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Demographic Mortality Measures as Indicators of Amenable or Avoidable Deaths in the 50 States of the United States of America. An Example of a Population-Based Health Care Quality Indicator - Applied to Chronic Obstructive Pulmonary Disease (COPD)

Inaugural-Dissertation zur Erlangung des Doktorgrades der Humanmedizin
dem Fachbereich Medizin der Philipps-Universität Marburg
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Marburg 2023

Angenommen vom Fachbereich Medizin der Philipps-Universität Marburg am: 15.05.2023

Gedruckt mit Genehmigung des Fachbereichs Medizin

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To my Friend, Walid Husseini.
R.I.P.

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Abbreviations

AL: Alabama
AK: Alaska
AZ: Arizona
AR: Arkansas
CA: California
CO: Colorado
CT: Connecticut
DE: Delaware
DC: District of Columbia
FL: Florida
GA: Georgia
HI: Hawaii
ID: Idaho
IL: Illinois
IN: Indiana
IA: Iowa
KS: Kansas
KY: Kentucky
LA: Louisiana
ME: Maine
MD: Maryland
MA: Massachusetts
MI: Michigan
MN: Minnesota
MS: Mississippi
MO: Missouri
MT: Montana
NE: Nebraska
NV: Nevada
NH: New Hampshire
NJ: New Jersey
NM: New Mexico
NY: New York
NC: North Carolina
ND: North Dakota
OH: Ohio
OK: Oklahoma
OR: Oregon
PA: Pennsylvania
RI: Rhode Island
SC: South Carolina
SD: South Dakota
TN: Tennessee
TX: Texas
UT: Utah
VT: Vermont
VA: Virginia
WA: Washington
WV: West Virginia
WI: Wisconsin
WY: Wyoming

1. Introduction and Research Objectives

1.1. Introduction

Over the last 100 years, life expectancy in many countries around the world, among them the USA, has been increasing. In 2020, it reached 77.0 years for the USA, according to the CDC.[75]

This overall improvement in life expectancy is due to a variety of different factors. One of the main contributing factors is an increase in hygiene standards and developments in medical diagnostics, therapies, technological means, and compression of morbidity.[58] Although life expectancy in the USA has been steadily rising, it has exemplified periods of step-downs. Countries such as Japan, South Korea, Singapore, and Cuba have longer life spans (84 years in Japan and 83 in Singapore in 2019) and lower expenses for health care per capita.[32]

Demography is the study of changes in populations. These changes include birth, death, migration, and family status (e.g., divorced). Such changes are called events. They are influenced by “risk factors”. Risk factors increase or decrease the probability of such an event taking place (e.g., tobacco smoking significantly increases the risk of lung cancer).[63]

Events such as mortality and birth for a specific population (e.g., California) can be compiled in life tables,[41] which are a useful demographic tool for analyzing a cohort of people. A cohort is a homogenous group of people who might share a common starting point, but are then subject to varying risk factors. Deaths within the cohort are shown as age-specific mortality rates.[18,40] By studying mortality life tables for similar populations, it is possible to determine elevated death rates, which can be avoided by applying standard medical care across a select population.

The aim of this research is to investigate elevated death rates for a defined disease: COPD (chronic obstructive pulmonary disease) across the 50 states of America. Amenable deaths are deaths which could have been prevented with standard medical care. States with lower death rates for a specific disease may offer a better health care to their population. Identifying the states with lower age and disease specific mortality rates – i.e., the best practice states - helps identify factors that may play a role in decreasing mortality and increasing life expectancy.

Centralized datasets on general and specific mortality rates collected by the National Center for Health and Statistics provide the empirical basis to the research. The standardized methods of measurements across the 50 states in the USA provide a homogenous validated data set to analyze differences in mortality rates and life expectancies within the country. The WONDER database was also used to accessing COPD mortality data in the USA. CDC-WONDER is an online accessible database developed by the Centers for Disease Control and Prevention (CDC) to utilize public health data. It provides access to statistical data published by the CDC and queries to numeric data sets on the CDC's computers.

1.2. Research Objectives

The primary objective of this research is to contribute to the development of an internationally acceptable, purely demographic approach to determine the proportion of avoidable deaths caused by specific diseases (such as COPD), which under timely and effective medical interventions and public health efforts could be prevented.

This research proposes a novel and less arbitrary approach to studying avoidable deaths by developing normative life tables for certain chronic diseases, using COPD as the specific case study. The first implementation of normative life tables was promoted by the Global Burden of Disease Study to determine avoidable deaths depending on the general mortality in select populations. The use of normative life tables (see Appendix 5) allows for the predication of excess deaths due to COPD in different populations and could act as an indicator for the quality of health care and public health efforts.

The idea of normative life tables for disease specific mortality as an indicator for health care quality was first suggested by the supervisor of this dissertation. I further developed this idea and applied it to chronic obstructive lung disease.

2. Theoretical Framework

The following chapter develops the theoretical underpinnings of this research intervention and objectives, first by explaining what normative life tables are and highlighting the research gap that this study contributes to.

1. Literature Synthesis

In the 1970s, Dr. David Rutstein et al. introduced the first concept of avoidable mortality.[79] They argued that a certain increase in the rates of diseases, disability or untimely deaths for certain diseases could act as a measure of the quality of health care. Since then, the list of accepted conditions in which excessive deaths occur (thus reflecting an index of avoidable deaths) has come under intensive discussion and been the subject of countless research projects.[2] Rutstein also noted that the list should mirror the latest developments in medical health care and knowledge, as well changes in social and environmental factors.

In the last decade, the concept of avoidable deaths has witnessed extensive growth and become a comprehensive measure for the effectiveness of health care systems. However, determining the list of diseases to which death preventing measurements can be implemented depends on arbitrary choices. These choices often lead to misinterpretations of predicted avoidable deaths. These limitations are discussed extensively in Section 3 of this chapter.

2. What Are Normative Life Tables?

Normative life tables are best practice life tables. They are created using age dependent mortality rates for a defined population with subpopulations, for example, the USA. For each age (1 year old or 65 year old), the lowest observed or reported mortality rate within a population group is selected. Examples of this could be the age group 40 to 45 in California or 50 to 55 in Massachusetts, which are population groups within the USA. A usual radix of n = 100,000 fictitious individuals moves through the best practice, age-dependent mortality life tables. Other parameters, such as general life expectancy, the number of people alive at the beginning of each period, and the number of people dying at a certain age, are calculated using standard and widely accepted algorithms. The resulting normative life table shows the best practice life table for all ages. It also indicates the best life expectancy for each age within a defined population.

I have applied this approach for COPD as a chronic condition and a major cause of death throughout the United States. COPD is one of the 10 leading causes of death in industrialized nations, including the USA.[22] It is a common long-term condition, with most deaths occurring when older (approx. 65 years of age). Mortality statistics for COPD in almost all of the USA are well documented and accessible through CDC-WONDER.[13]

Normative life tables for COPD were created by setting up all the available mortality rates for the age group 50 to 84 for a specific year (e.g., 2016) in each US state (plus Washington, D.C.). Then, the lowest mortality rate for every age was isolated. The isolated values were then added to a pre-programmed life table algorithm which calculates life tables based on mortality rates for a fictious n = 100,000 population. Based on the resulting normative life tables, it is possible to assess amenable deaths due to COPD by two demographic parameters:
1) Life expectancy at birth and later in the fictitious COPD population for the given state. 2) Proportion of COPD deaths among all deaths: All those who, in hindsight, were determined to have died from that disease.

The novel part of this approach is using objective demographic measures to avoid the arbitrary selection of avoidable deaths for certain diseases. Some shortcomings in this approach are migrations within the states, which may lead to higher and/or lower deaths rates in certain regions, and that the resulting normative values for every age group will still be lower than one or multiple states could achieve. This is due to limitations in allocating medical, technological, and clinical resources to bring about optimal health care for the population in question.

The research question looks for demographic measures to quantify the share of amenable deaths within a defined population and to discuss factors which lead to an increase in mortality rates or a decrease in life expectancy within a specific population. Certain premature deaths from chronic obstructive pulmonary disease (COPD) should be preventable when appropriate prevention measures and health care are provided.[31] However, there is a remarkable heterogeneity in COPD death rates across the USA as well as in many other developed nations.[24]

3. State of the Literature

There is a popular and widely accepted opinion that medical care, especially due to the strong progress made in recent decades, plays an influential role in reducing mortality and expanding life expectancy. However, it is difficult to define a widely accepted method of studying the successes and failures of medical care in reducing mortality. Indeed, there is not yet a widely accepted definition of avoidable mortality.

In the late 1960s, Thomas McKeown argued that health care played an insignificant role in reducing mortalities. In his analysis of the history of mortality in England and Wales between 1848/1854 and 1971, McKeown attributed the major decline in mortalities in the late 19th and early 20th centuries to a decline in mortality from infectious diseases.[61,62] This pattern has also been witnessed in most heavily-industrialized countries.[21,73,81] As antibiotics like Sulfonamide first became available in the 1930s, the considerable decline in mortalities that began in the 19th century could not have resulted from medical care interventions. He argues that the decline in mortalities is mainly a result of improvements in living standards, not, as one might believe, due to advances in medical care. Changes in environment and health behavior have been far more wide-reaching in reducing mortality than medical care, McKeown believed.

To test this theory, Johan Mackenbach compared McKeown's findings with trends in mortality in the Netherlands from 1875/1879 to 1970.[54] Mackenbach found that while the decline in mortality from infectious diseases began well before the introduction of antibiotics, it accelerated considerably afterwards. Mortality from all infectious diseases in the Netherlands fell from 4% per year before the introduction of antibiotics to 10% per year after antibiotics were employed. In addition to antibiotics, public health efforts and vaccinations have also contributed to reducing the incidence of infectious diseases (e.g., pasteurizing milk reduced the incidence of non-respiratory tuberculosis).[54,55] Advances in surgical procedures such as appendectomy and cholecystectomy, as well as perinatal care in the 1930s, also played a major role in reducing mortalities.[7,9,64] While the role of medical interventions seem limited in reducing mortality during the 19th and early 20th centuries, their influence in reducing mortality rates, especially starting from the middle of the 20th century, is far from negligible.

In contrast to the 19th century, significant advances in medicine and public health efforts were made during the 20th century. These advances made medical care essential in treating and preventing diseases. Furthermore, the leading causes of death in most western countries have shifted from infectious diseases to more chronic conditions, such as heart diseases and cancer.[29] Such conditions require continuous medical care, with regular doctor visits, broad diagnostic tests and regular medication. Some chronic conditions, such as heart diseases and COPD, could be prevented to a certain extent by environmental and behavioral factors, such as smoking tobacco, exposure to organic dust and high-fat diets. Health care has thus become a complex multidisciplinary field that does not only depend on medical intervention, but also on public health efforts and the patient's own compliance.

In the 1970s, the Working Group on Preventable and Manageable Diseases, led by David Rutstein of Harvard Medical School, first introduced the concept of "avoidable deaths". The Working Group defined a list of 91 conditions, including chronic obstructive lung disease, for which "unnecessary untimely death" can be avoided with timely and effective medical care.[79] They aimed to establish a new method of measuring the quality of health care and to quantify cases of "unnecessary disease and disability and unnecessary untimely deaths". They defined medical care as "the application of all relevant medical knowledge, the services of all medical and allied health personnel, institutions and laboratories, the resources of governmental, voluntary, and social agencies, and the cooperative responsibility of the individual himself". The concepts of Rutstein's Working Group have, however, certain limitations. The 91 conditions they identified included cases that health care providers could not influence (e.g., lung cancer). Moreover, some conditions were only considered avoidable under arbitrary age limitations (e.g., acute respiratory infections under the age of 50).

In 1983 Charlton et al. applied Rutstein's concept of "avoidable deaths" to analyze differences in regional mortalities in England and Wales from 1974 to 1978.[16] They amended Rutstein's list of conditions for which "unnecessary untimely death" should be avoided to include only 14 disease groups, and introduced age limits to most conditions for 5 to 64 year-olds. Besides "avoidable deaths", they suggested a new concept: "conditions amenable to medical interventions". Conditions that were rare or could be prevented through prevention measures, such as lung cancer, were excluded.[14]

Based on Charlton's et al. work,[15] the European Community Concerted Action Project on Health Services and 'Avoidable Deaths' utilized the concept of "avoidable deaths" as a measure of health care delivery.[36] In 1988, the project published the first edition of the European Community Atlas of 'Avoidable Death', which has been updated twice since its publication.[36,34,35,35] In its most recent version, it included 16 conditions which were considered preventable or treatable by health care services. Health care services included primary and hospital care, as well as public health programs, such as screenings and immunizations. By monitoring these "avoidable death indicators" (referring to the 16 conditions included in the last version of the Atlas), countries can have "warning signals of potential shortcomings in their health care delivery".[36] However, the list of selected conditions didn't include all the cases which could be avoided through medical interventions or public health efforts. Age limits of under 65 were set for most cases.[36] Unlike with Charlton et. al, the EC Atlas of 'Avoidable Death' included conditions that could be partially averted through prevention measures.[34]

In 1988, Mackenbach et al. specified the impact of medical interventions in reducing mortalities in the Netherlands between 1950/54 and 1980/84.[56] They contributed the decline in mortality in 35 conditions (based on Rutstein's list) to certain innovations in medical care. Medical care was defined as "the application of biomedical knowledge through a personal service system". This approach was novel in that it dropped the age limits for most conditions. The list was later updated to include new innovations in medical care that improved life expectancy, such as the introduction of neoadjuvant radiotherapy to rectum resection in patients with rectal cancer.[57]

In 1998, Simonato et al. introduced a more innovative approach to quantifying avoidable deaths.[84] They divided the causes of avoidable mortality into three groups:

1. Causes amenable to primary prevention: this group deals with reducing the incidence of diseases. It includes neoplasms that are associated with certain lifestyle factors, such as the consumption of tobacco and alcohol.

