Age 90 | Diagnosis Age 86 | Symptom Onset Age 85 | CASI Score 83 | MOCA Score None | MMSE Score 23, H20.33.040 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age 98 | Diagnosis Age None | Symptom Onset Age None | CASI Score 93 | MOCA Score None | MMSE Score 27, H20.33.041 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age 91 | Diagnosis Age None | Symptom Onset Age None | CASI Score 86 | MOCA Score None | MMSE Score 25, H20.33.045 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 12 | Death Age 77 | Diagnosis Age 65 | Symptom Onset Age 63 | CASI Score None | MOCA Score None | MMSE Score 6, H20.33.046 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 3 | Death Age 94 | Diagnosis Age 91 | Symptom Onset Age 88 | CASI Score 68 | MOCA Score 20 | MMSE Score 18, H21.33.001 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 2 | Death Age 80 | Diagnosis Age 78 | Symptom Onset Age None | CASI Score 89 | MOCA Score None | MMSE Score 25, H21.33.002 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 5 | Death Age 70 | Diagnosis Age 65 | Symptom Onset Age 61 | CASI Score None | MOCA Score 17 | MMSE Score None, H21.33.005 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progression 4 | Death Age 95 | Diagnosis Age 91 | Symptom Onset Age 89 | CASI Score 98 | MOCA Score None | MMSE Score 30, H21.33.007 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 2 | Death Age 86 | Diagnosis Age 84 | Symptom Ons

et Age 80 | CASI Score 86 | MOCA Score None | MMSE Score 26, H21.33.008 | Se
x: Female | Cognitive Status: Dementia | Symptoms to Death Progression 8 | D
eath Age 91 | Diagnosis Age 83 | Symptom Onset Age 82 | CASI Score 67 | MOCA
Score None | MMSE Score 21, H21.33.009 | Sex: Female | Cognitive Status: Dem
entia | Symptoms to Death Progression 12 | Death Age 65 | Diagnosis Age 53 |
Symptom Onset Age 53 | CASI Score None | MOCA Score None | MMSE Score 11, H2
1.33.010 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Prog
ression 4 | Death Age 93 | Diagnosis Age 89 | Symptom Onset Age 88 | CASI Sc
ore 87 | MOCA Score None | MMSE Score 27, H21.33.012 | Sex: Female | Cogniti
ve Status: Dementia | Symptoms to Death Progression 3 | Death Age 93 | Diagn
osis Age 90 | Symptom Onset Age 88 | CASI Score 98 | MOCA Score None | MMSE
Score 30, H21.33.013 | Sex: Female | Cognitive Status: Dementia | Symptoms t
o Death Progression 10 | Death Age 94 | Diagnosis Age 84 | Symptom Onset Age
82 | CASI Score 80 | MOCA Score None | MMSE Score 23, H21.33.016 | Sex: Fema
le | Cognitive Status: Dementia | Symptoms to Death Progression 1 | Death Ag
e 94 | Diagnosis Age 93 | Symptom Onset Age 92 | CASI Score 80 | MOCA Score
16 | MMSE Score 22, H21.33.017 | Sex: Female | Cognitive Status: Dementia |
Symptoms to Death Progression 0 | Death Age 92 | Diagnosis Age 92 | Symptom
Onset Age 90 | CASI Score 78 | MOCA Score None | MMSE Score 19, H21.33.018 |
Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progression 0 |
Death Age 89 | Diagnosis Age 89 | Symptom Onset Age 86 | CASI Score 92 | MOC
A Score None | MMSE Score 23, H21.33.020 | Sex: Male | Cognitive Status: Dem
entia | Symptoms to Death Progression 1 | Death Age 82 | Diagnosis Age 81 |
Symptom Onset Age 79 | CASI Score 77 | MOCA Score 14 | MMSE Score 23, H21.3
3.021 | Sex: Male | Cognitive Status: Dementia | Symptoms to Death Progressi
on 2 | Death Age 99 | Diagnosis Age 97 | Symptom Onset Age 93 | CASI Score 8
6 | MOCA Score None | MMSE Score 24, H21.33.027 | Sex: Male | Cognitive Stat
us: Dementia | Symptoms to Death Progression None | Death Age 92 | Diagnosis
Age None | Symptom Onset Age None | CASI Score 71 | MOCA Score None | MMSE S
core 22, H21.33.029 | Sex: Male | Cognitive Status: Dementia | Symptoms to D
eath Progression 6 | Death Age 89 | Diagnosis Age 83 | Symptom Onset Age 82
| CASI Score 88 | MOCA Score None | MMSE Score 26, H21.33.031 | Sex: Male |
Cognitive Status: Dementia | Symptoms to Death Progression None | Death Age
84 | Diagnosis Age None | Symptom Onset Age 72 | CASI Score None | MOCA Scor
e 16 | MMSE Score 27, H21.33.034 | Sex: Female | Cognitive Status: Dementia
| Symptoms to Death Progression 4 | Death Age 90 | Diagnosis Age 86 | Sympto
m Onset Age None | CASI Score 66 | MOCA Score None | MMSE Score 18, H21.33.0
39 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death Progressio
n 2 | Death Age 88 | Diagnosis Age 86 | Symptom Onset Age 84 | CASI Score 70
| MOCA Score None | MMSE Score 20, H21.33.042 | Sex: Female | Cognitive Stat
us: Dementia | Symptoms to Death Progression 2 | Death Age 91 | Diagnosis Ag
e 89 | Symptom Onset Age 88 | CASI Score 80 | MOCA Score None | MMSE Score 2
1, H21.33.043 | Sex: Female | Cognitive Status: Dementia | Symptoms to Death
Progression 1 | Death Age 95 | Diagnosis Age 94 | Symptom Onset Age 93 | CAS
I Score 97 | MOCA Score None | MMSE Score 29, H21.33.044 | Sex: Female | Cog
nitive Status: Dementia | Symptoms to Death Progression 0 | Death Age 88 | D
iagnosis Age 88 | Symptom Onset Age 87 | CASI Score 81 | MOCA Score None | M
MSE Score 21, H21.33.045 | Sex: Female | Cognitive Status: Dementia | Sympto
ms to Death Progression 16 | Death Age 94 | Diagnosis Age 78 | Symptom Onset
Age 78 | CASI Score None | MOCA Score None | MMSE Score 17, H21.33.046 | Se
x: Male | Cognitive Status: Dementia | Symptoms to Death Progression 3 | Dea
th Age 97 | Diagnosis Age 94 | Symptom Onset Age 94 | CASI Score 81 | MOCA S
core None | MMSE Score 22]

