



Aging and
Retirement

Maximizing Health Span: A Literature Review on the Impact of a Healthy Lifestyle on Retirement



Maximizing Health Span

A Literature Review on the Impact of a Healthy Lifestyle in Retirement

AUTHORS

Howard Bolnick, FSA, MAAA
Actuarial Consultant
Vitality Group

Lianne E. Jacobs, MPH
Research Analyst
Vitality Group

Daniel Kotzen, MA
Director of R&D
Vitality Group

Francois Millard, FIA, FSA, MAAA
Senior Vice President
Vitality Group

Martin Stepanek, PhD
Lead Researcher
Vitality Research Institute

SPONSOR

Aging and Retirement Strategic Research
Program Steering Committee



Give us your feedback!

Take a short survey on this report.

[Click Here](#)



Caveat and Disclaimer

The opinions expressed and conclusions reached by the authors are their own and do not represent any official position or opinion of the Society of Actuaries Research Institute, Society of Actuaries, or its members. The Society of Actuaries Research Institute makes no representation or warranty to the accuracy of the information.

Copyright © 2021 by the Society of Actuaries Research Institute. All rights reserved.

CONTENTS

| | |
|---|-----------|
| Executive Summary | 2 |
| The Challenge of Health and Longevity in Retirement | 2 |
| Introduction | 2 |
| A Framework for Relating Lifestyle and Medical Conditions..... | 3 |
| Bridging the Gap Between Risk Factors and Interventions | 6 |
| Tobacco Use | 10 |
| Summary | 10 |
| Interventions..... | 11 |
| Body Mass Index..... | 12 |
| Summary | 12 |
| Interventions..... | 12 |
| Metabolic Risks (Fasting Plasma Glucose, Blood Pressure, Cholesterol) | 13 |
| Summary | 13 |
| Interventions..... | 13 |
| Dietary Risks | 14 |
| Summary | 14 |
| Interventions..... | 15 |
| Physical Activity..... | 15 |
| Summary | 15 |
| Interventions..... | 16 |
| Screenings | 17 |
| Summary | 17 |
| Interventions..... | 18 |
| Immunizations | 19 |
| Summary | 19 |
| Interventions..... | 20 |
| Social Engagement..... | 20 |
| Summary | 20 |
| Interventions..... | 21 |
| Cognitive and Mental Health | 22 |
| Summary | 22 |
| Interventions..... | 22 |
| An Emerging Evidence Base | 22 |
| Vision and Hearing Impairment | 24 |
| Purpose..... | 24 |
| Managing Activities of Daily Living..... | 25 |
| Aging in Place | 25 |
| The Acceleration of Digital Adoption Among Older Adults | 27 |
| The Role of Inequity..... | 27 |
| The Role of the Employer in Influencing Healthy Lifestyles | 28 |
| The Workplace can Be A Setting for Health Promotion..... | 29 |
| Incentives Can Have a Material Impact on Health Behaviors, and Utilize Well-Established Behavioral Science and Behavioral Economic Principles..... | 29 |

| | |
|---|-----------|
| The Role of Government in Influencing Healthy Lifestyles | 31 |
| U.S. Health Care Costs Associated with Modifiable Behavior in Retirement | 32 |
| Potential Areas for Future Research..... | 33 |
| Acknowledgments | 35 |
| References..... | 36 |
| About The Society of Actuaries Research Institute | 61 |

Definition List

Health Span: The gap between total years lived and years lived in good health.

Years Lived in Disability (YLDs): The number of years lived in less-than-ideal health. It is measured by taking the prevalence of a condition multiplied by the disability weight of that condition. Disability weights reflect the severity of different conditions and are developed through surveys of the general public.

Theoretical Minimum Risk Exposure Level (TMREL): The lowest plausible level of risk factor exposure in a given population.

Disability-Adjusted Life Years (DALYs): A universal metric that allows researchers and policymakers to compare very different populations and health conditions over time. DALYs equal the sum of years of life lost (YLLs) and years lived with disability (YLDs). One DALY equals one lost year of healthy life. DALYs allow researchers and policymakers to estimate the total number of years lost due to specific causes and risk factors at the country, regional, and global levels.

Morbidity: Years lived with disability caused by a risk factor.

Mortality: Years of life lost due to premature death caused by a risk factor.

Population Attribution Factors (PAFs): counter-factual estimates of the proportion of each medical condition causatively related to the histories of the risk factor in excess of its theoretical minimum.



Give us your feedback!

Take a short survey on this report.

