

Worldwide Alzheimer's Disease Prevalence Projection Model

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Table of Contents

Table of Contents	2
Introduction	3
Definition of the Problem	6
Methods	7
Explanation of the Variables in the Model	9
Gender	9
Age Groups	9
Population Growth	9
The Model	9
Algebraic Model and Variables	9
Model in Python	10
Model Testing	11
Discussions	11
Areas for Improvement	12
References	13

Introduction

Dementia is a disorder in which a person's cognitive performance — thinking, recognizing, and rationalization — deteriorates to the point where it interferes with daily life and activities. Some dementia patients end up losing emotional control, and their personalities shift. Dementia can range in severity from the mildest stage, when it is just beginning to affect a person's ability to function, to the most severe stage, when the person is utterly dependent on others for basic everyday routines.

Dementia comes in different forms, including Alzheimer's disease. The most common dementia diagnosis among elderly individuals is Alzheimer's disease. Changes in the brain, such as abnormal protein buildups referred to as amyloid plaques and tau tangles, cause it. Alzheimer's disease is a brain disease that gradually deteriorates memory and concentration, as well as the ability to carry out even the most basic tasks. Symptoms of late-onset type appear in the mid-sixties in the large percentage of people with the disease. Early-onset Alzheimer's disease is extremely uncommon and represents less than 10% of all Alzheimer's patients. and occurs between the ages of 30 and 60. ^[12]

One of the two main risk factors for Alzheimer's is gender. Women make up the majority of the more than 5 million Americans of all ages living with Alzheimer's dementia. They represent roughly two-thirds of those diagnosed with Alzheimer's disease dementia almost every year. At 65, a woman's lifetime risk of developing Alzheimer's is estimated to be 1 in 5. While breast cancer is a serious concern for women's health, women in their 60s are about twice as likely to develop Alzheimer's disease over the course of their lives as they are to develop breast cancer. On the other hand, women also have a longer life expectancy than men, and secondly, age is also the main significant predictor for Alzheimer's disease dementia. As a result, like other aging-related diseases, women have a higher mortality rate of AD dementia. ^[11]

Not only are women more likely to develop Alzheimer's disease, but they are also more likely to be caregivers for Alzheimer's patients. Women are more likely to face discrimination at work as a result of their caregiving responsibilities. Nearly one-fifth of female Alzheimer's caregivers had to quit their jobs, either to become caregivers or because their caregiving requirements became too demanding. Female caregivers are more likely than male caregivers to experience depression and poor health. These discrepancies are thought to arise because female caregivers spend more time nurturing others, take on more caregiving tasks, and care for people with more cognitive, functional, and/or behavioral issues. ^[6]

As a result, women are twice as likely as men to suffer from depression. Even though mood and memory map to some of the same brain regions, depression has repercussions for cognition across the lifespan. As the intensity of mood swings or depression increases the more cognitive skills are impacted upon. Thus according to studies, depression is a major risk for AD dementia in both men and women, however, it estimates that women are more likely to have it. As high as a 70% increased risk of AD dementia for those suffering from depression in their mid-life (40-50). As a result, women have a higher lifetime incidence of depression, a diagnosis of depression may have a greater overall impact on AD dementia risk among women. ^[11]

Low education has continuously been linked with an increased risk of Alzheimer's disease dementia in both men and women. However, women didn't have access as much as men have to education during the last century; as a direct consequence, AD dementia is higher in women than men. The risk of AD dementia and low education is proportional. Additionally, one study also suggested that lower education may have a stronger negative effect on Alzheimer's disease dementia in women, regardless of access to education.

Even though factors of age and gender are directly relevant to an individual's risk of having Alzheimer's disease, three of the most significant aspects of total Alzheimer's cases are population aging, population growth, and hence life expectancy. Thus, since changes in the general scheme of a local or the global population affect the total number of people affected by Alzheimer's disease, our model's main focus is directed to changes in the elderly population. ^[13] Because of trends regarding the older section of the population, the total number of people affected by Alzheimer's disease globally -as it is largely affected by population aging- ^[14] is expected to increase. In this way, it can be suggested that the global age structure is altered by improvements in life expectancy and decreasing fertility rates, ^[13] which causes dramatic changes in the reported Alzheimer's cases worldwide.