Now, we proceed into making a bar chart! Our first graph we use to answer the question is to check if there is a male/female split in the progression of the disease. We do this by

first counting how many male and female diseased patients there are, using our filter:

In [93]:
```
#USE OUR FILTER TO PULL OUT AND COUNT SUB-SETS OF PATIENTS THAT ARE FILTERED
fem_diseased_patients = range(len(Patient.filter(Patient.all_patients, sex =
male_diseased_patients = range(len(Patient.filter(Patient.all_patients, sex

print(f'Female Diseased Patients = {len(fem_diseased_patients)} | Male Disea

dementia_patients= range(len(Patient.filter(Patient.all_patients, cog_stat =
```

```
Female Diseased Patients = 27 | Male Diseased Patients = 15
```

To create our bargraph, we use matplotlib, scipy, numpy, and statistics. The bar graph is made using matplotlib, but we perform a t test using the scipy, numpy, and statistics modules.

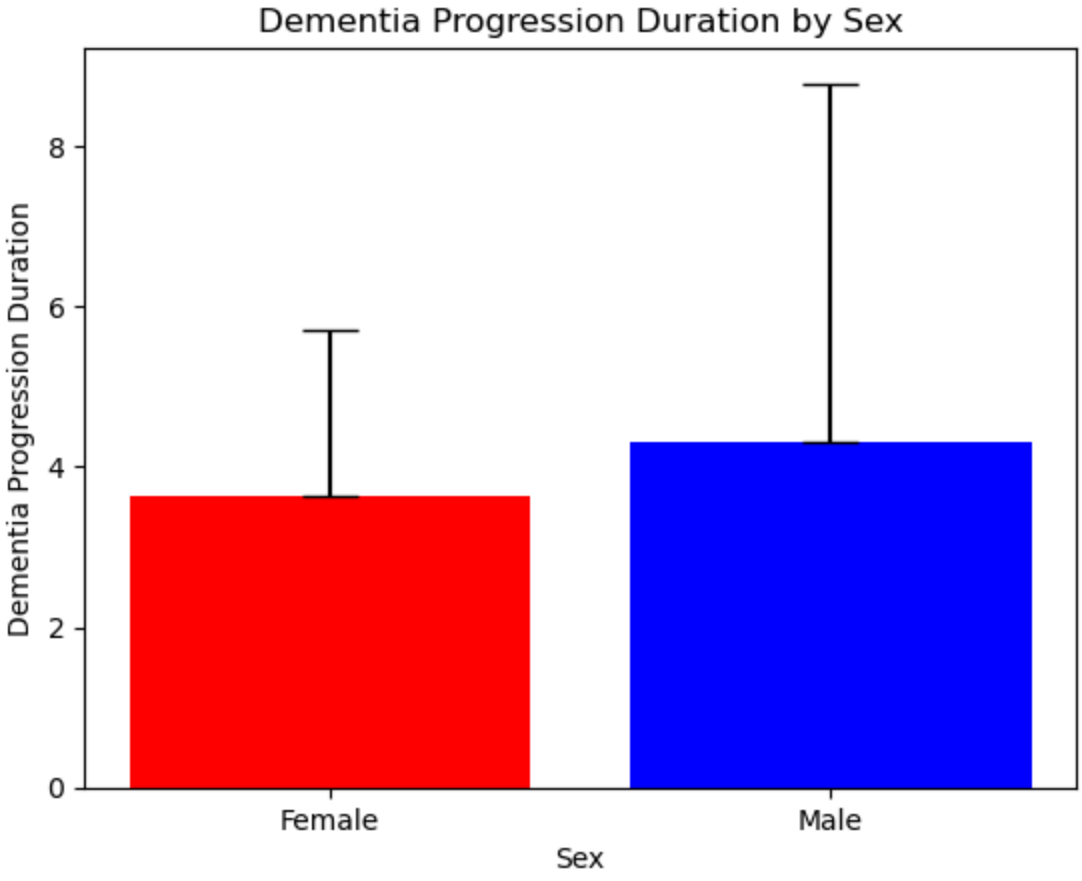
Our hypothesis is that there would be a significant difference between the progression of the disease between males and females. Our null hypothesis was that there would be no difference.