[Click Here](#)

SOA
Research
INSTITUTE

Maximizing Health Span

A Literature Review on the Impact of a Healthy Lifestyle in Retirement

Executive Summary

With older adults comprising a growing proportion of the United States population, there is increased urgency to understand not only how best to help this population maximize their longevity, but also how best to enhance the quality of those remaining years (or health span).

Though there are a plethora of innovations being explored to extend longevity – ranging from advancements in supercentenarian genome sequencing to mRNA vaccines for certain cancers – it is not yet clear how many of these research endeavors will materialize as practical interventions in the foreseeable future and whether they will lead to meaningful improvements in health, rather than solely extensions of life. [1] However, the existing literature contains evidence of the material impacts that stem from healthy lifestyle behaviors and chronic condition management. The primary purpose of this report is to review this literature to provide a resource for actuaries and others on relevant issues, and secondarily to call out areas of emerging evidence that could be further researched.

The field of healthy aging is complex, encompassing activities of primary and secondary prevention; physical, cognitive, and mental health; and, of course, social engagement, all with a view towards ensuring older adults maintain resolve and meaning throughout retirement. To many, retirement itself is no longer viewed as a coda to the primary chapters of life, but an integral second half of life, ripe with opportunity, provided individuals can sustain their health and finances.

Importantly, the retirement-age population is heterogeneous, comprised of generations spanning Gen X through multi-dimensional Baby Boomers and the Silent Generation. However, even these generational divides oversimplify matters for within these generations there is great variability in technological savvy, employment status, financial security, and health and wellbeing. These diverse experiences mean that interventions that help bolster health span will necessitate a multi-pronged approach that engages the individual themselves, as well as employers and governments to facilitate the delivery of said interventions, to ensure that individuals have equitable access to the appropriate facilities and services that will help them to thrive.

The Challenge of Health and Longevity in Retirement

INTRODUCTION

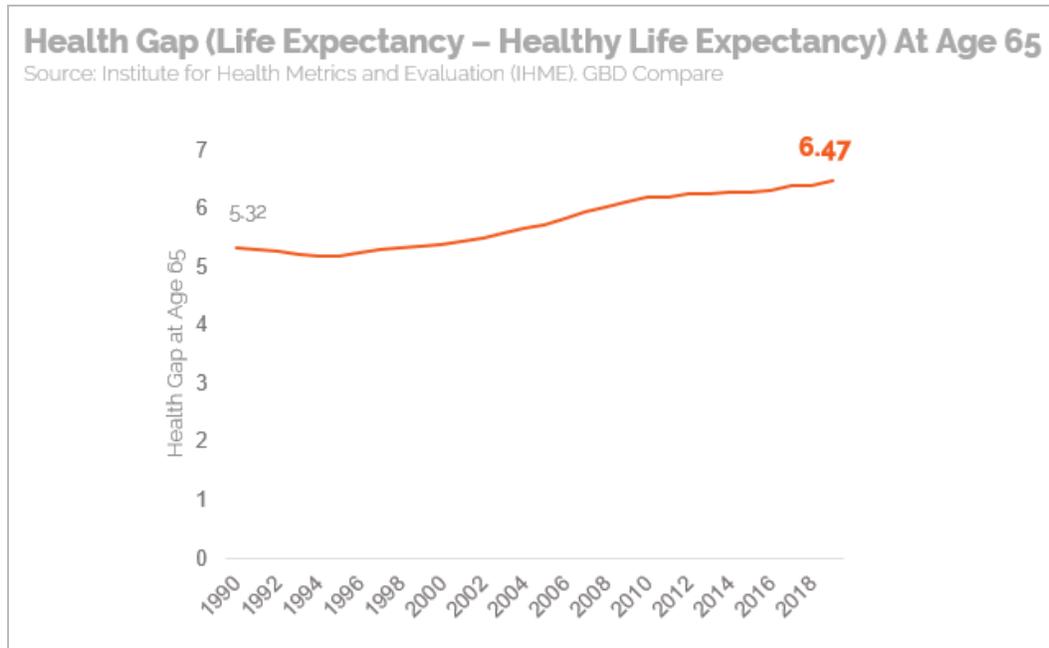
The United States is experiencing substantial growth in the older adult population, driven in large part by the aging of the Baby Boomer generation. The number of Americans aged 65 and older is projected to nearly double from 52 million in 2018 (16% of total population) to 95 million by 2060 (23% of total population). [2]

Within this context, there is a great need to understand and address the challenge of sustaining health through the second half of life to ensure that people are not only living longer, but that those additional years are imbued with good health – this gap will be referred to as “health span” throughout the paper.