2. Causes amenable to secondary prevention: the second group includes conditions amenable to early detection and treatment, such as breast cancer and melanomas.

3. Causes amenable to tertiary prevention: the last group considers conditions amenable to improved medical interventions, such as ulcers, complications of pregnancy and appendicitis.

This approach was later refined by Tobias and Jackson by assigning scales to the preventability of each condition through primary, secondary, and tertiary prevention.[94]

In their report “Does Health Care Save Lives?”, Nolte and Mckee traced the evolution of the concept of “avoidable deaths” since its publication in the 1970s by Rutstein.[79,65] They presented a comprehensive review of all relevant works regarding avoidable deaths worldwide. Their work describes avoidable deaths as indicators of potential weaknesses in health care that should be further investigated. It sheds light on issues within health care services that would otherwise be overlooked.

Nolte and Mckee applied a more refined method to measuring mortality amenable to health care. Based on their earlier analysis of “avoidable deaths” and the work of Tobias and Jackson (as well as Mackenbach and Charlton et al.), they selected 35 conditions that are amenable to health care.[16,57,65,67,94] Their definition of health care included primary and hospital care as well as collective health care services, such as screenings and immunizations. Because of the questionable reliability of death certifications for individuals older than 75 years old, they set an age limit of 75 for most cases. The approach was applied to the period from 1980 to 1998, and to selected European Union countries. It measured changes in life expectancy that would result from the reduction in mortality for the 35 pre-selected conditions that are amenable to health care. Nolte and Mckee’s work was essential for developing the OECD/Eurostat lists of preventable and treatable causes of death.[28,65,66]

In 2018, the Organization for Economic Co-operation and Development (OECD) and the EUROSTAT worked on a joint list of preventable and treatable causes of mortality.[28] The list provides a way of measuring health care performance and public health efforts in reducing mortalities within the European Union. The term “amenable” has been replaced with “treatable” to emphasize the role of medical interventions. The list differentiates between preventable mortality and treatable mortality. Preventable mortality refers to deaths that could be avoided through public health measures, while treatable mortality refers to deaths that could be avoided through timely and effective health care. The following principles were considered when creating the list:

1. The list should build on the work of Nolte and McKee, Eurostat, and CIHI/Statistics Canada.[5,10,65,11,71,72]
2. The attribution of causes of death to preventable or treatable mortality should be based on the predominant effect of prevention or health care intervention.
3. Causes of death that can be both widely prevented and treated should be labeled as preventable.
4. Causes of death that can't be fractioned should use a 50%-50% allocation.
5. Double counting of the same causes of death should be avoided.
6. Causes with a small number of deaths should be excluded.
7. The same age threshold should be used across all the selected causes of death.
8. The two lists should be periodically updated.

In 2000, the World Health Organization (WHO) published its World Health report about health system performances. The report outlines three criteria for measuring health system performance: health attainment, health responsiveness and fairness of financing.[90] Health attainment is defined as life expectancy, which is set arbitrarily in many countries due to a lack of comprehensive data on mortality. Health attainment depends on various factors that are outside the influence of health care systems. According to the WHO's report, health responsiveness refers to how health care systems respond to individual expectation of treatment through health care providers, prevention efforts and non-personal services. Fairness of financing concerns distributing the costs of health care across households according to their financial capabilities instead of distributing the costs based on their risk of illness.[90,46] The publication of this report highlights the importance of stipulating a fair and acceptable way of measuring and comparing international health care performances.

The idea of normative tables provides a novel approach to measuring amenable deaths, solving the problem of arbitrary age limitations by considering the life expectancy of the population studied. It can be applied to conditions that are amenable to medical interventions and public health programs. It also serves as an indicator of health care deficits and offers a fair approach to detecting disparities in health care performance.

4. COPD

4.1. Definition, Epidemiology and Risk Factors

The Global Initiative for Chronic Obstructive Lung Disease (GOLD), a project initiated by the National Heart, Lung, and Blood Institute (NHLBI) and the World Health Organization (WHO), defines COPD as follows:

"COPD is a frequent, preventable, and treatable disease that is characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gases and influenced by host factors including abnormal lung development. Significant comorbidities may have an impact on morbidity and mortality." [33]

COPD is the fourth leading cause of death in the USA, with more than 120,000 deaths every year. [44]

Complex interactions between genetics and environmental factors lead to the development of COPD. Smoking is a major risk factor. Surprisingly, however, only 50% of heavy smokers develop COPD in their lifetime. Still, around 80% of all COPD patients in the USA have a history of smoking.[47] However, there are other factors that play a role in the development of airflow limitations.

Risk factors include exposure to fumes from burning fuel or cooking, organic or inorganic dust and chemical agents.[17] Asthma seems to play a significant role in the development of chronic airway limitation. In a longitudinal study conducted by Silva et al. (2004), patients with asthma had a twelvefold higher risk of developing COPD than those without asthma after adjusting for smoking.[83]

Genetic dispositions for COPD include severe hereditary deficiency of alpha 1 antitrypsin (AATD), a serine protease inhibitor which is a genetic condition affecting around 5 in 10,000 individuals. Alpha 1 antitrypsin is a protein produced in the liver, the main function of which is to protect the lungs from elastolytic damage. Decreased serum levels of a1 antitrypsin lead to an imbalance between the a1-antitrypsin's protective role and the burden of the neutrophil elastase, which leads to an accelerated lung breakdown and greater risk of COPD.[87]

4.2. Pathology

COPD not only affects the airways, but also the lung parenchyma and blood vessels surrounding the alveoli. The changes depend on the type and severity of underlying diseases, such as emphysema, chronic bronchitis, and protein deficiency (e.g., a1 antitrypsin insufficiency).[91]

Changes in the airways include chronic inflammation, increased mucus secretion in underlying mucus glands, and constricted or collapsed bronchioles. These lead to decreased FEV1 (Forced Expiratory Volume: the amount of air an individual can force out of their lungs in one second) and decreased gas transfer.[89]

4.3. Symptoms and Clinic

Symptoms in chronic obstructive lung disease do not present until significant changes have accumulated in the lungs. The 3 most notable symptoms in individuals with COPD are:

1. Dyspnea
2. Chronic cough
3. Sputum production (clear, white, yellow, or greenish)

Other symptoms may include:

1. Wheezing and chest tightness
2. Fatigue

3. Weight loss (due to dyspnea while eating)
4. Weight gain (due to lack of physical activity)
5. Depression
6. Anxiety
7. Comorbidities (e.g., lung cancer, cardiovascular diseases, metabolic syndrome, skeletal muscle weakness and osteoporosis).[33,86,27,6,43]

4.4. Diagnosis

Patients with dyspnea, chronic cough and/or sputum production, especially if they have a history of exposure to tobacco smoke or other risk factors, are suggestive of COPD. The diagnosis is confirmed via Spirometry. The presence of incompletely reversible FEV1/FVC ratio of less than 0.7 confirms the diagnosis.[78]

The global initiative for COPD (GOLD) recommends a separate measure of FEV1/FVC ratio for individuals with FEV1/FVC between 0.6 and 0.8. They also defined key indicators for considering the diagnosis of COPD for individuals over the age of 40. These key indicators include:

1. Persistent dyspnea (which worsens with exercise)
2. Intermittent or unproductive cough
3. Chronic sputum production
4. Recurrent infections of the lower respiratory tract
5. History of risk factors (e.g., tobacco smoke, congenital deformities, occupational exposure)
6. Family history of COPD or childhood risk factors (such as low birthweight or childhood respiratory infections)[33,1,80]

4.5. Classification

According to the Global Initiative for Chronic Obstructive Lung Disease (GOLD), the classification of COPD should consider the following key aspects to assess disease severity and guide therapy:

1. Presence and severity of spirometric changes
2. Patient symptoms
3. Exacerbation risk
4. Comorbidities

Forced respiratory volume in one second (FEV1) is used to classify the severity of airflow limitation. A short-acting bronchodilator is used before performing a Spirometry to avoid fluctuations in measurements.[33,49]

Classification of airflow limitation severity in COPD, according to GOLD:

1. GOLD 1: Mild – FEV1 ≥ 80% predicted
2. GOLD 2: Moderate – 50% ≤ FEV1 ≤ 80% predicted
3. GOLD 3: Severe – 30% ≤ FEV1 ≤ 50% predicted
4. GOLD 4: Very severe – 30% ≤ FEV1 predicted

Measurements of the severity of airflow limitation should be combined with assessments of patient symptoms, since two patients with the same FEV1 could have a very different health status and mortality risk. The Modified Medical Research Council Questionnaire (modified MRC Dyspnea Scale) provides a simple and comprehensive way to measure, with 4 grades, dyspnea in patients with COPD.[76]

Modified MRC Dyspnea Scale:

I. **mMRC Grad 0:** Breathless after heavy exercise
II. **mMRC Grad 1:** Shortness of breath when walking quickly on a level ground or walking up a slight hill
III. **mMRC Grad 2:** Walking more slowly than people of the same age

IV. **mMRC Grad 3:** Stopping for breath after walking ~100 m or after few minutes

V. **mMRC Grad 4:** Too breathless to leave the house, breathless when dressing or undressing

An alternative to the modified MRC Dyspnea Scale (mMRC) is the COPD Assessment Test (CAT™), which is an 8-item questionnaire to measure health impairment in COPD patients.[39]

4.6. Therapy

Chronic obstructive pulmonary disease causes irreversible damage to the lung tissue. Treatment measures focus on controlling the symptoms, limiting disease progression, reducing the risk of complications and exacerbation, and improving the patient's quality of life.

A multimodal treatment approach which includes non-pharmacological and pharmacological measures is needed when dealing with patients with COPD.

Non-pharmacological therapies:

1. Smoking cessation: substantially reduces the rate of decline in lung function.[4]
2. Inhaler techniques: patient education about appropriate inhaler techniques, especially when different inhalers are prescribed.[51]
3. Pulmonary rehabilitation: includes regular physical activity, a healthy diet, and adherence to medication.[60]
4. Supplemental oxygen.
5. Vaccination: including pneumococcal, influenza, pertussis, and COVID-19.[8,45]
6. Interventional bronchoscopy and surgery: in later stages.[92]

Pharmacological therapies:

1. Bronchodilators: these alter the smooth muscles of the airways and increase expiratory flow. They include short and long-acting Beta2-agonists (SABA, and LABA), short and long-acting antimuscarinic agents (SAMA, and LAMA), methylxanthines, inhaled corticosteroids (ICS), phosphdiestarase-4 inhibitors, and mucolytic agents.[33]
2. Oral glucocorticoids: mainly used for treating acute exacerbations in hospitalized patients.[88]
3. Theophylline: an oral nonselective phosphodiesterase inhibitor and a bronchodilator.[77]
4. Phosphodiesterase-4 (PDE-4) inhibitors: reduce inflammation without direct effects on bronchial activity.[25]

4.7. Prognosis

The prognosis of COPD depends on numerous clinical factors that influence the prognosis and outcome of the disease. [30]

These factors include:

1. Smoking cessation: in the Lung Health Study (LHS), a group of 5887 smokers with mild to moderate chronic obstructive lung disease were observed over a 5 year period. The study showed that sustained tobacco quitters experienced a decline of 34ml/year in their FEV1 (Forced expiratory volume). Those who continued smoking experienced a decline of 63ml/year in their FEV1. These findings were also associated with a reduced risk of hospitalization and mortality.[3,85,53(p15)]
2. Airway responsiveness: airway hyper-responsiveness leads to bronchoconstriction after exposure to pharmacological or physical stimuli.