Our final t-test yielded a t statistic of 3.07 and p-value of 0.0028, which means we reject the null hypotheiss. there is a statistically significant difference between the two groups and our original hypothesis was proven by the data.

In [94]:
```
#BAR GRAPH- progression disease by gender
from matplotlib import pyplot as plt
from scipy import stats
import numpy as np
import statistics

#Create 2 lists for male and female
progression_male = []
progression_female = []

for patient in Patient.filter(Patient.all_patients, cog_stat= "Dementia", se
    if patient.progression_years is not None:
        progression_male.append(patient.progression_years)
for patient in Patient.filter(Patient.all_patients, cog_stat= "Dementia", se
    if patient.progression_years is not None:
        progression_female.append(patient.progression_years)

#Bar Graph Stats
x_fem_bar = (statistics.mean(progression_female))
x_male_bar = (statistics.mean(progression_male))

x= [x_fem_bar, x_male_bar]
progression_fem_stdev = (statistics.stdev(progression_female))
progression_male_stdev = (statistics.stdev(progression_male))

print(f'x_fem_bar = {x_fem_bar}, progression_fem_stdev {progression_fem_stde
print(f'x_male_bar = {x_male_bar}, progression_male_stdev {progression_male_

x_fem_vals = range(len(Patient.filter(Patient.all_patients, sex = "Female"))
```

```
x_male_vals = range(len(Patient.filter(Patient.all_patients, sex = "Male")))

sex_cols = ['Female', 'Male']
mean_sex_progression = [x_fem_bar, x_male_bar]
stdev_sex_progression= [progression_fem_stdev, progression_male_stdev]
colors = ["pink", "blue"]
yerr = [np.zeros(len(mean_sex_progression)), stdev_sex_progression]

# Equal variance assumed
t_stat, p_val = stats.ttest_ind(x_fem_vals, x_male_vals)
print("t-statistic:", t_stat)
print("p-value:", p_val)

plt.bar(sex_cols, mean_sex_progression, yerr=yerr, capsize=10, color=["red",
plt.title("Dementia Progression Duration by Sex")
plt.xlabel("Sex")
plt.ylabel("Dementia Progression Duration")
plt.show()
```

```
x_fem_bar = 3.6363636363636362, progression_fem_stdev 2.062654952856986
x_male_bar = 4.32, progression_male_stdev 4.460194315647395
t-statistic: 3.0784872996263224
p-value: 0.0028295250986335257
```



Next, we decided to directly answer our question by creating a scatterplot of age of symptom onset and dementia progression duration compared. We started by creating two lists for age of symptom onset and dementia progression duration (filtered using

filter), then created a dataframe using those lists. We performed a linear regression using sklearn and made a scatterplot with the best fit line.

The slope of the line is -0.21 and the R^2 value is 0.33. This indicates there is a low-moderate correlation between the age of symptom onset and the progression of the disease.

In [95]:
```
progress_years = []
age_onset = []

for patient in Patient.filter(Patient.all_patients, cog_stat="Dementia"):
    if patient.progression_years is not None and patient.age_symp_on is not
        progress_years.append(float(patient.progression_years))
        age_onset.append(patient.age_symp_on)

# Create a DataFrame
df = pd.DataFrame({
    'Age of Symptom Onset': age_onset,
    'Dementia Progression Duration': progress_years
})

a = df["Age of Symptom Onset"].values.reshape(-1, 1)  # Independent variable
b = df["Dementia Progression Duration"].values
```

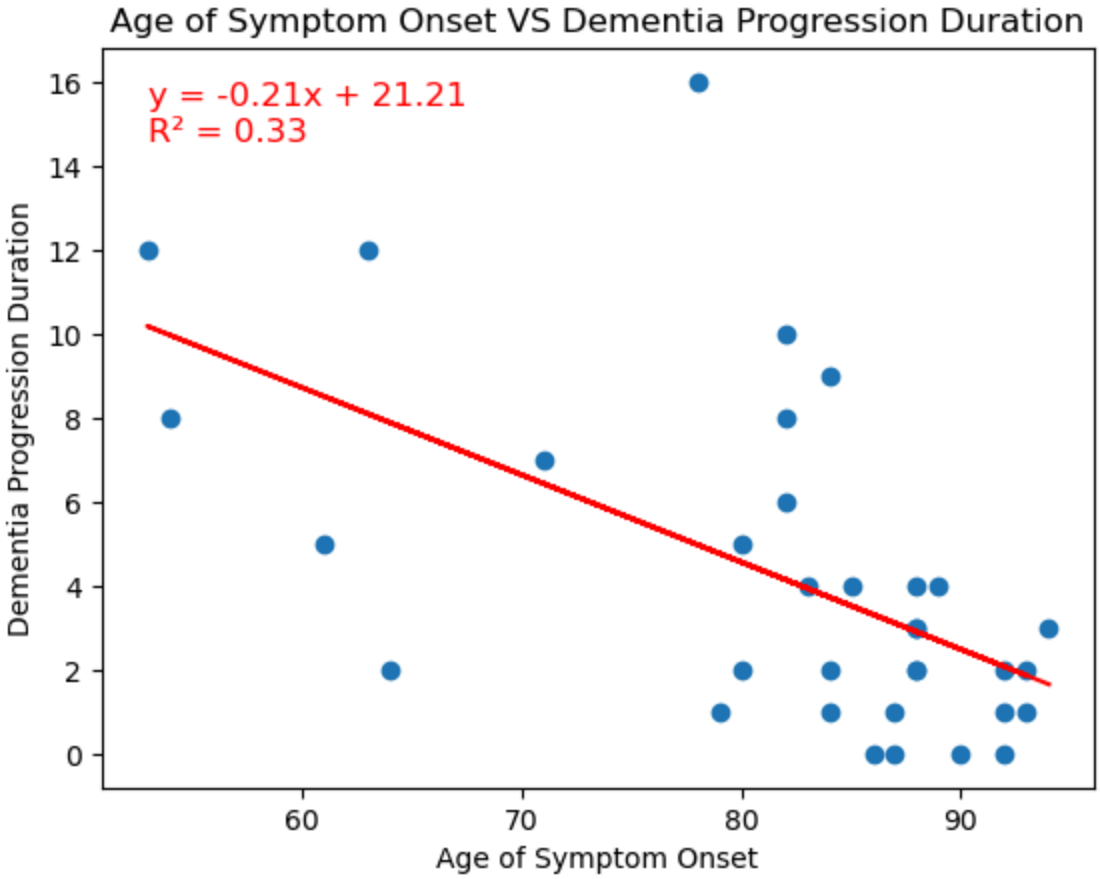
In [96]:
```
#LOAD LIBRARIES FOR A LINEAR REGRESSION

from sklearn.linear_model import LinearRegression
from sklearn.metrics import r2_score
```