However, it should be noted that it would be unreasonable to assume that the undeniable relationship between the number of Alzheimer's cases every year and the structure of the population, would be in the same form and weight in different regions. As studied in detail by Nichols et. al, a geographical heterogeneity in the number of Alzheimer's cases was observed, thus it can be inferred that population growth and aging affect the number of cases in different countries at different amounts. This variety is clearly seen as population growth is more significant of a factor than population aging in sub-Saharan Africa and vice versa in east Asia. ^[13]

Another important factor to be noticed is the availability and precision of the data presented. As this is widely discussed in terms of lack of data for Alzheimer's cases in various world regions, lack of data regarding population structure is also a major obstacle against constructing a correlation between population growth and aging. Therefore, the data for the model discussed in this report (gathered from the US) may not be applicable to different regions of the world, especially on the scale of population structure, which is a factor varying in significant amounts.

Alzheimer's disease seems to be more common in older people but is much less common in younger people. Beyond the age of 65, the number of people living with dementia doubles every 5 years. By 2060, this population is likely to be almost triple, to 14 million people. ^[12]

Life Expectancy By Stage of Alzheimer's / Dementia (according to the Reisberg / GDS Scale)		
Stage	Expected Duration of Stage	Estimated Life Expectancy (Years Remaining)
Stage 1: No Cognitive Decline	N/A	N/A
Stage 2: Very Mild Cognitive Decline	Unknown	More than 10 years
Stage 3: Mild Cognitive Decline	Between 2 years and 7 years	10 years
Stage 4: Moderate Cognitive Decline	2 years	Between 8 and 3 years
Stage 5: Moderately Severe Cognitive Decline	1.5 years	Between 6.5 and 1.5 years
Stage 6: Severe Cognitive Decline	2.5 years	4 years or less
Stage 7: Very Severe Cognitive Decline	1.5 to 2.5 years	2.5 years or less

Table A: Average life expectancies of Alzheimer's patients at every stage ^[9]

There are many variables that affect the life expectancy of Alzheimer's patients. For example, while men lived an average of 4.2 years following their initial diagnosis (according to research in 2004), women lived an average of 5.7 years after being diagnosed with Alzheimer's. Likewise, the researchers discovered a link between brain and spinal cord abnormalities and life expectancy. People with significant motor impairment, such as a history of falls or a proclivity to wander or walk away, were also found to have shorter life expectancies. Finally, Patients with heart disease, a history of heart attack, or diabetes lived shorter lives than those who did not have these complicating health issues. ^[10]

The rise in the number of people living with dementia emphasizes the importance of public health planning and policy to meet the requirements of this population. Estimates at the national scale can be used to guide national planning and decision-making. In order to address the predicted rise in the number of people

affected by dementia, multifaceted methods, such as scaling up programs to address modifiable risk factors and investing in research on biological causes, will be essential. Overall, it is important to predict the trend of Alzheimer's patient numbers so necessary research, as well as sufficient resources, can be prepared.

Overall, we have used UN total male and female population data, and we have divided 3 large age groups to predict the number of cases between the years starting from 2000 until 2020. The age groups are 50 to 65, 65 to 75, 75 to 85, and 85 and up. The percentages and numbers used for calculations are from the Alzheimer's Disease Facts and Figures (ADFF) reports. Additionally, we have predicted the prevalence of AD cases in 2050 for both genders.

We have done a data analysis based upon AD cases ranging from 2000-to 2020. For good measure and precision, we have also researched data based on gender and age groups for AD cases which are figures 1 and 2 attached below our analysis.