The first half of the 20th century saw material life expectancy improvements driven by a combination of effective treatments against infectious diseases and overall improvements in living and hygiene standards. Life expectancy gains in the latter half of the 20th century and the turn of the 21st century brings renewed focus on the treatment of noncommunicable diseases and their modifiable risk factors for although Americans are living longer, they are living

more years with disease. [3] While life expectancy at age 65 in the United States has climbed to 19.6 years, healthy life expectancy lags at only 13.1 years, and adults at age 65 can expect to live only 6.47 additional years in good health, on average (Figure 1). In fact, whilst life expectancy at age 65 has increased by over 2 years, on average, from 1990-2019, healthy life expectancy has only increased by 0.9 years over the same period. [4]

Figure 1
U.S. HEALTH SPAN



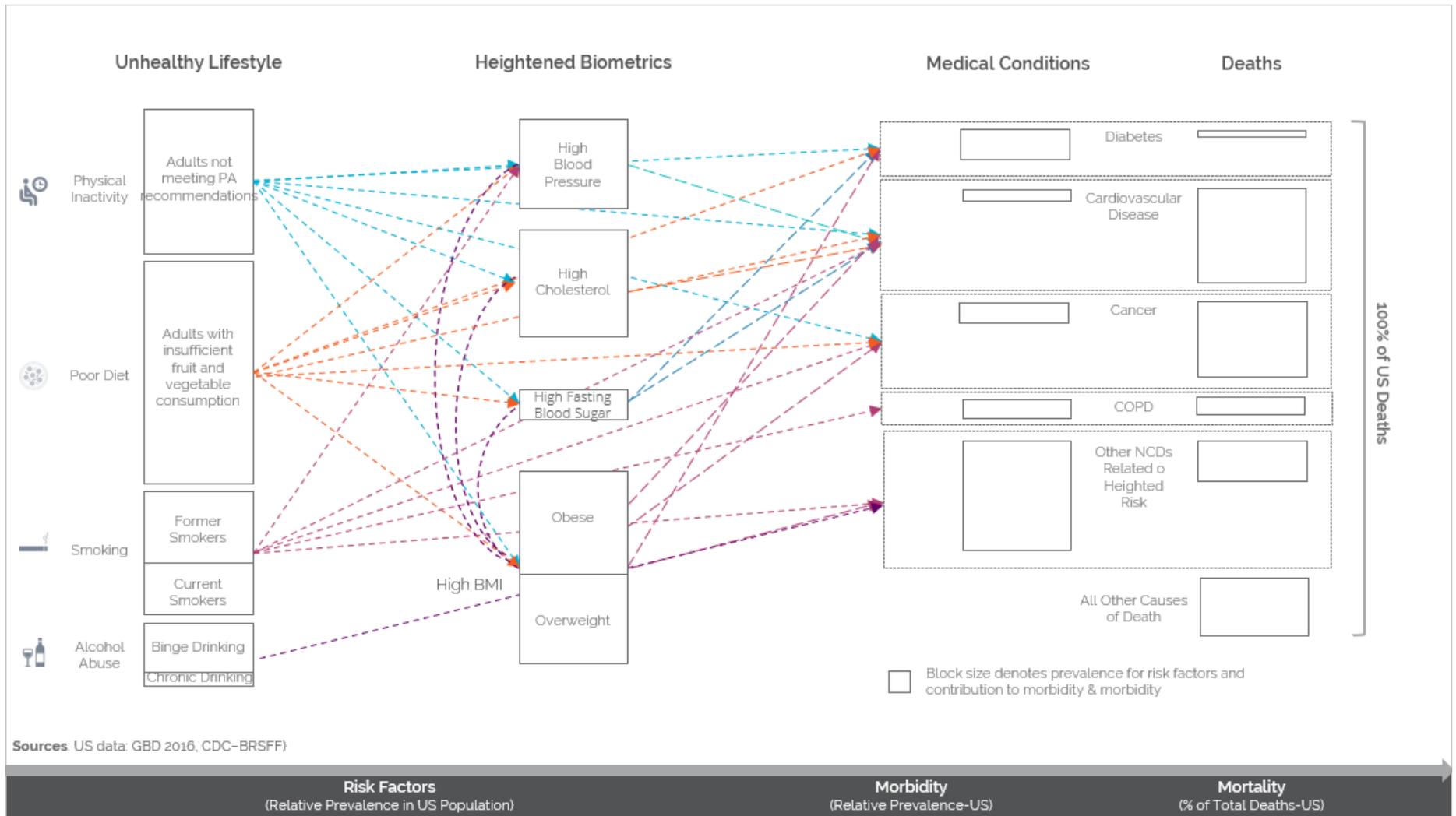
Behavioral and metabolic risks (high fasting plasma glucose, high blood pressure and high cholesterol) rank amongst the leading causes of deaths and years lived in disability (YLDs) (the number of years lived with some disease) amongst older adults, with 37.8% of years lived with disability and 58.6% of deaths in 2019 attributable to modifiable risk factors in excess of their theoretical minimum risk exposure level (TMREL), which is defined as the counterfactual scenario, or the lowest plausible level of risk factor exposure in a given population. [4]