In [97]:
```
#LOAD DATA SET FOR A LINEAR REGRESSION

x = df["Age of Symptom Onset"].values.reshape(-1, 1)  # Independent variable
y = df["Dementia Progression Duration"].values
```

In [98]:
```
#Perform the linear regression

model = LinearRegression()
model.fit(x, y)

slope = model.coef_[0]
intercept = model.intercept_
r2 = model.score(x, y)
```

In [99]:
```
#Make scatterplot
plt.scatter(x, y, label="Data")
plt.plot(x, model.predict(x), color="red")

# Annotate equation
equation = f"y = {slope:.2f}x + {intercept:.2f}\nR² = {r2:.2f}"
plt.text(x.min(), y.max(), equation, color="red", fontsize=12, verticalalign

# Annotate scatterplot with labeles and title
plt.xlabel("Age of Symptom Onset")
```

```
plt.ylabel("Dementia Progression Duration")
plt.title("Age of Symptom Onset VS Dementia Progression Duration")
plt.show()
```



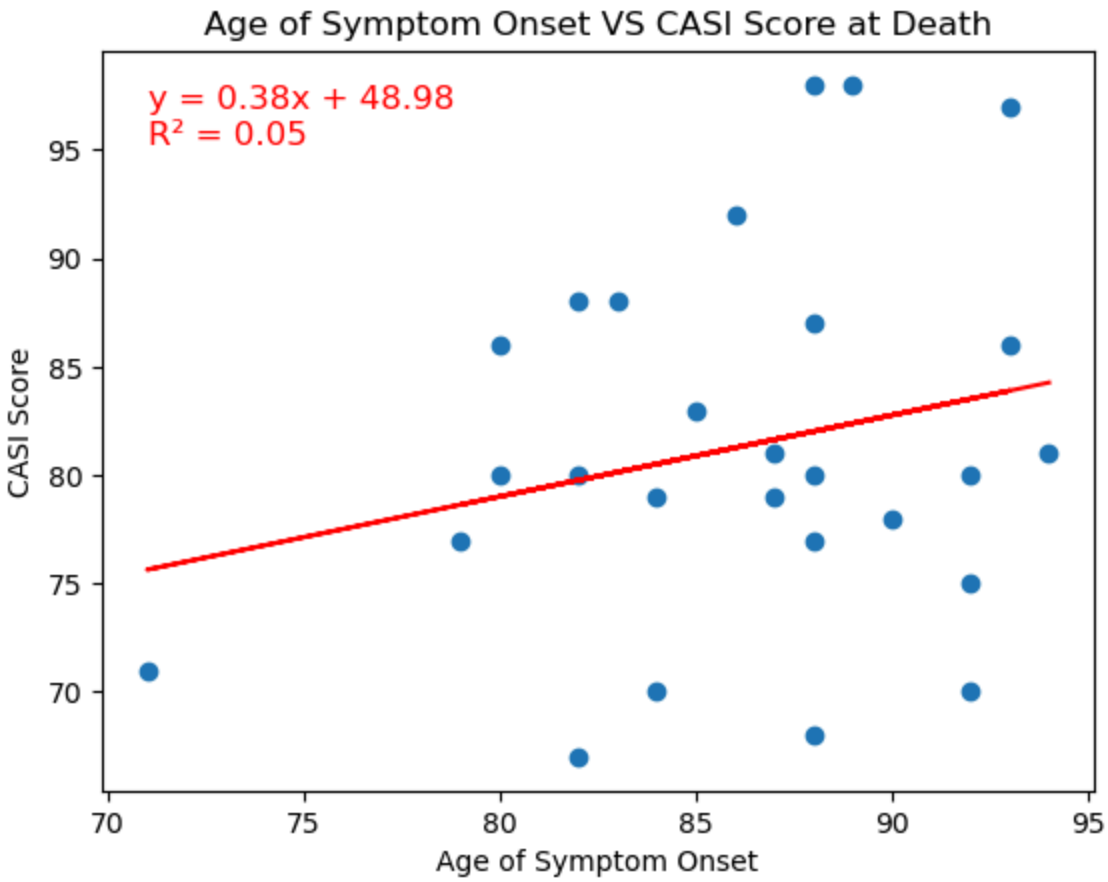
We decided to evaluate 2 additional factors, specifically assessing cognitive decline. This next graph helps us answer a question that is related to our original question, but answering it from a different standpoint: "Does earlier onset lead to different cognitive decline?"