People with hyper-responsive airways have an increased COPD mortality risk.[38]

3. Low body-mass index (BMI <21): lower body-mass index increases the risk of COPD mortality, while higher body-mass index is associated with better disease prognosis.[82] This could be due to muscle weakness and reduced gas exchange in patients with low BMI. It is also possible that the decline in BMI is a result of an advanced COPD stadium.[48]
4. Viral and bacterial infections: patients with viral or bacterial infections of the airways have higher hospitalization rates due to acute exacerbation, which leads to increased risk of COPD morality.[74]
5. Comorbidities such as cardiovascular diseases and lung cancer: comorbidities have a direct impact on health outcome. Some conditions (such as coronary heart disease) increase the risk of COPD mortality, and vice versa; symptoms of chronic bronchitis increase the risk of death due to coronary heart disease by up to 50%.[12]
6. High levels of CRP (>3mg/L): serum CRP (C-Reactive Protein) levels of 3 mg/L or higher are associated with a higher risk of hospitalization and death among patients with COPD.[20]
7. Male sex: studies have shown that mortality in males is higher than it is in females with similar COPD severity, which could be due to increased comorbidities, such as cardiovascular diseases and lung cancer.[95]

5. Reasons for Choosing COPD

I decided upon COPD as an amenable cause of death because COPD is a well-defined chronic condition that is easy to diagnose and treat. It has a high prevalence, which allows for the collection of sufficient data, even for relatively small populations. It is amenable to medical interventions and public health measures, such as reducing organic dust exposure and avoiding tobacco consumption.

3. Research Methodology

3.1. General Mortality Life Tables

Using the United States Mortality Database (www.usa.mortality.org), life tables can be viewed for the nation and by state.[97] The life tables are divided into 1 year age groups and range from 0 to 110+, showing the mortality data from 1959 to 2016. Due to the great amount of resulting data, the tables have not been provided in the printed version of this work, but they are provided as supplementary material (marked "Appendix 001") which is accessible via an external USB flash drive.

m(x)	This is the central rate of mortality, or the average number of deaths each year at age x.
q(x)	Age-specific mortality/mortality rate between age x and x+1, or the probability that a person aged exactly x will die before reaching age (x +1).
a(x)	The number of subjects alive at the beginning of each age group.
l(x)	This is the number of people who survive to exactly age x from 100,000 live births. These people are assumed to be subject to the mortality rates experienced throughout their lives.
d(x)	This is the number of people dying between exact age x and (x +1).
L(x_A)	This is the number of person years lived between age x and (x+1).
T(x)	This is the number of years lived from age x to the oldest age.
e(x)	Period of life expectancy.
SR	1-year survival rate.

Figure 1: Definitions of symbols occurring in the life tables

3.2. Normative Life Tables

By isolating the lowest mortality rates for every age group for all states in a specific year (1980, for example), it is possible to create normative life tables for this specific year. The normative life table represents a fictitious population (with a usual radix of n = 100,000 individuals) moving along the normative life table. These tables have the best possible mortality rates and, consequently, the highest life expectancies that occurred in each state for each age group. To create these tables, “q(x)” -age specific mortality- is isolated from general mortality life tables. Using a pre-programmed and an established standard algorithm in demography, additional standard values for life tables (such as life expectancy, the number of individuals alive at the beginning of each age, the number of years lived between age x and (x+1)), survival rates and other values are calculated. The syntax script of the algorithm was provided by the supervisor of this dissertation.

Normative life tables for females and males for the years 1960, 1970, 1980, 1990, 2000, 2010, 2016 have been created, and are accessible via an external USB flash drive under “Appendix 002”. Total Normative life tables (for both sexes males and females) in 2016 are likewise accessible under “Appendix 003”.

3.3. General COPD Mortality Life Tables

Using the CDC-WONDER database,[13] COPD mortality rates for underlying cause of death (J44: other chronic obstructive pulmonary diseases) for years of age at a state level from 2000 to 2016 were extracted. Other filters, including race and Hispanic origin, were not included. These filters lead to more suppressed values by the CDC, since further details on low mortality rate areas easily allowed for the identification of patients.[96]

Dividing COPD mortality life tables into male and female cohorts resulted in more suppressed values, which made it difficult to conduct a thorough analysis. However, according to the mortality data on COPD provided by the CDC-WONDER, the total COPD mortality rates (deaths per 100,000) for females in 2016 in California, Kentucky and Texas were 33.5, 77.7 and 35.1 respectively. For males, they were 30.2, 69.5 and 32.7. While California and Texas have similar COPD mortality rates for males and females, mortality rates for females in Kentucky are considerably higher than those for males. This can be explained through Kentucky's small population and its susceptibility to small changes in death cases. Small changes in the number of deaths for a smaller population will have a greater impact on the overall death rate. Kentucky's male population in 2016 was 2,186,553, and COPD deaths were 1519. The female population was 2,250,421, and COPD deaths were 1749. Females in the USA have a life expectancy which is five years higher than males (81.1 in comparison to 76.1).[44] Since death from COPD occurs in later life, a longer life span may lead to a higher mortality risk. Therefore, these additional five years will lead to an extra number of deaths due to COPD and other conditions that is not compensated for in the male population. Therefore, there is little that speaks in favor of substantial differences between the sexes in the regional variation of COPD mortality in the US.

The ICD-10 code for J44 (other chronic obstructive pulmonary diseases) includes:

1. J44.0 Chronic obstructive pulmonary disease with (acute) lower respiratory infection.
2. J44.1 Chronic obstructive pulmonary disease with (acute) exacerbation.
3. J44.9 Chronic obstructive pulmonary disease, unspecified.

The equivalent ICD-11 code CA22 (chronic obstructive pulmonary disease) includes:

1. CA22.0 Chronic obstructive pulmonary disease with acute exacerbation, unspecified.
2. CA22.1 Certain specified chronic obstructive pulmonary disease.
3. CA22.Z Chronic obstructive pulmonary disease, unspecified.

3.3.1. Cluster Analysis of COPD Mortality

To create an overview of the states with the highest and lowest COPD mortality rates, a cluster analysis using SPSS version 28.0 for the years 2000, 2010 and 2016 was conducted. Cluster analysis in this context has several limitations, including:

1. 13 states and the District of Columbia were excluded due to unavailable or missing data:
   Alaska, Delaware, District of Columbia, Hawaii, Idaho, Maine, Montana, New Hampshire, North Dakota, Rhode Island, South Dakota, Utah, Vermont, and Wyoming.
2. Only the age groups 70 to 84 were included in the cluster analysis.
3. Choosing the number of clusters is arbitrary.
4. The practical significance of the results is limited.

However, dividing the states into low, moderate, and high mortality rates offers a comprehensive overview of COPD mortalities across states.

The following steps were implemented when conducting the cluster analysis:

1. A descriptive analysis of COPD mortality data in the states from ages 70 to 84 was performed.
2. A hierarchical cluster analysis with a dendrogram was made, in order to obtain a better overview of the possible clusters
3. A K-mean cluster analysis was performed, clustering the states into three groups with low, moderate, and high centered death rates for COPD among age groups 70 to 84. K-mean cluster analysis is clustering objects (dividing objects into groups) according to the mean values of objects within a cluster (a group of objects).
4. A Welch and Brown-Forsythe test was done, which tests absolute differences of group means. A significant difference between the means

of the resulting clusters indicates that the resulting clusters are in fact significantly different from each other.

Figure 2 illustrates cluster membership of the states in low, moderate, and high mortality for COPD:

State	2000	2010	2016
Alabama	Moderate	Moderate	High
Arizona	Moderate	Low	Moderate
Arkansas	Low	Moderate	High
California	Low	Low	Low
Colorado	High	Moderate	Moderate
Connecticut	Low		Low
Florida	Low	Low	Low
Georgia	Moderate	Moderate	Moderate
Illinois	Low	Low	Low
Indiana	Moderate	Moderate	High
Iowa	Low	Moderate	Moderate
Kansas	Moderate	Moderate	Moderate
Kentucky	High	High	High
Louisiana	Low	Moderate	Moderate
Maryland	Low	Low	Low
Massachusetts	Low	Low	Low
Michigan	Low	Moderate	Moderate
Minnesota	Low	Low	Low
Mississippi	Moderate	Moderate	High
Missouri	Moderate	Moderate	Moderate
Nebraska		Moderate	
Nevada	High	Moderate	High
New Jersey	Low	Low	Low
New Mexico			Moderate
New York	Low	Low	Low
North Carolina	Moderate	Moderate	Moderate
Ohio	Moderate	Moderate	Moderate
Oklahoma	High	High	High
Oregon	Moderate	Moderate	Moderate
Pennsylvania	Low	Low	Low
South Carolina	Moderate	Moderate	Moderate

Tennessee	Moderate	Moderate	High
Texas	Low	Moderate	Moderate
Virginia	Moderate	Low	Low
Washington	High	Low	Low
West Virginia	High	High	High
Wisconsin	Low	Low	Low

Figure 2:
Overview of Cluster membership of the states after excluding states with incoherent and missing death reports for COPD, for 2000, 2010 and 2016

3.3.2. Normative COPD Mortality Life Tables

After creating COPD mortality life tables using the WONDER-Databank, the lowest mortality rates reported within every age group from 50 to 84 for the year 2016 were isolated from the data and marked as "minimal mortality". The minimal mortality values were inserted into the previous algorithm to calculate normative life tables. For ages 0 to 49, mortality values from previously calculated normative life tables for the USA were used. Since COPD is a chronic disease, mostly due to the heavy consumption of tobacco, and the fact that mortality from COPD occurs in the later years of life, the disease has very little significance for mortalities under the age of 50. 2016 was selected because, at the beginning of this dissertation, general mortality data was only available until 2016. Therefore, this work will focus on moralities that occurred during or before 2016. COPD mortalities in 2016 in California, Kentucky and Texas from age 50 to 84 are provided in Appendix 1. COPD mortality life tables for California, Kentucky and Texas in 2016 are provided in appendices 2, 3, and 4. Resulting normative COPD life tables for 2016 are provided in Appendix 5.

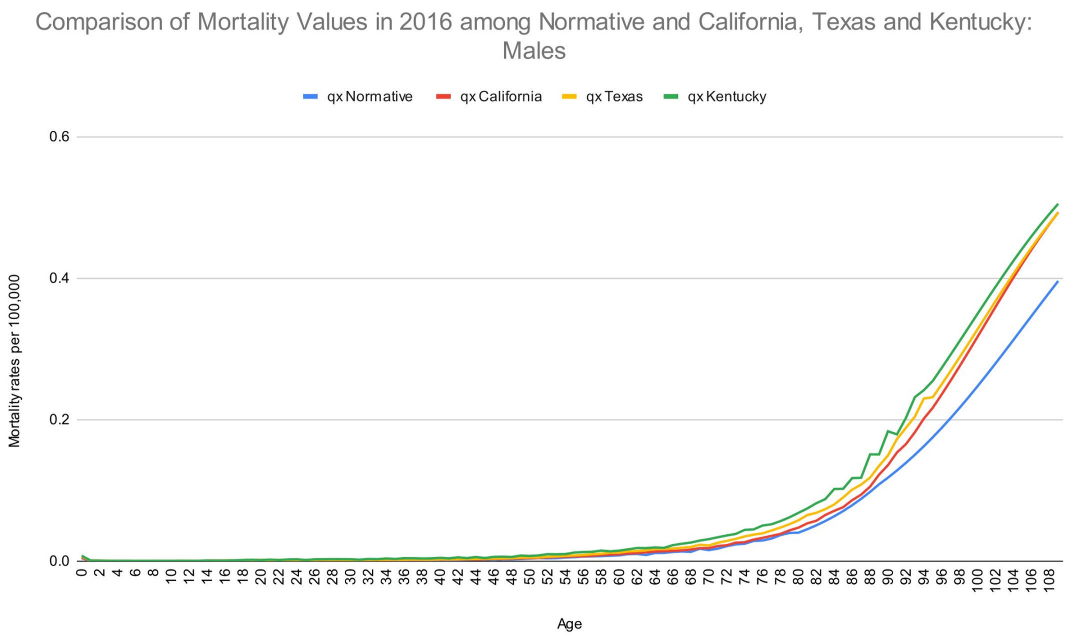
4. Results

4.1. Comparison of Normative Life Tables for the USA and the states of California, Texas and Kentucky

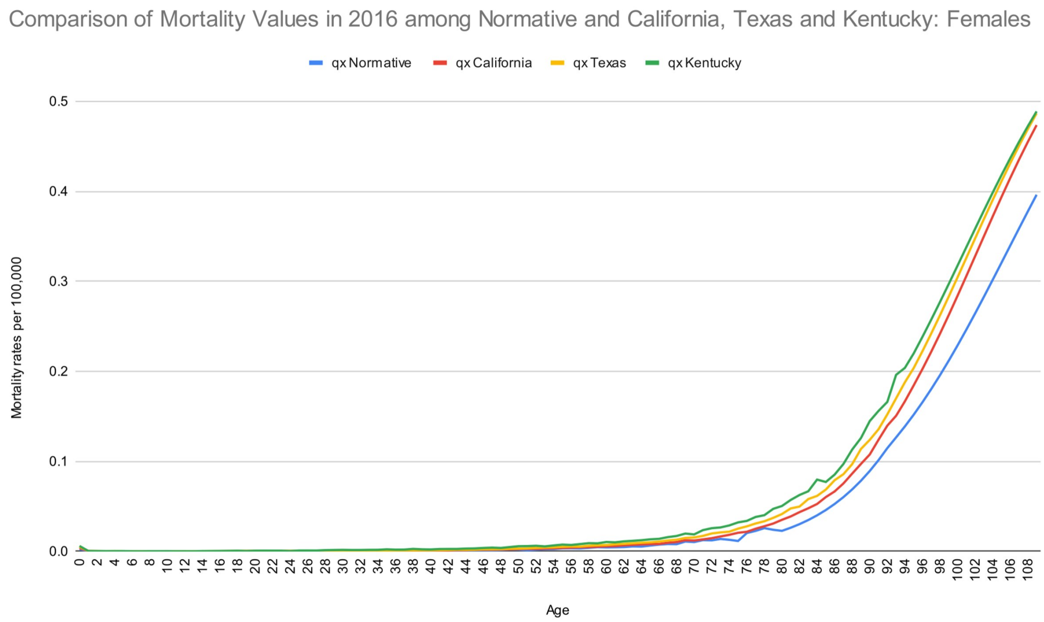
In Section 4.1, differences in general mortality rates and life expectancies for 2016 in California, Texas, Kentucky will be presented and discussed, along with normative life tables for males and females. These states were selected because they have the lowest (California), average (Texas) and highest (Kentucky) mortality rates in the USA. These states also presented sufficient mortality reporting due to COPD for most age groups, and will also be considered for COPD mortality analysis in Section 4.2.