Quantifying the most prominent risks provides us with a natural segue to risk management techniques, which shall be a focus of this paper. However, before delving into the risk factors themselves, it is important to understand the framework that captures the rich interplay between risk factors, medical conditions, and deaths.

A FRAMEWORK FOR RELATING LIFESTYLE AND MEDICAL CONDITIONS

The clinical and epidemiological literature related to a long and healthy life provides a rich tapestry of relationships between lifestyles and medical conditions. There is ample information on relationships among risk factors (e.g. how physical activity is related to high blood pressure) and between risk factors and medical conditions and deaths (e.g. how high blood pressure cases are related to cardiovascular disease). However, much of this literature focuses on separately relating each modifiable lifestyle risk factor to medical conditions or mortality. Organizing the large volume of these focused research findings into recommendations about how pre- and post-retirement Americans can lead long and healthy lives requires a comprehensive compilation of findings reflecting the facts that risk factors often affect each other and medical conditions are often causatively related to multiple risk factors. These – admittedly complex – interactions are illustratively depicted in Figure 2 below. Figure 2 serves to capture the rich and complex interactions amongst risk factors, though the rigor behind these relationships are out of scope of this paper.

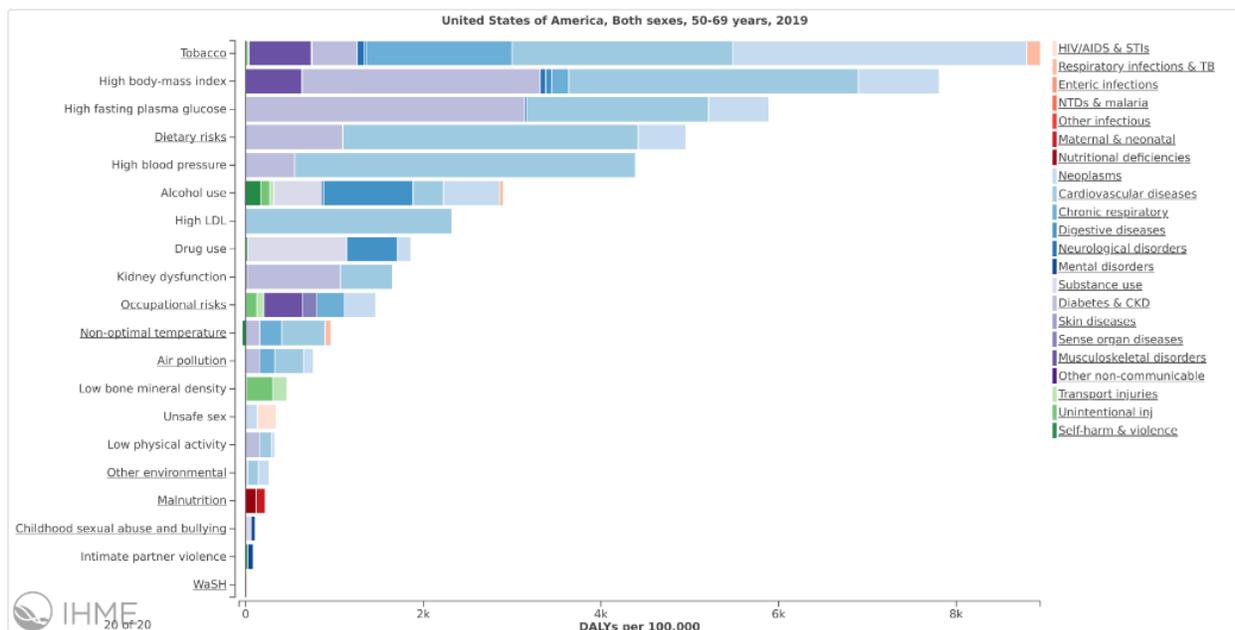
Figure 2
ILLUSTRATIVE CAUSATIVE RELATIONSHIPS BETWEEN RISK FACTORS AND HEALTH OUTCOMES



(Visual Created by Authors. Note: Relationships depicted in the chart are based largely on the GBD model supplemented by pathways identified by the authors in the epidemiological literature. The diagram is intended as an illustration of the many complicated interrelationships among its lifestyle risk factors and population morbidity and mortality.)