For this, we creaated another scatter plot of age of symptom onset vs CASI score. The R^2 for this analysis is 0.05, indicating there was little to no correlation between the variables.

In [100…

```
# Collect data
casi_scores = []
age_symp_onset = []

for patient in Patient.filter(Patient.all_patients, cog_stat="Dementia"):
    if patient.casi_score is not None and patient.age_symp_on is not None:
        casi_scores.append(float(patient.casi_score))
        age_symp_onset.append(patient.age_symp_on)

# Create a DataFrame
df = pd.DataFrame({
    'Age of Symptom Onset': age_symp_onset,
    'CASI Scores': casi_scores
})
```

```
a = df["Age of Symptom Onset"].values.reshape(-1, 1)  # Independent variable
b = df["CASI Scores"].values

#Perform the linear regression

model = LinearRegression()
model.fit(a, b)

slope = model.coef_[0]
intercept = model.intercept_
r2 = model.score(a, b)

#Make scatterplot
plt.scatter(a, b, label="Data")
plt.plot(a, model.predict(a), color="red")

# Annotate equation
equation = f"y = {slope:.2f}x + {intercept:.2f}\nR² = {r2:.2f}"
plt.text(a.min(), b.max(), equation, color="red", fontsize=12, verticalalign

# Annotate scatterplot with labeles and title
plt.xlabel("Age of Symptom Onset")
plt.ylabel("CASI Score")
plt.title("Age of Symptom Onset VS CASI Score at Death")
plt.show()
```

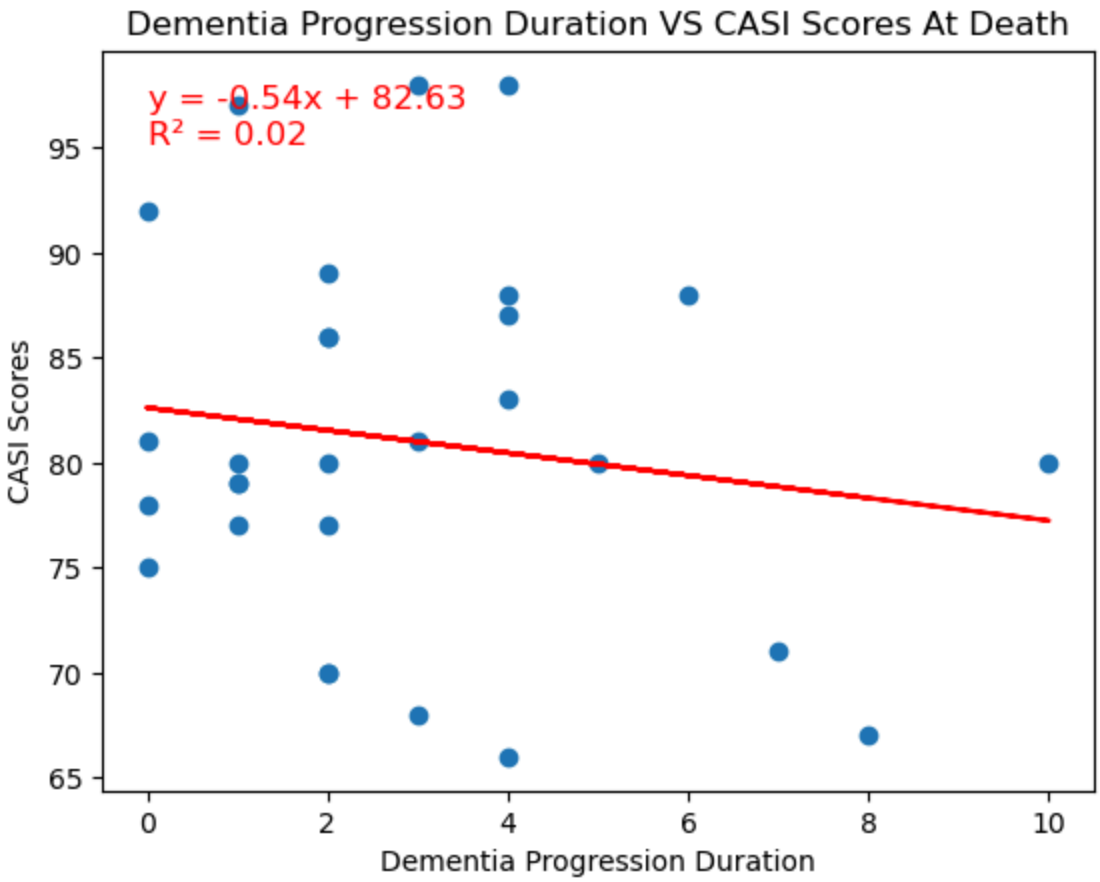


Our last graph assesses the second additional factor related to CASI score again. This question is related to our original question, specifically "Does longer disease duration lead to worse cognitive decline?"

Our R^2 value for this analysis is 0.02, very little to no correlation again.