4.1.1. Differences in Mortality Rates for Normative Life Tables, California, Texas and Kentucky in 2016

The mortality values "q(x)" from normative life tables were isolated and compared with "q(x)" for California, Texas, and Kentucky. The following diagrams show the comparisons for males and females:



Mortality for males in 2016: blue line: normative values, red line: California, yellow line: Texas, green line: Kentucky.



Mortality for females in 2016: blue line: normative values, red line: California, yellow line: Texas, green line: Kentucky.

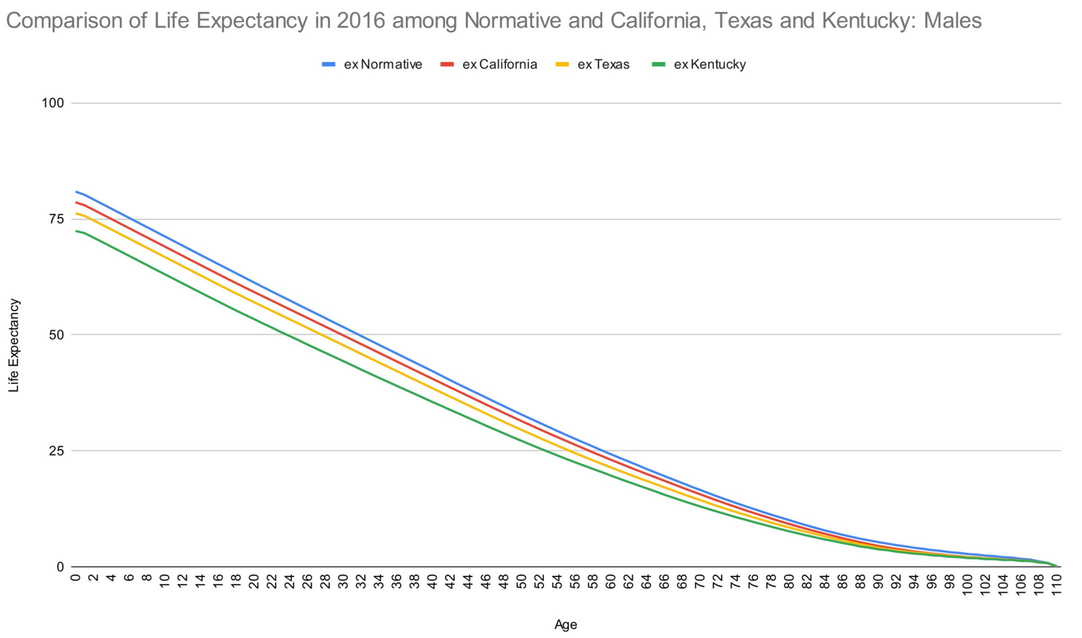
From the first years of age to the late 40s, mortality curves have very similar trends. They start to diverge around the age of 50 for both males and females. The differences in mortality rates increase and become more significant until later years (94). At this point, the curves of the three states (California, Texas, and Kentucky) come closer to each other and become more separated from normative values, indicating a greater difference in general mortality between these states and normative values. Because the second divergence occurs at 94, very late in life, it is insignificant for this work.

The diagrams seem to reflect a classification in low, moderate and high mortalities within the studied states. California, a state with very low and similar mortality values to those of the normative. Texas is a state with a moderate mortality when compared to the rest of the states observed. Kentucky has high mortality values, which in some cases are twice as high as the normative or the state of California, with peaks at 90, 88, 86 and 84 years of age for males and 93, 90 and 84 for females. In these cases, the mortality values were significantly higher than in the rest of the states observed.

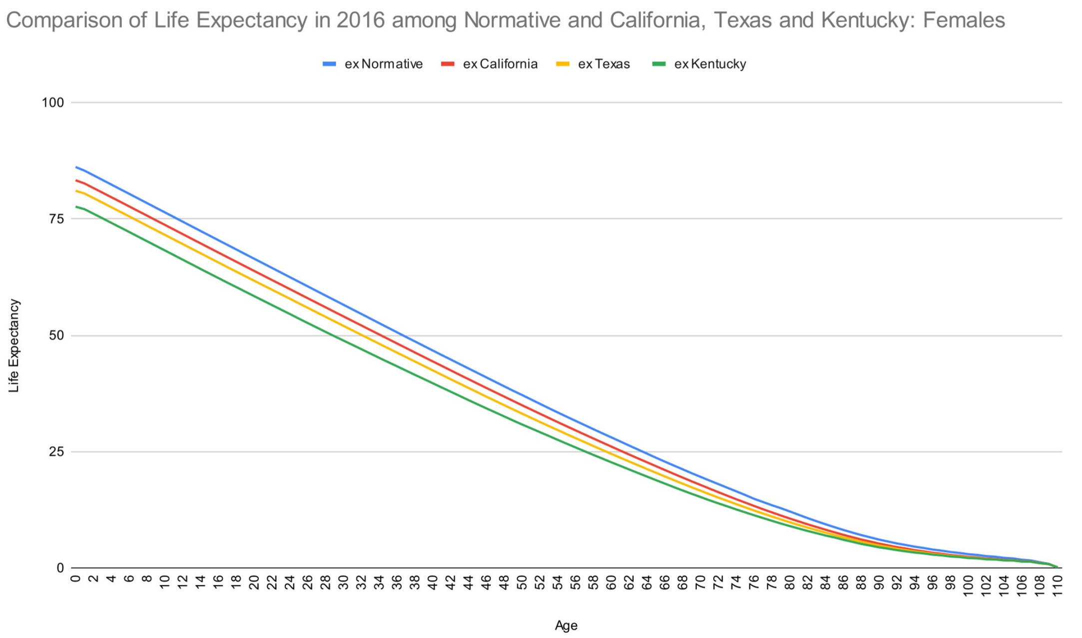
During the 76th and 78th years of age, mortality values for females in California were very close to those of the normative life tables, though not identical. This explains the spike at these ages.

4.1.2. Differences in Life Expectancy for Normative Life Tables, California, Texas and Kentucky in 2016

Mortality values "q(x)" for males and females from normative life tables, California, Texas, and Kentucky were isolated and added to a pre-programmed and widely-recognized algorithm to calculate life tables depending on mortality values "q(x)". The resulting "e(x)" values, also recognized as life expectancy for normative, California, Texas and Kentucky are shown in the following diagrams:



Life expectancy for males in 2016. Blue line: normative values, red line: California, yellow line: Texas, green line: Kentucky.



Life expectancy for females in 2016. Blue line: normative values, red line: California, yellow line: Texas, green line: Kentucky.

According to these diagrams, females have a life expectancy that is approximately 5 years higher than males in all the states included and in normative life tables.

Toward the later years of life (at around 60 years old), the convergence of the curves increases, reducing the gap in life expectancy among the states observed and normative values, which could be due to higher morbidity rates in old age.

In life expectancy, there is also a clear classification in high (California), moderate (Texas) and low (Kentucky) for both males and females. Kentucky has a life expectancy that is eight years lower than the normative and approximately five years lower than California for males and females. Texas has a life expectancy that is approximately five years lower than the normative for males and females. California's is approximately two years lower than the normative for males and females.

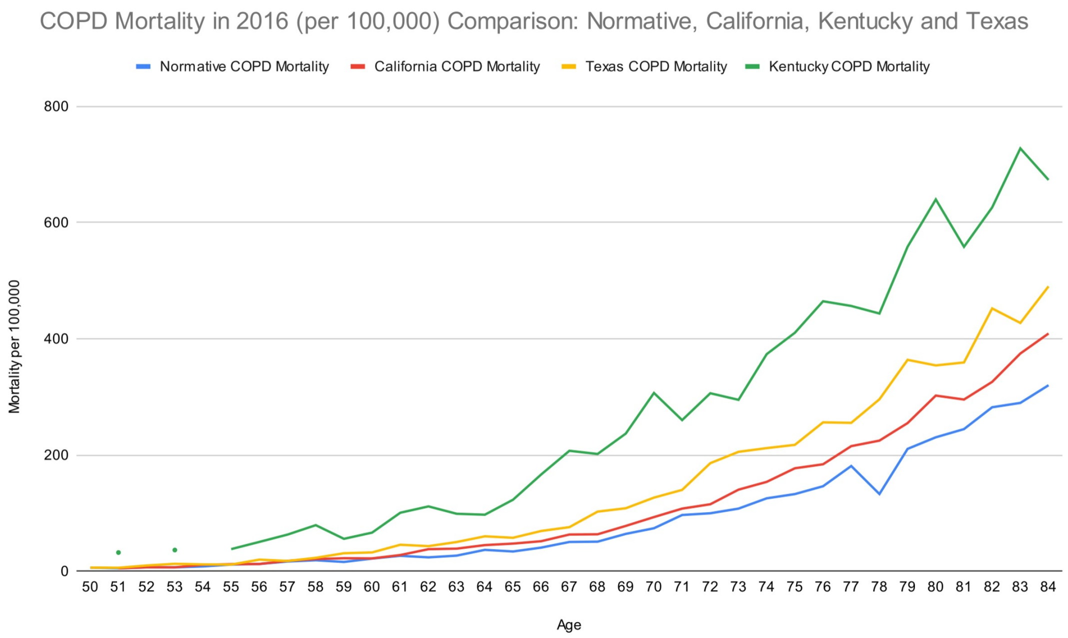
4.2. Comparison of COPD Normative Life Tables for the US, California, Texas and Kentucky

CDC WONDER COPD mortality values for all the US states can be viewed and exported. Beside suppressed values due to low mortality reports, several states failed to report their COPD mortality rates, leading to inconsistencies in death reports (including those for older age groups).[13]

COPD is a chronic health condition, with most deaths occurring in later years of life.[52] For this observation, the lowest mortality values "q(x)" from age 50 to 84 were inserted into a pre-programmed algorithm. The algorithm calculates life tables, including life expectancy, depending on the values inserted. Mortality values from 50 to 84 "q(x)" for the states of California, Texas and Kentucky were inserted into the same algorithm to calculate COPD life tables for these states. For 0 to 49, the corresponding data from general life tables were used.

4.2.1. Differences in COPD Mortality Rates for normative Life Tables, California, Texas and Kentucky in 2016

Here, the 2016 COPD mortality values for both sexes, ages 50 to 84, from normative life tables were compared with those of California, Texas and Kentucky. The comparison is shown in the following the diagram:



COPD mortality for males and females in 2016. Blue line: normative values, red line: California, yellow line: Texas, green line: Kentucky.

In the diagram, there is a classification in low (California), moderate (Texas) and high (Kentucky) mortality similar to that of general mortality. The curves increasingly separate from each other towards later years of life, due to higher COPD mortalities at those ages. This reveals further disparities in COPD morality rates for California, Kentucky, Texas, and normative values.