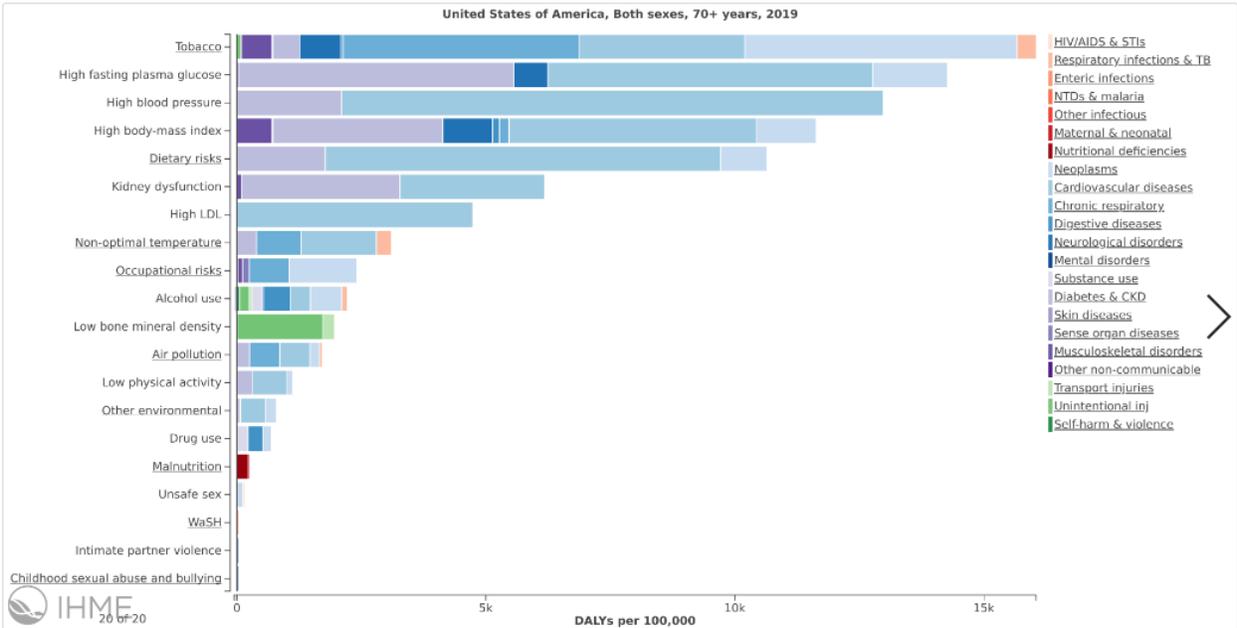
The Global Burden of Disease (GBD) Studies from the Institute for Health Metrics and Evaluation (University of Washington) is a comprehensive model that organizes these complicated relationships. The GBD estimates the relative importance of modifiable risk factors and their **causal relationships** to disability-adjusted life years for pre-retirement ages 50-69 (Figure 3) and post-retirement ages 70+ (Figure 4) for both sexes combined in the U.S. in 2019. The disability-adjusted life years (DALYs) is a measure of the impact of each risk factor on morbidity (years lived with disability caused by the risk factor) and mortality (years of life lost due to premature death caused by the risk factor). For each risk factor, GBD researchers make counter-factual estimates of the proportion of each medical condition causatively related to histories of the risk factor in excess of its theoretical minimum, known as population attribution factors (PAFs). For both the pre- and post-retirement age groups, **the five risk factors with the largest impacts on long and healthy lives are tobacco use, high body-mass index, high fasting plasma glucose, dietary risks, and high blood pressure**. There is slight reordering of these five risk factors moving from pre-retirement to post-retirement ages, as indicated in Figures 3 and 4; however, their consistency provides a strong indication of risk factors with the highest potential value to improve morbidity and mortality at older ages.

Figure 3
DALY AGES 50-69, BOTH SEXES 2019



Source: Institute for Health Metrics and Evaluation (IHME), "GBD Compare Data Visualization," IHME; University of Washington, Seattle, 2020. Visual can be accessed here: <http://ihmeuw.org/5jaj>. [4]

Figure 4
DALY AGES 70+, BOTH SEXES 2019



Source: Institute for Health Metrics and Evaluation (IHME), “GBD Compare Data Visualization,” IHME; University of Washington, Seattle, 2020. Visual can be accessed here: <http://ihmeuw.org/5jak>. [4]

BRIDGING THE GAP BETWEEN RISK FACTORS AND INTERVENTIONS

This paper seeks to bridge the gap between the knowledge of the biggest causal risk factors impacting health and longevity, and the optimal interventions, for which the GBD framework creates a robust conduit. Each risk factor can itself be divided into those that directly (proximal) or indirectly (distal) affect health, ensuring that both direct and indirect causes are addressed in the interests of maximizing an individual’s health span.