In [101…

```
# Collect data
casi_scores = []
progression_years = []

for patient in Patient.filter(Patient.all_patients, cog_stat="Dementia"):
    if patient.casi_score is not None and patient.progression_years is not N
        casi_scores.append(float(patient.casi_score))
        progression_years.append(patient.progression_years)

# Create a DataFrame
df = pd.DataFrame({
    'Dementia Progression Duration': progression_years,
    'CASI Scores': casi_scores
})

c = df["Dementia Progression Duration"].values.reshape(-1, 1)  # Independent
d = df["CASI Scores"].values

#Perform the linear regression

model = LinearRegression()
model.fit(c, d)

slope = model.coef_[0]
intercept = model.intercept_
r2 = model.score(c, d)

#Make scatterplot
plt.scatter(c, d, label="Data")
plt.plot(c, model.predict(c), color="red")

# Annotate equation
equation = f"y = {slope:.2f}x + {intercept:.2f}\nR² = {r2:.2f}"
plt.text(c.min(), d.max(), equation, color="red", fontsize=12, verticalalign

# Annotate scatterplot with labeles and title
plt.xlabel("Dementia Progression Duration")
plt.ylabel("CASI Scores")
plt.title("Dementia Progression Duration VS CASI Scores At Death")
plt.show()
```



Verify and validate your analysis:

Let's review this by graph/metric:

- 1- Dementia Progression Duration split by sex-
  - Our two bars had a noticeable difference, with males having a higher error bar and a larger bar than females (low error bar and lower bar). Our T-statistic and p-value tell us the data is significant, which can be visually supported by the difference in bars. Additionally, in our background research, we have learned there is a clear difference in prevalence of Alzheimers between women and men, with women affected more often. It is reasonable to assume there would also be differences in evaluated metrics by gender for that reason, so the progression of the disease can also be different by gender, with women having a more potentially agressive prognosis.
- 2- Age of Symptom Onset vs Dementia Progression Duration-
  - Visually, we notice the majority of the patient data points bunched at the 80-90's range (symptom onset age), and a lower overall disease progression in years for these patients. Those values are bunched around the line of best fit. In terms of reasoning, it makes sense that older patients (symptom onset) have a lower duration of the disease since they are already closer to their final years in age, leaving less room for time. We also see the data points more scattered

around the line of best fit as the age of onset symptoms is lower, which can make sense as there are also less data points for patients in that age, leaving more variabilty (as supported by our R^2-value).

- 3- Age of Symptom Onset vs CASI Score-
  - Visually, the data points are scattered all over the plot with no clear trend. This supports the R^2 value of 0.05.
- 4- Dementia Progression Duration vs CASI Score-
  - Visually, the data points are scattered all over the plot with no clear trend. This supports the R^2 value of 0.02.

Validation of our Data In a study done by Tort-Merino et al. (2022), researchers studied the differences in AD progression of early onset and late onset of AD. By studying a cohort of 195 patients, they found that earlier onset of the disease lead to a more aggressive cognitive decline and typically ended in a quicker death. They also found that the APOE4 gene had a role to play in the development of earlier onset AD which lead to this quicker decline. This was somewhat similar to what we found in our comparision of age of symptom onset and progression. However, our data set was much smaller than the one used by these researchers. We believe that if we had a larger dataset, we would be able to obtain similar results. Furthermore, this dataset was split into two groups, where one was patients under the age of 65 and one was over 65. In our dataset we focused mainly on patients older than 65; while researchers were collecting the data in our set, they weren't focused on this distinction. If we used similar methods, we believe that we would have found similar results.

Conclusions and Ethical Implications:

Through our research we found a low-moderate correlation between age of symptom onset and dementia progression. We obtained an R^2 value of 0.33 for our graph which shows this relationship. Furthermore, we found no correlation between age of symptom onset or dementia progression duration with CASI score. The R^2 value that we obtained for this statistical analysis was 0.05 and 0.02 respectivly. This shows that there wasn't a significant relationship between the intial age of onset compared to dementia progression.

- Bullet summary:
  - Found low-moderate correlation between age of symptom onset and dementia

progression- No correlation between CASI score and age of symptom onset/dementia progression

Ethical Implications:

Early Diagnosis can prepare families for a rapid decline- In the study that we used to validate our work, the researchers found that earlier onset of AD led to a more

aggressive disease progression, and typically ended in a sooner death. In these cases it would be important for doctors and caregivers to prepare the family of the patients for this rapid decline. These caregivers should be transparent in what they tell the families, which would give the best chance for families to support the patient.

Need for personalized care pathways- In same case, it is also important for doctors to develop personalized care pathways that fight against the more aggressive decline of the earlier onset of disease. This could include stronger medications/therapies that fight against the disease. The opposite is also true, where doctors may develop a lighter care pathway for later onset of AD, so patients experience less side effects and are able to live their last years more comfortably.

Adequate Caregiver support - There is a lack of caregiver support in today's society for AD patients. AD develops over many years and care is very expensive for patients and oftentimes they are forced to pay out of pocket because insurance doesn't cover a lot of treatment. Oftentimes, the care that is available is very expensive and can suck the funds out of the family of the patient. In lower socioeconomic regions, care may be impossible to obtain and could lead to the rapid decline of a patient. If care was more readily available, especially in these lower class communities, the survival rate of the disease could be higher.