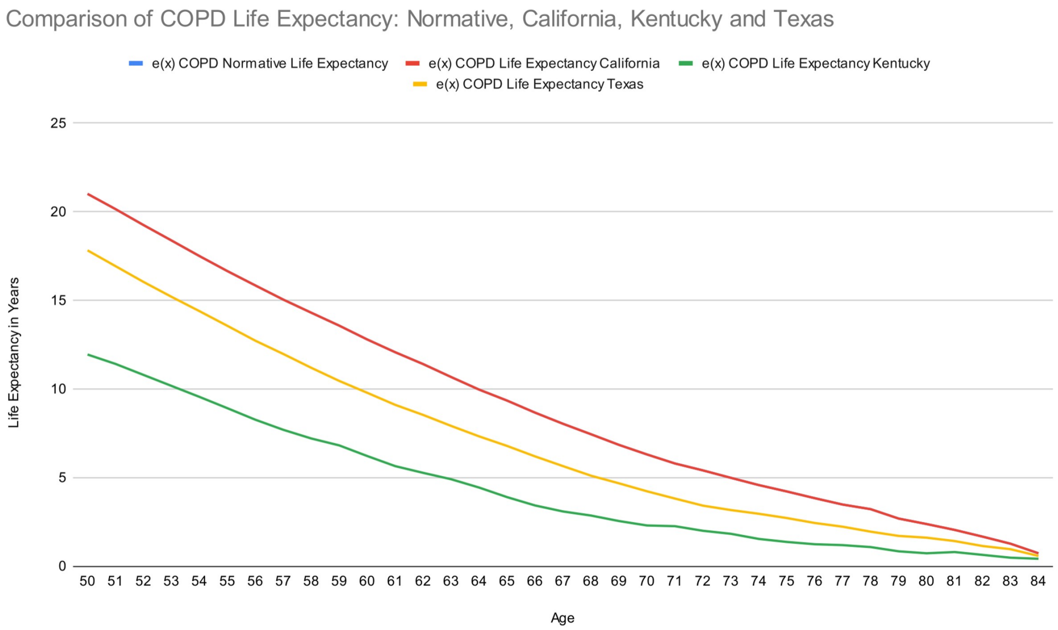
From 50 to 58 years of age, California and Texas have similar COPD morality values to those of the normative: the curves are almost identical. Starting at 59, the differences in COPD mortalities for Texas and California become increasingly apparent.

Kentucky has consistent high-to-very-high COPD mortality values for all the ages observed. Compared to California, COPD mortality rates in Kentucky for certain age groups are up to five times higher (age 53: Kentucky=0.03650, California=0.00670).

The value of 132.9 on the normative blue curve at age 78 is probably an outliner. The value comes from the state of New Jersey, which is a state with generally low COPD mortality values. For ages 77 and 79 in New Jersey mortality values were 181.1 and 224.0 respectively. Since both values at these ages are significantly higher than at age 78, we shall assume that 78 was an outlier due to late or missing deaths reports.

4.2.2. Differences in COPD Life Expectancy for Normative Life Tables, California, Texas and Kentucky in 2016

Here, 2016 COPD life expectancy values for ages 50 to 84 for both sexes from normative life tables were compared with those of California, Texas and Kentucky. The comparison is shown in the following the diagram:



COPD life expectancy for males and females in 2016. Blue line: normative values, red line: California, yellow line: Texas, green line: Kentucky.

In the COPD life expectancy curves, a classification of high (California), moderate (Texas) and low (Kentucky) life expectancy for individuals with COPD is apparent.

California, as the state with best life expectancy for COPD patients, has an identical curve to that of the COPD normative life expectancy. According to the diagram, at age 50, COPD patients in Kentucky have a life expectancy that is more than nine years lower than their peers in California (life expectancy at age 50 for Kentucky = 11.94, California = 21.01), and a life expectancy that is more than five years lower their peers in Texas (life expectancy at age 50 for Kentucky = 11.94, Texas = 17.82). At the same age, individuals with COPD in California have a life expectancy that is more than three years higher than their peers in Texas.

In later years of age, the curves tend to converge. At the age of 84, individuals with COPD in the states observed and in normative COPD life tables have less than one year of life expectancy (normative = 0.72 years, California = 0.72 years, Texas = 0.57 years, Kentucky = 0.41 years).

5. Discussion

In this work, the concept of normative life tables has been applied to measure amenable deaths in general and for chronic obstructive pulmonary disease in the United States of America. The goal of this work is to isolate the lowest mortality values for each year of age for each state in order to identify states with high mortalities and quantify unavoidable deaths: deaths that, with timely and effective health care, could have been avoided. Excess deaths are considered avoidable.

After extracting the 2016 COPD mortality data, differences between normative COPD life tables and COPD life tables for California, Texas and Kentucky were compared. These states represent the lowest, average and highest COPD mortalities in the United States, as well as the highest, average and lowest life expectancies for individuals with COPD. Normative COPD mortality values and life expectancy for individuals with COPD in 2016 were quite similar to those of California. This suggests that, with the current US health care policies and resources, California is a state with few avoidable COPD deaths. Texas and Kentucky, on the other hand, had higher mortality values and lower life expectancies. A considerable portion of these deaths could have been avoided if timely and effective health care had been provided. Further studies are needed to disentangle the influence of major COPD risk factors in areas with high mortality rates and to consider measures that should be implemented to limit their influence, thus lowering COPD mortality rates. Major risk factors include tobacco smoke, environmental and occupational exposures (such as mining, farming and air pollution), socioeconomic status, a history of asthma and respiratory infections.[101]

Urban environments seem to play a major role in elevated COPD mortality. Janet B. et al (2018) published an analysis conducted by the CDC to assess urban-rural variations in COPD mortality.[98] The study found increased COPD prevalence, hospitalization rates (for Medicare beneficiaries) and mortality rates in rural areas. Kentucky was one of four states (Arkansas, Mississippi, and West

Virginia were the others) with the highest outcome for all three measures. It also had the highest proportion of rural residents (22.3%). Certain COPD risk factors are more serious in rural than metropolitan areas. They include a higher percentage of smokers and second-hand smoke exposure, with limited access to smoking cessation programs.[23,59] Rural areas have higher numbers of uninsured residents and more people with lower socioeconomic status, as well as limited access to health care providers, COPD management and rehabilitation programs. These programs are essential in preventing disease progression and exacerbation. Access to these programs, as well as access to early diagnosis and treatment, are managed by pneumologists. However, as a study conducted by Croft JB. et al (2016) has shown, only 34.5% of rural residents have a pneumologist available within 10 miles. Therefore, many of these patients are looked after by their primary care providers, with limited resources and awareness to pulmonary rehabilitation programs.[26,19]

In a 2011 study conducted by Holt et al. on COPD hospitalization rates among Medicare beneficiaries (aged 65≥), researchers found higher COPD hospitalization rates in Texas than in California. Kentucky had one of the highest hospitalization rates in the country (20.8 per 1,000 Medicare beneficiaries).[37] A state-level comparison of COPD mortality and hospitalization rates shows geographic matches and mismatches, indicating frequent risk factors that must be further differentiated. Studies with both COPD hospitalization and mortality outcome are needed to lay out the potential links in geographical patterns.

One of the main criticisms of a 1976 study by Rutstein et al. (as well as other studies that are based on it, such as Charlton et al. (1983) and Holland (1986)) is the introduction of arbitrary age limitations.[15,16,79,36] Normative life tables take reduced life expectancy into account for every year. This solves the problem of arbitrary age limitations, since years lost due to illness are already part of the normative life table calculation. However, the concept of normative life tables has several limitations. One of these limitations is the unchangeable geographic and socioeconomic factors, such as increased mortality risk from skin cancer due to higher sun exposure in states like California and Texas. These factors marginally reduce the proportion of avoidable deaths. Another limitation is that disease-related normative life tables do not reflect comorbidities, but consider a single cause to result in death. Furthermore, the concept does not directly reflect on health care inputs, such as number of doctors per thousand patients. This data is easily accessible via the CDC and could be further examined when analyzing avoidable deaths. However, the idea of normative life tables is not about providing a method which measures 100% of all avoidable deaths. It is instead about providing a robust, real-world tool that estimates a substantial portion of deaths that could be avoided by allocating health care resources and identifying differences in socioeconomic factors that lead to a “substantial” increase in deaths.

6. Conclusion

In the last few decades, several approaches have been tested to quantify amenable deaths due to chronic and non-chronic conditions. The normative life table approach introduced in this research is a simple application that is easy to understand. It allows for the identification of groups of populations with higher and lower mortality rates for selected conditions. Identifying such populations paves the way to understanding contributing, influenceable factors within these groups. States with high mortality rates for certain conditions can compare their differences to states with lower mortality rates and implement changes that could reduce the number of amenable deaths and increase the life expectancy of its population.

By comparing COPD morality rates within the United States to normative COPD life tables, a heterogeneity in mortality is apparent. States such as Kentucky and Oklahoma show a significant rise in mortality rates across all available ages (50 to 84). For most ages, Kentucky has 200% to 300% more COPD deaths than California. In some cases, the difference is more than 500% (age 51 and 53). Furthermore, the differences in the states are also reflected in life expectancy. While California has an almost identical life expectancy to that of normative COPD life tables, states such as Texas and Kentucky experience a substantial decline in life expectancy. At the age of 50, Californians with COPD are expected to live for an additional 21 years, whereas Texans with COPD are expected to live for an additional 18 years, Kentuckians only 12.

Certain risk factors that are more prevalent in some states contribute to the disparities observed. These include higher numbers of smokers, a major contributing cause to COPD in rural and industrial regions, migration, environmental and socioeconomic aspects, such as air pollution, occupational exposure (mining, farming and construction) and limited access to health care. Further studies are required to identify additional underlining factors.

7. Limitations

Due to small populations and incomplete death reports, including suppressed data by the CDC as a consequence of low death rates and unavailable death figures, several states were excluded. Furthermore, COPD death rates were only accessible for ages 50 to 84. Since COPD is a chronic condition and most deaths occur in later life (approx. 65 years of age), a normal general mortality was assumed for ages 0 to 49 when creating COPD life tables. More detailed and consequent death reports for all ages and states are needed to create more comprehensible, conclusive assertions.

An attempt to further differentiate between COPD mortality data for males and females to assign cluster memberships to the states was not successful, because a considerable number of missing values required the exclusion of yet more states and age groups from the analysis. Several approaches to overcoming this differentiation led to impractical and fruitless analysis.

Before deciding in favor of COPD, I considered analyzing mortality rates for tuberculosis and influenza from 1960 to 2016. One of the challenges was the outdated and incomplete mortality data for 1960 to 1990. It was possible to access mortality data from 1960 for tuberculosis and influenza for the USA in general and the 50 states (including the District of Columbia), but a detailed differentiation for single age groups was not available. Furthermore, existing data was only available in an outdated PDF format. To generate new mortality life tables, every entry had to be typed manually into Excel sheets which, considering the substantial number of cases, might have led to incorrect results.[99] Despite extensive research, additional data for 1961 to 1998 could not be found online. The National Center for Health Statistics of the CDC provides mortality data on tuberculosis and influenza for the 50 states and District of Columbia in five-year age groups from 1999 to 2007.[70] This data was isolated and analyzed. Due to very low mortality rates from tuberculosis (776 people died of tuberculosis in the USA in 2000) and influenza (1765 people died of influenza in the USA in 2000), the analysis of this data was not statistically significant.

In 2008, the CDC introduced its new web tool WONDER, in which disease mortality rates for under ten people were suppressed to protect personal privacy and prevent information that may identify specific individuals from being revealed. In some individual cases, the suppressed values could be unlocked.[93] After contacting the CDC to ask for permission to access mortality rates for tuberculosis and influenza, the CDC agreed to unlock the mortality data, provided that this dissertation was completed in the USA and that the data was accessed from a university computer inside the USA. Since the latter two conditions could not be fulfilled for this dissertation, the possibility of analyzing the mortality rates for tuberculosis and influenza was dismissed.

Additional approaches considered included studying avoidable deaths of other infectious diseases, such as measles, syphilis, and HIV in the USA. Death rates from these infectious diseases in the USA has decreased substantially in recent decades thanks to broad prevention efforts.[42] For example, in 2000 in the USA, only 1591 people died from HIV/AIDS, 0 people died from measles and 4 people died from syphilis.[69] Because of their substantially lower mortality rates HIV, measles and syphilis were eliminated from further consideration.

I would therefore recommend that future studies use the approach of normative life tables to determine amenable deaths in diseases that are frequent, preventable and would lead to death in advanced stages if timely and effective care is not provided. COPD is an example of such a disease. It is common (around 12.5 million people are affected yearly in the USA), preventable and around 120,000 deaths occur in the USA each year.[44,50] Other diseases to which the approach of normative life tables applies are acute myocardial infarction (ICD-10: I21), pulmonary heart disease (ICD-10: I27.9) and infectious diseases in endemic regions (such as tuberculosis ICD-10: A15-A19, diphtheria ICD-10: A36, and tetanus ICD-10: A35). Although diabetes is a leading cause of death in the USA, it is often attributed to other comorbidities.[29] These include arterial hypertension, hyperlipoproteinemia, depression and peripheral artery disease (PAD).[68] Further studies could apply the approach of normative life tables to investigating mortality rates among patients with type 2 diabetes. I would recommend creating two groups or more of populations with type 2 diabetes, one group with low to no comorbidities and the second group with moderate to high comorbidities. Populations with type 2 diabetes which are in the same comorbidity group should have similar mortality rates. Higher than average mortality rates would indicate amenable deaths.