Table 1 represents the central GBD risk factors that shall serve as the focus of this paper and subsequent discussion.

Table 1

GBD RISK FACTORS AND ASSOCIATED RISK MANAGEMENT RECOMMENDATIONS

| GBD Risk Factors | Causative-Temporal Dynamics | | Risk Management Recommendations |
|-----------------------------------|--------------------------------|--------------------------------------|--|
| | Proximal (Direct) Risk Factors | Distal (Indirect) Risk Factors | |
| Tobacco Use | Tobacco Use | | Smoking cessation |
| High BMI | High BMI | Low PA Unhealthy Diet | Weight control programs Physical activity and healthy diet Surgical intervention Medication for weight loss |
| High Fasting Plasma Glucose (FPG) | High FPG | High BMI Low PA | Risk awareness - medical care Physical activity and healthy diet Medication adherence |
| Unhealthy Diet | Unhealthy Diet | | Dietary guidelines |
| High Blood Pressure (BP) | High BP | High BMI Low PA Unhealthy Diet | Risk awareness - medical care Physical activity and healthy diet Medication adherence |
| Total Cholesterol | High Total Cholesterol | Unhealthy Diet Low PA | Risk awareness - medical care Physical activity and healthy diet Medication adherence |
| Insufficient Physical Activity | Insufficient Physical Activity | | Physical activity guidelines, incorporating aerobic and muscle-strengthening activities |

The GBD model is designed to capture well-established causal relationships among modifiable risk factors and their consequent morbidity and mortality. It is a widely recognized comprehensive model built upon expert panels' assessments of the epidemiology and clinical literature on the relationships between its chosen risk factors and morbidity and mortality. The most important of these relationships for older-age adults are discussed in this report. This design, though, has limitations. [5] In addition, there are other limitations to the GBD framework specifically related to this report, namely:

- It does not allow for the impact of well-established preventative behaviors, such as immunizations and early detection screenings (including vision and hearing screenings).
- It excludes emerging risk factors such as stress and depression, sleep, and social risk factors such as social engagement and purpose. These are currently not well-defined, well-measured, and widely-accepted risks, though this may change given the extensive research being conducted in these areas.

Many of these exclusions, however, have ample evidence of their importance to healthy aging, and thus, will be highlighted given their known importance in the ageing space. This includes frailty for which there are recommended screenings and modified physical activity guidelines. Other risk factors include obtaining the appropriate screenings and vaccinations, a central behavior for the management of underlying medical conditions;

the management of mental and nervous conditions, which spans the gamut from stress and severe mental diseases to various dementias associated with aging; and sleep, which is an evolving and likely important distal risk factor that necessitates further exploration.

This paper further seeks to provide actuaries with a deeper understanding of how modifiable lifestyle risk factors interact with other risk factors and subsequently affect health and longevity. The implementation of robust interventions for modifiable risk factors not only stands to benefit the individual, but also provides a clear framework for the management of health-care costs in retirement. Table 2 reflects some of the key risk factors considered in this paper.

Table 2

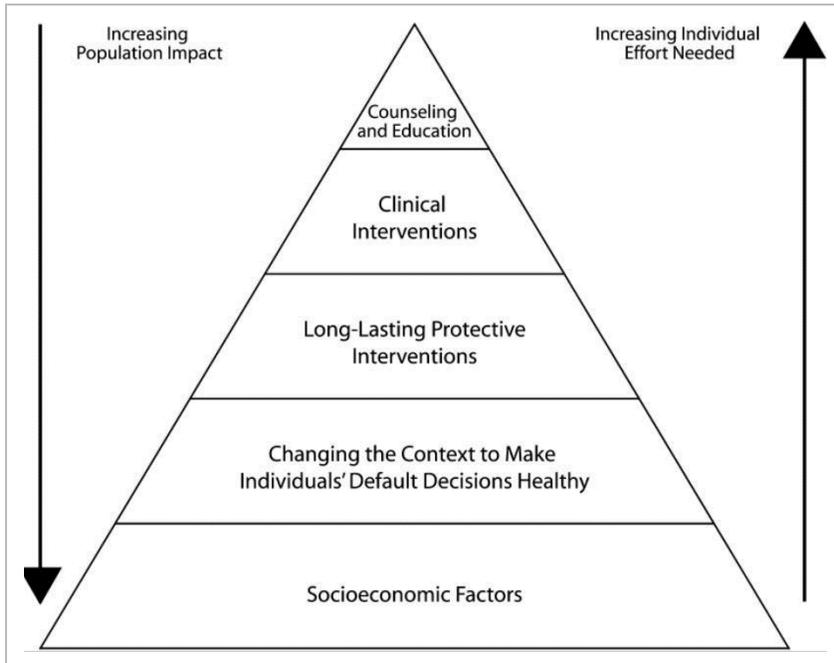
SUMMARY MORTALITY AND MORBIDITY EVIDENCE FOR THE KEY RISK FACTORS AND INTERVENTIONS COVERED IN THIS PAPER.