After researching through cases, reviews, and data analysis from the United States, we have come to the conclusion that the global data gathered from each case was pointing out that the estimation of AD diseases in various age groups was extremely uncommon. Hence, we have decided to approximate the total amount of global AD cases collected from United State data. We have conducted our approximated value by using the sum of the male and female population and adding the prevalence of AD is divided by age groups in the US.

In Table C we have laid out the data we have done for the estimated number of people with AD cases divided into age and gender groups.

Definition of the Problem

As highlighted in the Alzheimer's disease definition provided by IM²C, Alzheimer's disease is a type of dementia that covers 60-70% of the new dementia cases every year. Regarding funding and personnel to support those with Alzheimer's and in need of care, it becomes an important issue to estimate the number of people affected by Alzheimer's. However, Alzheimer's is a neurodegenerative disease that depends on many factors ranging from body-mass index to educational level of the individual. Therefore, the prevalence of Alzheimer's disease becomes a complex problem, depending on various different factors, most of which are diverse according to the world's different regions. This report approaches the problem

by finding a mathematical model to predict the total number of people worldwide that are directly affected by Alzheimer's disease.

Methods

Bearing in mind that the prevalence of Alzheimer's disease (AD) varies among different age groups and is more prevalent among women than men, we retrieved United Nations (UN)'s annual worldwide male and female population data (Table A) between 2000 and 2020 and researched the AD prevalence among both sexes and four different age groups (50-65, 65-75, 75-85, 85+). The age groups were determined according to the previous studies we analyzed.^[1,2]

Alzheimer's Disease Facts and Figures (ADFF) reports published by the Alzheimer's Association in 2010 and 2015 have been our major sources in determining the percentage of males and females affected by AD for each of the above-mentioned age groups. We considered the percentages mentioned in the 2010 ADFF reports (Fig. 1) to estimate the number of AD cases between the years 2000 and 2005, using UN's total male and female population data. Likewise, taking into account the percentages mentioned in the 2015 ADFF report (Fig. 2), we predicted the number of AD cases between 2010 and 2020. While the ADFF reports have only presented the AD prevalence for 65-75, 75-85, and 85+ years of age, Nichols et al. have also considered 50-65 years of age in their study and made a projection of 0.5% prevalence for both males and females globally in 2050.^[15] Hence, we also included this age group as a variable in our mathematical model, and because there were no such data available for previous years, we assumed the AD prevalence among ages 50-65 to be 0.4% for both men and women, between the years 2000-2020.

Years	Year Number	50-65 F	65-75 F	75-85 F	85+ F	50-65 M	65-75 M	75-85 M	85+ M
2000	0	335965000	145697000	72288000	20288000	327012000	126008000	48859000	9069000
2005	5	392030000	158995000	84493000	22357000	383026000	139434000	59012000	10580000
2010	10	457105000	170763000	56919000	27881000	446788000	151019000	68729000	13610000
2015	15	524107000	195742000	106454000	34639000	513122000	173853000	79020000	17839000
2020	20	583758000	242195000	117308000	41286000	572005000	216125000	88404000	22287000