8. Summary

In this work, a novel approach to measuring amenable deaths is introduced. The lowest age-specific mortality rates in the USA have been isolated to create normative life tables. The concept of normative life tables was first described in the context of the Global Burden of Disease Study at the University of Washington in Seattle, for measuring the general burden of disease in specific populations. Normative life tables provide an ideal life table for the USA, and shed light on shortcomings in states with comparatively high mortality rates. The normative life table approach is applied for a chronic and frequent health condition in the USA, namely COPD (Chronic Obstructive Lung Disease). The lowest COPD mortality rates in the USA for 2016 have been isolated to create normative COPD life tables. These normative life tables show the best practice for COPD in the USA. Excess deaths in COPD across the states are regarded as amenable deaths, i.e., deaths that with timely and effective medical interventions and public health efforts could have been prevented. California has the lowest proportion of amenable deaths due to COPD. Texas has moderate mortality rates for COPD, while Kentucky has the highest COPD mortalities in the USA, and therefore the highest proportion of amenable deaths in COPD. These changes are also reflected in the life expectancy of individuals with COPD. California has the highest life expectancy for individuals with COPD. In 2016, 50-year-olds with COPD in California were expected to live for an additional 21.01 years, while in Texas they had an additional 17.82 years to live and in Kentucky, only 11.94 years.

The normative life table approach adds to current efforts by providing a fair way of measuring health care performance. It acts as an indicator of health care quality by measuring the share of amenable deaths that, with timely and effective medical interventions and public health efforts, could have been avoided.

9. Zusammenfassung

In dieser Arbeit wird ein neues Konzept zur Bestimmung von vermeidbaren Todesfällen vorgestellt. Das Konzept beschreibt eine so genannte normative Sterbetafel (aus dem Englischen: normative life table). Dieses wurde erst im Kontext der Global Burden of Disease Study zur Bestimmung der allgemeinen Krankheitslast in der Bevölkerung an der Universität Washington in Seattle dargelegt. In dieser Arbeit wurden die niedrigsten Mortalitätsraten aus den USA für alle Lebensjahren (0-109 Jahre alt) isoliert und in einen Algorithmus zur Berechnung von normativer Sterbetafel eingeführt. Die neue normative Sterbetafel (normative life table) beschreibt eine ideale Sterbetafel für das betroffene Land (in diesem Beispiel: die USA). Überschussige Todesfälle sind unter zeitnahe und effektive medizinische Interventionen und Gesundheitsinitiativen vermeidbar. Das Konzept der normativen Sterbetafel wurde für eine chronische und häufig auftretende Erkrankung in den USA nämlich COPD (chronisch obstruktive Lungenerkrankung) eingesetzt. Anhand der niedrigsten COPD-Sterberaten in den USA wurde eine normative COPD-Sterbetafel erstellt. Im Vergleich zu den normativen COPD-Sterberaten hat Kalifornien den niedrigsten Anteil an vermeidbaren Todesfällen für COPD. Zudem sind COPD-Sterberaten in Texas moderat erhöht. Kentucky hat die höchsten COPD-Sterberaten und somit den höchsten Anteil an vermeidbaren Todesfällen für COPD. Hohe COPD-Sterblichkeit schränkt die Lebenserwartung der betroffenen Individuen ein. In Kalifornien leben Personen mit COPD im Alter von 50 Jahren zusätzliche 21.01 Jahre, in Texas 17.82 Jahre und in Kentucky nur 11.94 zusätzliche Jahre.

Das Konzept der normativen Sterbetafel zur Bestimmung von vermeidbaren Todesfällen sollte bereits etablierte Methoden zur Bestimmung von vermeidbaren Todesfällen nicht ersetzten, sondern ergänzen. Mithilfe von öffentlich zugänglichen Daten können normative Sterbetafel auf einer einfachen Art und Weise erstellt werden. Sie stellen ein Qualitätsmass zur Begutachtung der Entwicklung und Leistungsfähigkeit des Gesundheitswesens dar.

10. Appendix

Appendix 001: Life tables for the USA and states from 1959-2016 in 1-year age group for males and females including Survival rates. External USB flash drive.

Appendix 002: Normative life tables for females and males for the years 1960, 1970, 1980, 1990, 2000, 2010, 2016. External USB flash drive.

Appendix 003: Normative life tables total (both sexes females and males) for 2016. External USB flash drive

Appendix 1: COPD Mortality per 100,000 in 2016 in California, Texas, and Kentucky from Age 50 to 84 years old

Age	California COPD Mortality	Texas COPD Mortality	Kentucky COPD Mortality
50		6.3	
51	5.1	6	32.2
52	6.8	9.9	
53	6.7	12.8	36.5
54	11.2	11.8	
55	12.2	11.5	38.1
56	12.5	20	50.5
57	17.9	17.7	63.1
58	21	23.1	79.3
59	22.4	31	55.8
60	22.1	32.4	66.5
61	27.9	45.6	100.7
62	38	43.2	111.6
63	38.9	50.3	98.9
64	45	60.1	97.3
65	47.6	57.6	123.1
66	51.7	69.3	166.6

67	63.2	75.9	207.3
68	63.6	102.6	201.8
69	78	108.4	236.9
70	93.2	126.7	306.8
71	107.8	140	260.1
72	115.3	186	306.3
73	140.4	205.5	295
74	153.8	211.9	373.6
75	177.2	217.5	410.4
76	184.1	256.2	464.6
77	215.3	255.4	456.5
78	224.8	295.9	443.5
79	255	363.8	558.5
80	302.3	354.2	639.8
81	295.5	359.3	558.3
82	325.9	452.2	626.1
83	374.7	427.3	727.6
84	409.1	490.2	673.4

Appendix 2: COPD Mortality Life Table in 2016 in California

Age	l(x)	q(x)	p(x)	d(x)	L(x)	T(x)	e(x)
0	100000	0.00417	0.99677	323	99717.2372	6972946.28	69.73
1	99677	0.00031	0.99984	16	99663.0384	6873229.04	68.96
2	99661	0.00019	0.99989	11	99651.4546	6773566	67.97
3	99650	0.00017	0.99992	8	99643.1101	6673914.55	66.97
4	99642	0.00013	0.99997	3	99639.5001	6574271.44	65.98
5	99639	0.00008	0.99996	4	99635.6386	6474631.94	64.98
6	99635	0.00011	0.99996	4	99631.6532	6374996.3	63.98
7	99631	0.0001	0.99996	4	99627.6679	6275364.65	62.99
8	99627	0.00011	0.99995	5	99622.8107	6175736.98	61.99
9	99622	0.0001	0.99997	3	99619.5738	6076114.17	60.99
10	99619	0.00009	0.99998	2	99617.4573	5976494.59	59.99
11	99617	0.0001	0.99998	2	99615.4649	5876877.14	58.99
12	99615	0.00012	0.99998	2	99613.4726	5777261.67	58
13	99613	0.00009	0.99995	5	99608.8642	5677648.2	57
14	99608	0.00014	0.99989	11	99598.6518	5578039.34	56
15	99597	0.00026	0.99993	7	99591.1835	5478440.68	55.01
16	99590	0.00028	0.99992	8	99583.3403	5378849.5	54.01
17	99582	0.00041	0.99988	12	99571.8866	5279266.16	53.01

18	99570	0.0005	0.9999	10	99561.6813	5179694.27	52.02
19	99560	0.00065	0.99978	22	99541.2662	5080132.59	51.03
20	99539	0.00065	0.99962	38	99505.4249	4980591.33	50.04
21	99501	0.00077	0.99952	48	99458.9023	4881085.9	49.06
22	99453	0.00075	0.99948	52	99407.6795	4781627	48.08
23	99401	0.00077	0.99959	41	99365.5595	4682219.32	47.1
24	99360	0.00078	0.99935	65	99303.9437	4582853.76	46.12
25	99296	0.00082	0.99954	46	99255.9122	4483549.82	45.15
26	99250	0.00078	0.99923	76	99183.3197	4384293.9	44.17
27	99174	0.00086	0.99962	38	99140.8081	4285110.58	43.21
28	99136	0.00089	0.99932	67	99077.0987	4185969.78	42.22
29	99069	0.00081	0.99937	62	99014.0626	4086892.68	41.25
30	99006	0.00082	0.99947	52	98960.351	3987878.61	40.28
31	98954	0.0009	0.99919	80	98883.6465	3888918.26	39.3
32	98874	0.001	0.99927	72	98810.4753	3790034.62	38.33
33	98801	0.00095	0.99933	66	98743.5333	3691224.14	37.36
34	98735	0.00096	0.99914	85	98660.9524	3592480.61	36.38
35	98650	0.00112	0.99907	92	98570.0587	3493819.66	35.42
36	98559	0.00114	0.99909	90	98480.1141	3395249.6	34.45
37	98469	0.0012	0.99905	94	98387.0491	3296769.48	33.48

38	98375	0.00119	0.99881	117	98272.9125	3198382.43	32.51
39	98258	0.00128	0.99881	117	98155.9678	3100109.52	31.55
40	98141	0.00142	0.99896	102	98052.0495	3001953.55	30.59
41	98039	0.00138	0.99906	92	97958.658	2903901.5	29.62
42	97947	0.00148	0.99867	130	97833.1361	2805942.85	28.65
43	97817	0.00175	0.99854	143	97691.8859	2708109.71	27.69
44	97674	0.00173	0.99834	162	97532.1545	2610417.82	26.73
45	97512	0.00204	0.99813	182	97352.3245	2512885.67	25.77
46	97330	0.00219	0.99839	157	97192.429	2415533.35	24.82
47	97173	0.00233	0.99787	207	96991.7139	2318340.92	23.86
48	96966	0.00257	0.99784	209	96782.575	2221349.2	22.91
49	96756	0.00294	0.99742	250	96537.9493	2124566.63	21.96
50	96507	0.004025	0.9937	608	95974.5984	2028028.68	21.01
51	95899	0.0051	0.9949	489	95470.7013	1932054.08	20.15
52	95410	0.0068	0.9932	649	94841.8095	1836583.38	19.25
53	94761	0.0067	0.9933	635	94205.1808	1741741.57	18.38
54	94126	0.0112	0.9917	781	93442.1654	1647536.39	17.5
55	93345	0.0122	0.9885	1073	92405.1024	1554094.22	16.65
56	92271	0.0125	0.9875	1153	91261.6669	1461689.12	15.84
57	91118	0.0179	0.9832	1531	89777.8975	1370427.45	15.04

58	89587	0.021	0.9811	1693	88104.9321	1280649.56	14.3
59	87894	0.0224	0.984	1406	86662.8886	1192544.62	13.57
60	86488	0.0221	0.9782	1885	84837.1433	1105881.74	12.79
61	84602	0.0279	0.9734	2250	82632.1908	1021044.59	12.07
62	82352	0.038	0.9761	1968	80628.8256	938412.402	11.4
63	80384	0.0389	0.9731	2162	78490.6868	857783.576	10.67
64	78221	0.045	0.9632	2879	75701.3648	779292.889	9.96
65	75343	0.0476	0.966	2562	73100.2343	703591.524	9.34
66	72781	0.0517	0.9593	2962	70187.939	630491.29	8.66
67	69819	0.0632	0.9496	3519	66738.4128	560303.351	8.03
68	66300	0.0636	0.9491	3375	63345.7764	493564.938	7.44
69	62925	0.078	0.9357	4046	59383.3165	430219.162	6.84
70	58879	0.0932	0.926	4357	55064.9877	370835.845	6.3
71	54522	0.1078	0.9032	5278	49901.9302	315770.858	5.79
72	49244	0.1153	0.9002	4915	44942.0936	265868.927	5.4
73	44330	0.1404	0.8922	4779	40146.4123	220926.834	4.98
74	39551	0.1538	0.8745	4964	35205.7826	180780.422	4.57
75	34587	0.1772	0.8672	4593	30566.4219	145574.639	4.21
76	29994	0.1841	0.8537	4388	26152.7215	115008.217	3.83
77	25606	0.2153	0.8189	4637	21546.4932	88855.4956	3.47

78	20969	0.2248	0.8671	2787	18529.2142	67309.0023	3.21
79	18182	0.255	0.7894	3829	14829.9262	48779.7881	2.68
80	14353	0.3023	0.7695	3308	11456.7017	33949.8619	2.37
81	11045	0.2955	0.7554	2702	8679.60317	22493.1602	2.04
82	8343	0.3259	0.7178	2354	6281.95147	13813.557	1.66
83	5989	0.3747	0.7103	1735	4469.86506	7531.60553	1.26
84	4254	0.4091	0.6799	1362	3061.74047	3061.74047	0.72