| Risk Factor | Key Interventions | Impact on Morbidity | Impact on Mortality | Trends in Attributable Deaths, 70+ years, 1990-2019 (U.S.) | Trends in Attributable YLDs, 70+ years, 1990-2019 (U.S.) |
|--|--|---------------------|---------------------|--|--|
| GBD Risk Factors | | | | | |
| Tobacco Use | Combinations of group behavioral therapy; intensive physician advice; nicotine replacement therapy; and individual counseling plus financial incentives. | + | + | ↓ | ↓ |
| Body Mass Index | Combination of physical activity and healthy diet. | + | + | ↑ | ↑ |
| Metabolic Risks (Fasting Plasma Glucose, Blood Pressure and Cholesterol) | In-person discussion with pharmacist; human reminders; utilization of emerging technology (e.g. electronic pill bottles) | + | + | ↓ | ↑ |
| Dietary Risks | Limit added sugars, saturated fat, sodium and alcoholic beverages. Dietary education especially effective in older adults. | + | + | ↓ | ↑ |
| Physical Activity | Combination of aerobic and muscle strengthening activity; balance training. Combination of educational, behavioral and cognitive-behavioral strategies. Technology solutions like wearables and mobile apps. | + | + | ↓ | ↓ |
| Additional Risk Factors | | | | | |
| Screenings | Regular screening as per national guidelines. Targeted and tailored reminders from health care providers; outreach and educational campaigns. | + | + | N/A | N/A |

| Risk Factor | Key Interventions | Impact on Morbidity | Impact on Mortality | Trends in Attributable Deaths, 70+ years, 1990-2019 (U.S.) | Trends in Attributable YLDs, 70+ years, 1990-2019 (U.S.) |
|-------------------------------|---|-----------------------------|---------------------------------|--|--|
| Immunizations | Regular immunization as per national guidelines. Proactive communication from health care providers; vaccination outreach. | + | + | N/A | N/A |
| Social Engagement | One-to-one personal contact and activity group interventions. | - | - | N/A | N/A |
| Cognitive and Mental Health | Healthy lifestyle (physically active, manage cardiovascular disease risk factors, including high blood pressure, diabetes, and smoking); healthy diet, healthy body weight, socially engaged. | + | - | N/A | N/A |
| Sleep | 7-9 hours per night; follow consistent sleep schedule; avoid electronics before bed; engage in physical activity; limit caffeine intake. | - | - | N/A | N/A |
| Vision and Hearing Impairment | Annual eye exams; hearing exams every three years for adults 50+ years. | - | - | N/A | N/A |
| Purpose | Continue in contributing family/work roles; participate in meaningful activities, such as volunteering opportunities, hobbies, or learning new skills; maintain social connections. | - | - | N/A | N/A |
| | | + Strong affirming evidence | × Strong contradictory evidence | - Additional research required | |

Although the focus of this paper is primarily on lifestyle risk factors, socioeconomic factors play an important role in health outcomes. In this regard, it is valuable to consider the different types of health interventions required to improve health in the context of the Health Impact Pyramid proposed by Dr. Thomas Frieden, former Director of the Centers for Disease Control and Prevention. [3]

Figure 5
HEALTH IMPACT PYRAMID



Source: Frieden, TR. "A Framework for Public Health Action: The Health Impact Pyramid." *American Journal of Public Health*. 2010;100(4):590-595. [3]

The health impact pyramid captures how sustained and meaningful health impact necessitates a combination of individual and population-based approaches. At the base of the pyramid are socioeconomic factors – often referred to as social determinants of health – followed by public health interventions, both of which typically benefit from broad government-driven interventions and support structures. Moving up the pyramid involves more personalized approaches that cater to individuals, described in detail in this paper, and includes one-off infrequent protective interventions such as immunizations and cancer screenings. Evidence-based clinical care can create healthy life years, but the impact of these interventions rests upon sustained healthy behavior change by the individual, which itself is predicated on intervention access, compliance, and effectiveness.