Table B: Worldwide Male and Female Population in Different Age Groups by Year

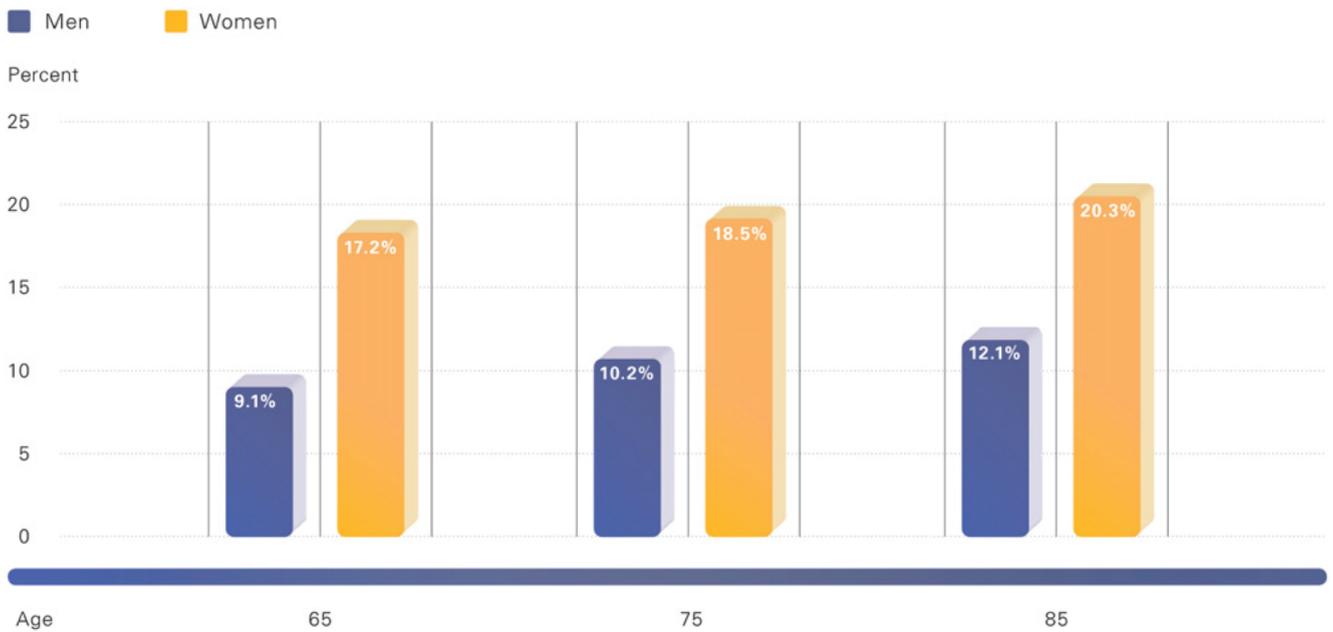


Figure 1: The Estimated Prevalence of AD by Age and Gender presented on 2010 Alzheimer’s Disease Facts and Figures report.^[1]

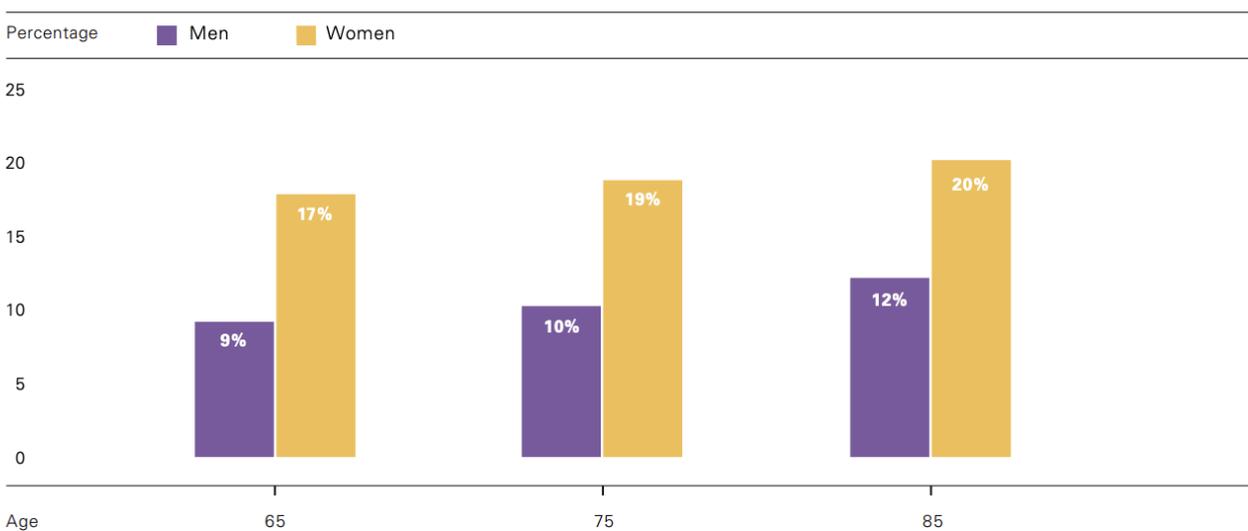


Figure 2: The Estimated Prevalence of AD by Age and Gender presented on 2015 Alzheimer’s Disease Facts and Figures report.^[2]

Conducting a detailed literature review and dataset research, we found out that worldwide data for AD prevalence within different age groups were highly scarce, whereas the most attainable and prevalent data were collected and presented by the U.S. Therefore, using the total male and female population data and taking into consideration the prevalence of AD in different age groups in the U.S., we made the estimations of the number of worldwide AD cases based on the U.S. data.