Appendix 3: COPD Mortality Life Table in 2016 in Kentucky

Age	l(x)	q(x)	p(x)	d(x)	L(x)	T(x)	e(x)
0	100000	0.00665	0.99335	665	99417.8413	5943131.54	59.43
1	99335	0.00051	0.99949	51	99290.6501	5843713.7	58.83
2	99284	0.00036	0.99964	36	99253.0493	5744423.05	57.86
3	99249	0.00016	0.99984	16	99234.6952	5645170	56.88
4	99233	0.0002	0.9998	20	99215.3428	5545935.31	55.89
5	99213	0.00025	0.99975	25	99191.1571	5446719.96	54.9
6	99188	0.00007	0.99993	7	99181.989	5347528.81	53.91
7	99181	0.00007	0.99993	7	99175.0463	5248346.82	52.92
8	99174	0.00014	0.99986	14	99162.0266	5149171.77	51.92
9	99160	0.00018	0.99982	18	99144.6717	5050009.75	50.93
10	99142	0.00018	0.99982	18	99126.8256	4950865.07	49.94
11	99125	0.00016	0.99984	16	99110.7183	4851738.25	48.95
12	99109	0.00014	0.99986	14	99096.5959	4752627.53	47.95
13	99095	0.00012	0.99988	12	99084.4573	4653530.93	46.96
14	99083	0.00044	0.99956	44	99044.8104	4554446.48	45.97
15	99039	0.0004	0.9996	40	99004.6988	4455401.67	44.99
16	99000	0.00043	0.99957	43	98962.4969	4356396.97	44
17	98957	0.00065	0.99935	64	98900.8845	4257434.47	43.02

18	98893	0.00095	0.99905	94	98810.6269	4158533.59	42.05
19	98799	0.00103	0.99897	102	98709.8375	4059722.96	41.09
20	98697	0.00089	0.99911	88	98620.2626	3961013.12	40.13
21	98609	0.00133	0.99867	131	98494.5075	3862392.86	39.17
22	98478	0.00097	0.99903	96	98394.5456	3763898.35	38.22
23	98383	0.00136	0.99864	134	98265.5134	3665503.81	37.26
24	98249	0.00129	0.99871	127	98137.893	3567238.29	36.31
25	98122	0.00109	0.99891	107	98028.4748	3469100.4	35.35
26	98015	0.00153	0.99847	150	97883.8696	3371071.92	34.39
27	97865	0.0016	0.9984	157	97728.1101	3273188.06	33.45
28	97709	0.00188	0.99812	184	97547.7948	3175459.95	32.5
29	97525	0.00194	0.99806	189	97359.2824	3077912.15	31.56
30	97336	0.00198	0.99802	193	97166.997	2980552.87	30.62
31	97143	0.0016	0.9984	155	97006.9221	2883385.87	29.68
32	96988	0.0021	0.9979	204	96809.2583	2786378.95	28.73
33	96784	0.00206	0.99794	199	96609.348	2689569.69	27.79
34	96585	0.00254	0.99746	245	96369.7474	2592960.34	26.85
35	96339	0.00249	0.99751	240	96129.1852	2496590.6	25.91
36	96099	0.00282	0.99718	271	95862.0613	2400461.41	24.98
37	95828	0.00283	0.99717	271	95590.8914	2304599.35	24.05

38	95557	0.00303	0.99697	290	95303.6385	2209008.46	23.12
39	95268	0.00287	0.99713	273	95028.2124	2113704.82	22.19
40	94994	0.00319	0.99681	303	94728.8701	2018676.61	21.25
41	94691	0.00307	0.99693	291	94436.6325	1923947.74	20.32
42	94400	0.00386	0.99614	364	94081.4259	1829511.1	19.38
43	94036	0.00331	0.99669	311	93763.5485	1735429.68	18.45
44	93725	0.00426	0.99574	399	93375.2445	1641666.13	17.52
45	93326	0.00368	0.99632	343	93024.8517	1548290.88	16.59
46	92982	0.0047	0.9953	437	92599.4933	1455266.03	15.65
47	92545	0.00501	0.99499	464	92139.1606	1362666.54	14.72
48	92081	0.00464	0.99536	427	91707.3693	1270527.38	13.8
49	91654	0.00614	0.99386	563	91161.4924	1178820.01	12.86
50	91091	0.03834	0.96166	3492	88034.0096	1087658.52	11.94
51	87599	0.0322	0.9678	2821	85129.6405	999624.508	11.41
52	84778	0.03435	0.96565	2912	82228.8992	914494.868	10.79
53	81866	0.0365	0.9635	2988	79250.2508	832265.968	10.17
54	78878	0.0373	0.9627	2942	76302.3751	753015.718	9.55
55	75936	0.0381	0.9619	2893	73403.1155	676713.342	8.91
56	73043	0.0505	0.9495	3689	69813.557	603310.227	8.26
57	69354	0.0631	0.9369	4376	65522.9712	533496.67	7.69

58	64978	0.0793	0.9207	5153	60466.9622	467973.699	7.2
59	59825	0.0558	0.9442	3338	56902.6848	407506.737	6.81
60	56487	0.0665	0.9335	3756	53198.3992	350604.052	6.21
61	52730	0.1007	0.8993	5310	48081.9775	297405.653	5.64
62	47420	0.1116	0.8884	5292	42787.6288	249323.675	5.26
63	42128	0.0989	0.9011	4166	38480.9092	206536.046	4.9
64	37962	0.0973	0.9027	3694	34728.3198	168055.137	4.43
65	34268	0.1231	0.8769	4218	30575.2729	133326.817	3.89
66	30050	0.1666	0.8334	5006	25667.1297	102751.544	3.42
67	25043	0.2073	0.7927	5192	20498.6902	77084.4147	3.08
68	19852	0.2018	0.7982	4006	16344.8959	56585.7245	2.85
69	15846	0.2369	0.7631	3754	12559.5933	40240.8286	2.54
70	12092	0.3068	0.6932	3710	8844.29053	27681.2354	2.29
71	8382	0.2601	0.7399	2180	6473.54466	18836.9449	2.25
72	6202	0.3063	0.6937	1900	4538.93961	12363.4002	1.99
73	4302	0.295	0.705	1269	3191.22207	7824.46059	1.82
74	3033	0.3736	0.6264	1133	2041.10727	4633.23852	1.53
75	1900	0.4104	0.5896	780	1217.34156	2592.13125	1.36
76	1120	0.4646	0.5354	520	664.592862	1374.78969	1.23
77	600	0.4565	0.5435	274	360.075882	710.19683	1.18

78	326	0.4435	0.5565	145	199.410946	350.120949	1.07
79	181	0.5585	0.4415	101	92.7097439	150.710002	0.83
80	80	0.6398	0.3602	51	35.2312529	58.0002586	0.72
81	29	0.5583	0.4417	16	14.7485238	22.7690057	0.79
82	13	0.6261	0.3739	8	5.75812549	8.02048184	0.63
83	5	0.7276	0.2724	3	1.72962784	2.26235635	0.47
84	1	0.6734	0.3266	1	0.53272851	0.53272851	0.41

Appendix 4: COPD Mortality Life Table in 2016 in Texas

Age	l(x)	q(x)	p(x)	d(x)	L(x)	T(x)	e(x)
0	100000	0.00571	0.99429	571	99500.1314	6580930.67	65.81
1	99429	0.00038	0.99962	38	99395.9237	6481430.54	65.19
2	99391	0.00027	0.99973	27	99367.7244	6382034.61	64.21
3	99364	0.0002	0.9998	20	99346.9841	6282666.89	63.23
4	99345	0.00022	0.99978	22	99325.3753	6183319.91	62.24
5	99323	0.00017	0.99983	17	99307.8712	6083994.53	61.25
6	99306	0.00011	0.99989	11	99296.205	5984686.66	60.27
7	99295	0.00016	0.99984	16	99280.9361	5885390.45	59.27
8	99279	0.00013	0.99987	13	99267.6585	5786109.52	58.28
9	99266	0.0001	0.9999	10	99257.3607	5686841.86	57.29
10	99256	0.00012	0.99988	12	99245.6972	5587584.5	56.29
11	99244	0.00016	0.99984	16	99230.3125	5488338.8	55.3
12	99228	0.00016	0.99984	16	99214.4356	5389108.49	54.31
13	99212	0.00016	0.99984	16	99198.5613	5289894.05	53.32
14	99197	0.00019	0.99981	19	99180.0843	5190695.49	52.33
15	99178	0.00026	0.99974	26	99155.1625	5091515.41	51.34
16	99152	0.00036	0.99964	36	99120.7022	4992360.25	50.35
17	99116	0.0005	0.9995	50	99072.871	4893239.54	49.37

18	99067	0.00064	0.99936	63	99011.193	4794166.67	48.39
19	99003	0.00079	0.99921	78	98934.8253	4695155.48	47.42
20	98925	0.00088	0.99912	87	98848.8727	4596220.65	46.46
21	98838	0.00092	0.99908	91	98758.4247	4497371.78	45.5
22	98747	0.00094	0.99906	93	98665.838	4398613.36	44.54
23	98654	0.00094	0.99906	93	98573.0921	4299947.52	43.59
24	98562	0.00088	0.99912	87	98485.6104	4201374.43	42.63
25	98475	0.00097	0.99903	96	98391.1844	4102888.82	41.66
26	98379	0.00087	0.99913	86	98304.3573	4004497.63	40.7
27	98294	0.00106	0.99894	104	98202.4832	3906193.27	39.74
28	98190	0.00106	0.99894	104	98098.3886	3807990.79	38.78
29	98085	0.00102	0.99898	100	97997.839	3709892.4	37.82
30	97985	0.00099	0.99901	97	97900.4546	3611894.56	36.86
31	97888	0.00102	0.99898	100	97800.9623	3513994.11	35.9
32	97789	0.0012	0.9988	117	97685.7961	3416193.15	34.93
33	97671	0.00122	0.99878	119	97566.8631	3318507.35	33.98
34	97552	0.00131	0.99869	128	97440.1455	3220940.49	33.02
35	97424	0.00133	0.99867	130	97310.7932	3123500.34	32.06
36	97295	0.00135	0.99865	131	97179.6663	3026189.55	31.1
37	97163	0.00149	0.99851	145	97036.5655	2929009.88	30.15

38	97019	0.00147	0.99853	143	96893.6796	2831973.32	29.19
39	96876	0.00148	0.99852	143	96750.3979	2735079.64	28.23
40	96733	0.00169	0.99831	163	96589.424	2638329.24	27.27
41	96569	0.00174	0.99826	168	96421.9609	2541739.82	26.32
42	96401	0.00191	0.99809	184	96239.8401	2445317.85	25.37
43	96217	0.00216	0.99784	208	96034.9643	2349078.01	24.41
44	96009	0.00223	0.99777	214	95821.6453	2253043.05	23.47
45	95795	0.00247	0.99753	237	95587.8363	2157221.41	22.52
46	95558	0.00269	0.99731	257	95333.3304	2061633.57	21.57
47	95301	0.00293	0.99707	279	95056.8607	1966300.24	20.63
48	95022	0.00312	0.99688	296	94762.539	1871243.38	19.69
49	94726	0.00368	0.99632	349	94420.4417	1776480.84	18.75
50	94377	0.0063	0.9937	595	93856.5096	1682060.4	17.82
51	93782	0.006	0.994	563	93289.8435	1588203.89	16.93
52	93220	0.0099	0.9901	923	92411.837	1494914.04	16.04
53	92297	0.0128	0.9872	1181	91262.6423	1402502.21	15.2
54	91115	0.0118	0.9882	1075	90174.2454	1311239.56	14.39
55	90040	0.0115	0.9885	1035	89133.8364	1221065.32	13.56
56	89005	0.02	0.98	1780	87446.501	1131931.48	12.72
57	87225	0.0177	0.9823	1544	85873.1964	1044484.98	11.97

58	85681	0.0231	0.9769	1979	83948.2013	958611.785	11.19
59	83702	0.031	0.969	2595	81430.1281	874663.584	10.45
60	81107	0.0324	0.9676	2628	78806.3898	793233.456	9.78
61	78479	0.0456	0.9544	3579	75346.188	714427.066	9.1
62	74900	0.0432	0.9568	3236	72067.7693	639080.878	8.53
63	71665	0.0503	0.9497	3605	68509.0078	567013.109	7.91
64	68060	0.0601	0.9399	4090	64479.106	498504.101	7.32
65	63970	0.0576	0.9424	3685	60743.9134	434024.995	6.78
66	60285	0.0693	0.9307	4178	56627.5963	373281.082	6.19
67	56107	0.0759	0.9241	4259	52379.1271	316653.485	5.64
68	51849	0.1026	0.8974	5320	47191.6472	264274.358	5.1
69	46529	0.1084	0.8916	5044	42113.5346	217082.711	4.67
70	41485	0.1267	0.8733	5256	36883.8215	174969.177	4.22
71	36229	0.14	0.86	5072	31788.8203	138085.355	3.81
72	31157	0.186	0.814	5795	26083.7057	106296.535	3.41
73	25362	0.2055	0.7945	5212	20799.1901	80212.8292	3.16
74	20150	0.2119	0.7881	4270	16412.0619	59413.6391	2.95
75	15880	0.2175	0.7825	3454	12856.4953	43001.5772	2.71
76	12426	0.2562	0.7438	3184	9639.21927	30145.0819	2.43
77	9243	0.2554	0.7446	2361	7176.12429	20505.8626	2.22