Limitations and Future Work:

(Think about the answer your analysis generated, draw conclusions related to your overarching question, and discuss the ethical implications of your conclusions.

Future Steps:

- Deepen Analysis (Include MMSE, MoCA scores)
    - In the future, we could deepen our analysis to include MMSE and MoCA scores. In our study we only looked at CASI scores, which give an overall measure of cognitive ability. By using MMSE and MoCA scores (scale all 3 scores to some standard metric), we could truly assess AD severity in the patient. This could help use find more specific results that relate to different stages of AD and how dementia develops in these patients.
- Explore how APOE genotype and sex interact with age of onset
    - Additionally, we could explore the APOE4 allele that is a genetic variation that causes a higher risk of developing AD. By looking at this aspect, we can see how much AD symptoms devleop and how that impacts the progression of dementia in a patient. This gene typically leads to an earlier onset of AD, which could lead to a more aggressive cognitive decline.

Curiosity:

- After completing this research we are curious about the following quesitons:
  - Could resilience factors buffer progression despite an earlier age of onset?
  - Why do some early-onset patients decline faster? Is it purely Biology based, or could

socioeconomic factors play a role? This research sparked our intrest in these areas and in the future we could pursue more research to find that answers to these.

Notes from our Team:

Agenda/previous work dates:

09/11/25- started background research, began qualitatively observing the data to understand all features/terms and quantitatively searching the data for trends

09/14/25- completed more background research for topic and dataset, narrowed down list of questions to one

09/17/25- discussed potential ideas for what factors can be compared to see disease progression by age

09/19/25- narrowed data to only female and male diseased patients and performed a t-test to see if there was a relation. Also programmed new variable for splitting patients by diagnosis age and age at death to answer question, but ran into problem sorting null types. Will fix on next revisit

09/25/25- Both of us were sick and couldn't come to class. We instead discussed independently of additional graphs that can be added to the data to better supplement our questions (CASI score addition)

09/30/25- Wrap up, we cleaned up our code and added reasoning, along with specifying our original research to incorporate information specific to our question

Questions for our TA:

Although we have a set research question, is our data analysis limitied to trying to understand and answer the question or are there general python data analysis points or tests we have to do with the data to better summarize the overall dataset? [ANSWERED]

Other general question (would prefer an answer after we have our question answered): With our data analysis to answer our question, how can we expand on our research in an industry/biotech setting rather than for general knowledge purposes? [ANSWERED]

ALL REFERENCES: (IN APA format)

- Prevalence & incidence
  - Alzheimer's Association. “2025 Alzheimer’s Disease Facts and Figures.” 2025. https://www.alz.org/getmedia/ef8f48f9-ad36-48ea-87f9-b74034635c1e/alzheimers-facts-and-figures.pdf
  - Lennon, J. C., Aita, S. L., Del Bene, V. A., Rhoads, T., Resch, Z. J., Eloi, J. M., & Walker, K. A. (2021). Black and white individuals differ in dementia prevalence, risk factors, and symptomatic presentation. Alzheimer’s & Dementia, 18(8), 1461–1471. https://doi.org/10.1002/alz.12509
- Economic burden
  - 2024 Alzheimer's disease facts and figures. (2024). Alzheimer's & dementia : the journal of the Alzheimer's Association, 20(5), 3708–3821. https://doi.org/10.1002/alz.13809
  - Skaria, Anita. “The Economic and Societal Burden of Alzheimer Disease: Managed Care Considerations.” Supplements and Featured Publications, vol. 28, no. 10, 12 Sept. 2022, www.ajmc.com/view/the-economic-and-societal-burden-of-alzheimer-disease-managed-care-considerations. Accessed Sept. 2025.
- Risk factors (genetic, lifestyle)
  - Alzheimer's Society. “Who Gets Alzheimer’s Disease?” Alzheimer’s Society, 13 Apr. 2023, www.alzheimers.org.uk/about-dementia/types-dementia/who-gets-alzheimers-disease.
- Societal determinants
  - He, S. Y., Su, W. M., Wen, X. J., Lu, S. J., Cao, B., Yan, B., & Chen, Y. P. (2024). Non-Genetic Risk Factors of Alzheimer's Disease: An Updated Umbrella Review. The journal of prevention of Alzheimer's disease, 11(4), 917–927. https://doi.org/10.14283/jpad.2024.100
  - CDC. “Non-Medical Factors That Affect Alzheimer’s Disease and Related Dementias Risk.” Alzheimer’s Disease and Dementia, 2024, www.cdc.gov/alzheimers-dementia/php/sdoh/index.html.
- Symptoms
  - Alzheimer's Association. “10 Early Signs and Symptoms of Alzheimer’s.” Alzheimer’s Disease and Dementia, Alzheimer’s Association, 2025, www.alz.org/alzheimers-dementia/10_signs.* Diagnosis
  - Mayo Clinic. “Diagnosing Alzheimer’s: How Alzheimer’s Is Diagnosed.” Mayo Clinic, 13 Mar. 2024, www.mayoclinic.org/diseases-conditions/alzheimers-disease/in-depth/alzheimers/art-20048075.
- Standard of Care Treatments
  - Mayo Clinic. “Alzheimer’s Disease - Diagnosis and Treatment.” Mayo Clinic, 10 July 2024, www.mayoclinic.org/diseases-conditions/alzheimers-disease/diagnosis-treatment/drc-20350453.
  - National Institute on Aging. “How Is Alzheimer’s Disease Treated?” National Institute on Aging, 2023, www.nia.nih.gov/health/alzheimers-treatment/how-

alzheimers-disease-treated.
    - "Paying for Care." Alzheimer's Disease and Dementia, 2020, www.alz.org/help-support/caregiving/financial-legal-planning/paying-for-care.
- Disease Progression
    - "Stages of Alzheimer's." Alzheimer's Disease and Dementia, Alzheimer's Association, 2025, www.alz.org/alzheimers-dementia/stages.
    - "Alzheimer's Stages: How the Disease Progresses." Mayo Clinic, 7 June 2023, www.mayoclinic.org/diseases-conditions/alzheimers-disease/in-depth/alzheimers-stages/art-20048448 .