Years	Year Number	50-65 F	65-75 F	75-85 F	85+ F	50-65 M	65-75 M	75-85 M	85+ M
2000	0	671930	12384245	6686640	2059232	654024	5733364	4983618	1097349
2005	5	784060	13514575	7815602	2269235	766052	6344247	6019224	1280180
2010	10	914210	14514855	5407305	2788100	893576	6795855	6872900	1633200
2015	15	1048214	16638070	10113130	3463900	1026244	7823385	7902000	2140680
2020	20	1167516	20586575	11144260	4128600	1144010	9725625	8840400	2674440

Table C: Estimated Worldwide Number of Females and Males with AD in Different Age Groups by Year

Explanation of the Variables in the Model

We based our models on three main factors:

Gender

According to the estimations made by Nichols et al., there were more women with dementia than men globally in 2019, and they predict this pattern to continue to 2050.

Age Groups

Since the prevalence of AD varies among different age groups, we determined four different age groups (50-65, 65-75, 75-85, 85+) according to the previous studies we analyzed.

Population Growth

Considering that populations change exponentially, we performed an exponential regression in order to build our model.

The Model

Algebraic Model and Variables

x: The number of years since 2000	
Y₁: The number of AD cases in women aged 50-65 worldwide	$Y_1 = 680532 \cdot 1.0283^x$
Y₂: The number of AD cases in women aged 65-75 worldwide	$Y_2 = 11958805 \cdot 1.0248^x$
Y₃: The number of AD cases in women aged 75-85 worldwide	$Y_3 = 6159077 \cdot 1.0259^x$
Y₄: The number of AD cases in women aged 85+ worldwide	$Y_4 = 1978870 \cdot 1.037^x$
Y₅: The number of AD cases in men aged 50-65 worldwide	$Y_5 = 663163 \cdot 1.0286^x$
Y₆: The number of AD cases in men aged 65-75 worldwide	$Y_6 = 5556972 \cdot 1.0257^x$
Y₇: The number of AD cases in men aged 75-85 worldwide	$Y_7 = 5110876 \cdot 1.0288^x$
Y₈: The number of AD cases in men aged 85+ worldwide	$Y_8 = 1057238 \cdot 1.047^x$
Y: Total number of AD cases worldwide	$Y = \sum_{i=1}^8 Y_i$