78	6882	0.2959	0.7041	2036	5099.34022	13329.7384	1.94
79	4846	0.3638	0.6362	1763	3302.41238	8230.39814	1.7
80	3083	0.3542	0.6458	1092	2126.90297	4927.98576	1.6
81	1991	0.3593	0.6407	715	1364.66531	2801.08279	1.41
82	1276	0.4522	0.5478	577	770.603819	1436.41748	1.13
83	699	0.4273	0.5727	299	437.368192	665.813661	0.95
84	400	0.4902	0.5098	196	228.445469	228.445469	0.57

Appendix 5: Normative COPD Life Table in 2016

Age	l(x)	q(x)	p(x)	d(x)	L(x)	T(x)	e(x)
0	100000	0.003230	0.996770	323	99717.2372	6972946.28	69.73
1	99677	0.000160	0.999840	16	99663.0384	6873229.04	68.96
2	99661	0.000110	0.999890	11	99651.4546	6773566	67.97
3	99650	0.000080	0.999920	8	99643.1101	6673914.55	66.97
4	99642	0.000030	0.999970	3	99639.5001	6574271.44	65.98
5	99639	0.000040	0.999960	4	99635.6386	6474631.94	64.98
6	99635	0.000040	0.999960	4	99631.6532	6374996.3	63.98
7	99631	0.000040	0.999960	4	99627.6679	6275364.65	62.99
8	99627	0.000050	0.999950	5	99622.8107	6175736.98	61.99
9	99622	0.000030	0.999970	3	99619.5738	6076114.17	60.99
10	99619	0.000020	0.999980	2	99617.4573	5976494.59	59.99
11	99617	0.000020	0.999980	2	99615.4649	5876877.14	58.99
12	99615	0.000020	0.999980	2	99613.4726	5777261.67	58.00
13	99613	0.000050	0.999950	5	99608.8642	5677648.2	57.00
14	99608	0.000110	0.999890	11	99598.6518	5578039.34	56.00
15	99597	0.000070	0.999930	7	99591.1835	5478440.68	55.01
16	99590	0.000080	0.999920	8	99583.3403	5378849.5	54.01
17	99582	0.000120	0.999880	12	99571.8866	5279266.16	53.01

18	99570	0.000100	0.999900	10	99561.6813	5179694.27	52.02
19	99560	0.000220	0.999780	22	99541.2662	5080132.59	51.03
20	99539	0.000380	0.999620	38	99505.4249	4980591.33	50.04
21	99501	0.000480	0.999520	48	99458.9023	4881085.9	49.06
22	99453	0.000520	0.999480	52	99407.6795	4781627	48.08
23	99401	0.000410	0.999590	41	99365.5595	4682219.32	47.10
24	99360	0.000650	0.999350	65	99303.9437	4582853.76	46.12
25	99296	0.000460	0.999540	46	99255.9122	4483549.82	45.15
26	99250	0.000770	0.999230	76	99183.3197	4384293.9	44.17
27	99174	0.000380	0.999620	38	99140.8081	4285110.58	43.21
28	99136	0.000680	0.999320	67	99077.0987	4185969.78	42.22
29	99069	0.000630	0.999370	62	99014.0626	4086892.68	41.25
30	99006	0.000530	0.999470	52	98960.351	3987878.61	40.28
31	98954	0.000810	0.999190	80	98883.6465	3888918.26	39.30
32	98874	0.000730	0.999270	72	98810.4753	3790034.62	38.33
33	98801	0.000670	0.999330	66	98743.5333	3691224.14	37.36
34	98735	0.000860	0.999140	85	98660.9524	3592480.61	36.38
35	98650	0.000930	0.999070	92	98570.0587	3493819.66	35.42
36	98559	0.000910	0.999090	90	98480.1141	3395249.6	34.45
37	98469	0.000950	0.999050	94	98387.0491	3296769.48	33.48

38	98375	0.001190	0.998810	117	98272.9125	3198382.43	32.51
39	98258	0.001190	0.998810	117	98155.9678	3100109.52	31.55
40	98141	0.001040	0.998960	102	98052.0495	3001953.55	30.59
41	98039	0.000940	0.999060	92	97958.658	2903901.5	29.62
42	97947	0.001330	0.998670	130	97833.1361	2805942.85	28.65
43	97817	0.001460	0.998540	143	97691.8859	2708109.71	27.69
44	97674	0.001660	0.998340	162	97532.1545	2610417.82	26.73
45	97512	0.001870	0.998130	182	97352.3245	2512885.67	25.77
46	97330	0.001610	0.998390	157	97192.429	2415533.35	24.82
47	97173	0.002130	0.997870	207	96991.7139	2318340.92	23.86
48	96966	0.002160	0.997840	209	96782.575	2221349.2	22.91
49	96756	0.002580	0.997420	250	96537.9493	2124566.63	21.96
50	96507	0.006300	0.993700	608	95974.5984	2028028.68	21.01
51	95899	0.005100	0.994900	489	95470.7013	1932054.08	20.15
52	95410	0.006800	0.993200	649	94841.8095	1836583.38	19.25
53	94761	0.006700	0.993300	635	94205.1808	1741741.57	18.38
54	94126	0.008300	0.991700	781	93442.1654	1647536.39	17.50
55	93345	0.011500	0.988500	1073	92405.1024	1554094.22	16.65
56	92271	0.012500	0.987500	1153	91261.6669	1461689.12	15.84
57	91118	0.016800	0.983200	1531	89777.8975	1370427.45	15.04

58	89587	0.018900	0.981100	1693	88104.9321	1280649.56	14.30
59	87894	0.016000	0.984000	1406	86662.8886	1192544.62	13.57
60	86488	0.021800	0.978200	1885	84837.1433	1105881.74	12.79
61	84602	0.026600	0.973400	2250	82632.1908	1021044.59	12.07
62	82352	0.023900	0.976100	1968	80628.8256	938412.402	11.40
63	80384	0.026900	0.973100	2162	78490.6868	857783.576	10.67
64	78221	0.036800	0.963200	2879	75701.3648	779292.889	9.96
65	75343	0.034000	0.966000	2562	73100.2343	703591.524	9.34
66	72781	0.0407	0.959300	2962	70187.939	630491.29	8.66
67	69819	0.0504	0.949600	3519	66738.4128	560303.351	8.03
68	66300	0.0509	0.949100	3375	63345.7764	493564.938	7.44
69	62925	0.0643	0.935700	4046	59383.3165	430219.162	6.84
70	58879	0.074	0.926000	4357	55064.9877	370835.845	6.30
71	54522	0.0968	0.903200	5278	49901.9302	315770.858	5.79
72	49244	0.0998	0.900200	4915	44942.0936	265868.927	5.40
73	44330	0.1078	0.892200	4779	40146.4123	220926.834	4.98
74	39551	0.1255	0.874500	4964	35205.7826	180780.422	4.57
75	34587	0.1328	0.867200	4593	30566.4219	145574.639	4.21
76	29994	0.1463	0.853700	4388	26152.7215	115008.217	3.83
77	25606	0.1811	0.818900	4637	21546.4932	88855.4956	3.47

78	20969	0.1329	0.867100	2787	18529.2142	67309.0023	3.21
79	18182	0.2106	0.789400	3829	14829.9262	48779.7881	2.68
80	14353	0.2305	0.769500	3308	11456.7017	33949.8619	2.37
81	11045	0.2446	0.755400	2702	8679.60317	22493.1602	2.04
82	8343	0.2822	0.717800	2354	6281.95147	13813.557	1.66
83	5989	0.2897	0.710300	1735	4469.86506	7531.60553	1.26
84	4254	0.3201	0.679900	1362	3061.74047	3061.74047	0.72

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12. Anhang

Lebenslauf

Platzhalter

Verzeichnis der akademischen Lehrer/-innen

Meine akademischen Lehrenden waren in Marburg in alphabetischer Reihenfolge:

Adamkiewicz, Ahrens, Alter, Apitzsch, Arndt, Bartsch, Baum, Bette, A. Becker, K. Becker, S. Becker, Bein, Best, Bien, Bliemel, Bohlander, Bösner, Brehm, Brendel, Bü cking, Burchert, Cetin, Czubayko, Daut, Decher, Denzer, Depboylu, Dettmeyer, Dinges, Dodel, Donner-Banzhoff, Eberhart, Eickmann, Eggers, Eggert, El-Zayat, Eming, Engenhart-Cabillic, Eschbach, Feldmann, Feuser, Frink, Fritz, Frohme, Fuchs-Winkelmann, Gallmeier, Gebhardt, Geisthoff, Geks, Goos, Görg, Gress, Greulich, Grgic, Grimm, Grosse, Häußermann, Heers, Hegele, Hertl, A. Heverhagen, Heyse, Hildebrandt, Hilt, Hofmann, Holland, Holzer, Hoyer, Hundt, Irqsusi, Jacob, Jansen, Jerrentrup, Josephs, Kalder, Kamp-Becker, Kann, Kanngießer, Karatolios, Kaufmann, Keil, Kemkes- Matthes, Kinscherf, Kircher, Kirschbaum, Kirtschig, Klauss, Knecht, Koczulla, Köhler, Kömhoff, König, Koolman, Kruse, Kühnert, Lechler, Lill, Leonhard, Lohoff, Lüsebrink, Luster, Mahnken, Maier, Mandic, Markus, Menzler, Mirow, Mittag, Moll, Moosdorf, Morin, R. Müller, Mueller, Mutters, Neff, Nenadic, Neubauer, Neumü ller, Nikolaizik, Nimsky, Nockher, Oberkircher, Oberwinkler, Olbert, Oliver, Otero, Pagenstecher, Pankuweit, Parahuleva, Peterlein, Pfützner, Plant, Preisig-Müller, Printz, Reese, Renz, Repp, del Rey, Richter, Rost, Ruchholtz, Rüsch, Sachs, Sattler, Schäfer, Schieffer, Schiffmann, Schneider, Schratt, Schulze, Schütt, Schütz, Schwarzmeier, Seitz, Sekundo, Sevinc, Sharkova, Skrobek, Sommer, Stahl, Steiniger, Stief, Strik, Stuck, Swaid, Tackenberg, Teymoortash, Thieme, Timmermann, Torossian, Tschaidse, Verburg, Vogelmeier, Vogt, Vorwerk, Wächstershäuser, Wagner, Wahl, Waldmann, Wallot, Weber, Weihe, Werner, Westermann, Wiesmann, Wilhelm, Wissniowski, Wolf, Worzfeld, Wrocklage, Wulff, Zentgraf, Ziller

Danksagung

Ich möchte mich bei meinem Doktorvater Prof. Dr. Dr. Mueller für die freundliche Überlassung des Themas und für die stets zuverlässige und exzellente Betreuung im Rahmen dieser Dissertation bedanken. Ebenfalls danke ich Prof. Dr. Alter für sein tolles Feedback und angenehme Zusammenarbeit.

Ich bedanke mich bei Frau Wittkowsky für die stets zuverlässige Kommunikation.

Von ganzem Herzen möchte ich meiner Frau Rachel Falk für ihre ansteckende Lebensfreude sowie ihre bedienungslose Liebe und großartige Unterstützung während des Studiums und der Anfertigung dieser Arbeit bedanken. Ebenso möchte ich meinen Schwiegereltern Dr. Heidelinde und Michael Falk für ihre unermüdliche Unterstützung bedanken. Ohne sie wäre ein erfolgreiches Absolvieren dieser Dissertation kaum möglich gewesen.

Außerdem bedanke mich bei allen jenen, die mich während meines Studiums und meiner Dissertation auf unterschiedliche Arten und Weisen unterstützt haben.

Ehrenwörtliche Erklärung

„Ich erkläre ehrenwörtlich, dass ich die dem Fachbereich Medizin Marburg zur Promotionsprüfung eingereichte Arbeit mit dem Titel „Demographic Mortality Measures as Indicators of Amenable or Avoidable Deaths in the 50 States of the United States of America. An Example of Population-Based Health Care Quality Indicators" im Institut für Versorgungsforschung und Klinische Epidemiologie unter Leitung von Prof. Dr. Max Geraedts mit Unterstützung von Prof. Dr. Dr. Ulrich Mueller ohne sonstige Hilfe selbst durchgeführt und bei der Abfassung der Arbeit keine anderen als die in der Dissertation aufgeführten Hilfsmittel benutzt habe. Ich habe bisher an keinem in- oder ausländischen Medizinischen Fachbereich ein Gesuch um Zulassung zur Promotion eingereicht, noch die vorliegende oder eine andere Arbeit als Dissertation vorgelegt.

Ich versichere, dass ich sämtliche wörtlichen oder sinngemäßen Übernahmen und Zitate kenntlich gemacht habe.

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