  -Johns Hopkins Medicine. "Stages of Alzheimer's Disease." Stages of Alzheimer's Disease, 2019, www.hopkinsmedicine.org/health/conditions-and-diseases/alzheimers-disease/stages-of-alzheimer-disease.
- Continuum of care providers
    - Alzheimer's Orange County. (2016, January). The continuum of care [PDF]. Alzheimer's Orange County. https://www.alzoc.org/wp-content/uploads/2015/11/RESPITE-Continuum-of-Care-AlzOC-1.2016-exp-6.2016.pdf
    - Wang, H., Xie, H., Qu, Q., Chen, W., Sun, Y., Zhang, N., Liu, Y., Li, T., Chan, K. Y., Gauthier, S., Yu, X., & Global Dementia Prevention Program (GloDePP) (2019). The continuum of care for dementia: needs, resources and practice in China. Journal of global health, 9(2), 020321. https://doi.org/10.7189/jogh.09.020321
    - "Long-Term Care Options for Someone with Alzheimer's Disease." Cleveland Clinic, 3 Jan. 2024, health.clevelandclinic.org/long-term-care-for-alzheimers-patients.
- Biological mechanisms (anatomy, organ physiology, cell & molecular physiology)
    - Gulisano, W., Maugeri, D., Baltrons, M. A., Fà, M., Amato, A., Palmeri, A., D'Adamio, L., Grassi, C., Devanand, D. P., Honig, L. S., Puzzo, D., & Arancio, O. (2018). Role of Amyloid-β and Tau Proteins in Alzheimer's Disease: Confuting the Amyloid Cascade. Journal of Alzheimer's disease : JAD, 64(s1), S611–S631. https://doi.org/10.3233/JAD-179935
    - Siddappaji, K. K., & Gopal, S. (2021). Molecular mechanisms in Alzheimer's disease and the impact of physical exercise with advancements in therapeutic approaches. AIMS neuroscience, 8(3), 357–389. https://doi.org/10.3934/Neuroscience.2021020
    - Hampel, H., Hardy, J., Blennow, K., Chen, C., Perry, G., Kim, S. H., ... Vergallo, A. (2021). The amyloid-β pathway in Alzheimer's disease. Molecular Psychiatry, 26(12), 5481–5503. https://doi.org/10.1038/s41380-021-01249-0
- Clinical Trials/next-gen therapies
    - Rabinovici, G. D., Selkoe, D. J., Schindler, S. E., Aisen, P., Apostolova, L. G., Atri, A., Greenberg, S. M., Hendrix, S. B., Petersen, R. C., Weiner, M., Salloway, S., & Cummings, J. (2025). Donanemab: Appropriate use recommendations. The

Journal of Prevention of Alzheimer's Disease, 12(5), Article 100150. https://doi.org/10.1016/j.tjpad.2025.100150
    - ClinicalTrials.gov. (n.d.). A Study of Remternetug (LY3372993) in Early Alzheimer's Disease (TRAILRUNNER-ALZ 3) (NCT06653153). Retrieved September 30, 2025, from https://clinicaltrials.gov/study/NCT06653153
    - Acumen Pharmaceuticals, Inc. (2025, March 26). Acumen Pharmaceuticals completes enrollment of ALTITUDE-AD, a Phase 2 clinical trial of sabirnetug (ACU193) in early Alzheimer's disease. https://investors.acumenpharm.com/news-releases/news-release-details/acumen-pharmaceuticals-completes-enrollment-altitude-ad-phase-2
    - Biogen Inc. (2025, April 2). Biogen's investigational tau-targeting therapy BIIB080 receives FDA Fast Track designation for the treatment of Alzheimer's disease. https://investors.biogen.com/news-releases/news-release-details/biogens-investigational-tau-targeting-therapy-biib080-receives

Code Citations

- Chat GPT (used for filtering null values for dementia progression duration metric)
    - OpenAI. (2025). ChatGPT (GPT-5) [Large language model]. https://chat.openai.com/
- Claude AI (used for reviewing minor bug fixes and code syntax)
    - Anthropic. (2025). Claude (version 4) [Large language model]. https://claude.ai

Validation/Verification Citations

- University of Barcelona Study – Early and Late-Onset Alzheimer's Disease
    - Tort-Merino, Adrià, et al. "Early-Onset Alzheimer's Disease Shows a Distinct Neuropsychological Profile and More Aggressive Trajectories of Cognitive Decline than Late-Onset." Annals of Clinical and Translational Neurology, vol. 9, no. 12, 17 Nov. 2022, pp. 1962–1973, www.ncbi.nlm.nih.gov/pmc/articles/PMC9735361/, https://doi.org/10.1002/acn3.51689.