Table D : Algebraic Model and Variables

Model in Python

```
def numberofpeoplewithalzheimerein (x): # The function to look at the data of a year
    W50and65=680532.1693 * 1.0283**x # The number women with alzheimer age between 50 and 65 in that year
    W65and75=11958804.9118 * 1.0248**x # The number of women with alzheimer age between 65 and 75 in that
year
    W75and85= 6159077.4796 * 1.0259**x #The number of women with alzheimer age between 75 and 85 in that year
    W85ormore=1978869.6312*1.037**x # The number of women with alzheimer age 85 or older in that year
    M50and65=663163.2568*1.0286**x #The number of men with alzheimer age between 50 and 65 in that year
    M65and75= 5556972 * 1.0257**x #The number of men with alzheimer age between 65 and 75 in that year
    M75and85=5110876 * 1.0288**x #The number of men with alzheimer age between 75 and 85 in that year
    M85ormore=1057238.3805 * 1.047**x #The number of men with alzheimer age 85 or older in that year

    totalnumber=(M85ormore + M75and85 + M65and75 + M50and65+ W85ormore +W75and85 +
    W65and75 + W50and65) # this part is for the main function we look, which is sum of 8 functions we made to find
the total number

    # We asked these questions for someone who wants to find for a specific age group we gave but I restricted the
options with the sub-functions we had
    Gender=input('What gender do you want to look at? (male or female)') #asks for a gender
```

```

ageinterval=str(input('What age interval do you want to look at from 50 to 65 or to 75 or 75 to 85 or more than 85?
(Write in form of 50/65 or 85ormore')) # asks for the age interval they want to look
#these if statements are for giving the specific data we asked you to choose
if Gender=='male':
    if ageinterval=='50/65':
        print(M40and65//1 , ' men in age 50 to 65 have alzheimer.')
    if ageinterval=='65/75':
        print(M65and75//1 , ' men in age 65 to 75 have alzheimer.')
    if ageinterval=='75/85':
        print(M75and85//1 , ' men in age 75 to 85 have alzheimer.')
    if ageinterval=='85ormore':
        print(M85ormore//1 , ' men in age 85 or more have alzheimer.')
if Gender=='female':
    if ageinterval=='50/65':
        print(W40and65//1 , ' women in age 50 to 65 have alzheimer.')
    if ageinterval=='65/75':
        print(W65and75//1 , ' women in age 65 to 75 have alzheimer.')
    if ageinterval=='75/85':
        print(W75and85//1 , ' women in age 75 to 85 have alzheimer.')
    if ageinterval=='85ormore':
        print(W85ormore//1 , ' women in age 85 or more have alzheimer.')

if x>21:
    print ('Nearly ' , totalnumber//1 , ' people will have alzheimer in' , x+2000 )
else:
    print ('Nearly ' , totalnumber//1 , 'people had alzheimer in' , x+2000 )
#these are for writing the total data for that year

```

```

year=int(input('What year should we look at? You can not chose a year earlier than 2000.)) # we asked for a year
yearminus2000=year-2000 # we took 2000 as starting point which is f(0) for us so we subtract 2000 from the year
numberofpeoplewithalzheimerin (yearminus2000) # used this to use the main function with the year we asked you to
choose to give you people with Alzheimer's that year.
#note every value rounded to greatest lower integer

```

Model Testing

YEAR	Actual AD Cases Worldwide	Number of AD Cases_Predicted
2015	More than 46 million people	49828140
2021	More than 55 million people	57136120
2030	-	75274346
2040	-	99463689
2050	-	131866306

Table E: Actual Values of Dementia Cases and Predicted Values of AD cases worldwide in different years using our model

Discussions

Because we are dealing with populations, we expected the Alzheimer's cases to increase exponentially, and the data plot we constructed proved that it increased exponentially. Knowing that AD prevalence varies among both sexes and different age groups, we developed 8 separate functions and took the sum of them to obtain the number of AD cases in the total population worldwide. Therefore, this model not just provides the total number of AD cases worldwide, but also the prevalence among males and females in different age groups. Moreover, we did not consider the data that were collected and published before 2000, because the data we encountered in three different articles did not match, therefore were not reliable. Nichols et al. predicted the AD cases to be 83.2 (95% CI 73.0–94.6) million in 2030, 116.0 (100.7–132.1) million in 2040, and 152.8 (130.8–175.9) million in 2050^[13]; and our predictions, as can be seen on Table E, were highly close to their predictions.

Areas for Improvement

- 1) Conducting a detailed literature review and dataset research, we found out that worldwide data for AD prevalence within different age groups were highly scarce, whereas the most attainable and prevalent data were collected and presented by the U.S. Therefore, using the total male and female population data and taking into consideration the prevalence of AD in different age groups in the U.S., we made the estimations of the number of worldwide AD cases based on the U.S. data. This resulted in our predictions being overestimated.
- 2) According to Nichols et al., education, diet, world regions, smoking were also factors that had impacts on the prevalence of AD cases. We decided not to take these factors into consideration when building our model, since there were no thorough datasets available on the internet.

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