The sections that follow shall provide an overview of the interventions that help ameliorate the risk factors summarized in Table 2.

Tobacco Use

SUMMARY

Smoking trends in the U.S. are encouraging – amongst U.S. individuals aged 65-69, daily smoking prevalence decreased from 13.7% in 2000 to 11.1% in 2015, mirroring the overall decline in smoking prevalence amongst the U.S. population. (Interestingly, dietary and smoking risks tend to improve with age, whilst the converse is seen with the other factors that shall be explored. [6]) Smoking cessation prior to age 40 leads to the greatest gains in life expectancy (individuals who quit smoking between ages 25 to 34 gain an average of 10 years relative to those who continue smoking); however, even as one approaches retirement age, individuals who stop smoking between ages 45 to 54 stand to gain 6 extra years of life relative to those who continue smoking. [7,8]

Smoking increases risk of cardiovascular disease, chronic obstructive pulmonary disease (COPD), and stroke and markedly increases all-cause mortality, as well as death from cardiovascular disease and cancer. According to 2019 GBD data, 16.6% of deaths and 10.3% of years lived in disability among adults 70 years and older in the United States were attributable to smoking. [4] Encouragingly, both deaths and years lived in disability (YLDs) attributable to smoking have decreased by 24.1% and 21.5% amongst this cohort since 1990.

Older smokers who quit not only have a reduced risk of premature death, but also marked reductions in ill health in general, [9] including reduced risk of coronary events, slower decline in pulmonary function, and slower progression of osteoporosis, which serves to reduce the risk of hip fractures. [10]

While smoking cessation in retirement cannot eliminate excess mortality risk altogether, it can significantly reduce risk. According to The Physicians' Health Study, compared with current smokers, the risk of dying was significantly reduced among past smokers within 10 years of quitting and, by 20 years of quitting, the risk was further reduced to the level of never smokers. [11] Even smokers who quit late in life gain significant extensions to life – among those who quit at age 65, men gained up 1.4 to 2.0 years and women 2.7 to 3.7 years of life. [12]

In summary, though smoking cessation cannot undo all the accumulated adverse health effects, quitting smoking can reduce the risk of dying from cancer and other diseases even amongst the oldest old (those aged 80 and over). [13]

INTERVENTIONS

Systematic reviews of smoking cessation interventions have found that the most effective interventions appealed to a combination of group behavioral therapy, intensive physician advice, nicotine replacement therapy, individual counseling, telephone counseling, nursing interventions and tailored self-help interventions. (The homebound elderly may benefit especially from proactive telephone counseling. [14]) Importantly, programs that leverage both counseling and financial incentives were found to have a higher rate of success than those without financial incentives. [15] At a societal level, evidence suggests that higher tax rates reduce smoking rates amongst older adults. [16-18]

Some of the key intervention guidelines for tobacco smoking cessation amongst adults may be found in the U.S. Preventive Services Task Force (USPSTF) recommendations. [19] The USPSTF also recommends annual screening for lung cancer with low-dose computed tomography in adults aged 50 to 80 years who have a 20 pack-year smoking history and currently smoke or have quit within the past 15 years. [20]

Whilst the benefits of smoking cessation are material, it is a notoriously difficult habit for individuals to break – in a 2015 study, researchers found that while 70% of surveyed adults wanted to quit smoking, only 7% were successful. Compared with younger adults, fewer older adults expressed interest in quitting (53.7% of adults 65+ years compared to 62.3% of those 18-24 years; 72.7% of those 25-44 years; 68.7% of those 45-64 years) or made a quit attempt (47.2% of adults 65+ years compared to 66.7% of those 18-24 years; 59.8% of those 25-44 years; 49.6% of those 45-64 years). [21] Similarly, between 2005 and 2015, smoking prevalence among older adults fell by only 2.1% (from 8.6% to 8.4%), compared to a 27.7% decline among adults overall (20.9% to 15.1%). [22] Scientists continue to develop interventions and tools that will help individuals break this habit. This includes a nicotine vaccine that would lower nicotine levels in the blood to prevent the dopamine boost smokers usually receive; drugs to help with withdrawal symptoms; and, in the digital domain, virtual reality therapy is now being used to help recreate triggering situations and allows therapists to equip patients with the appropriate coping mechanisms. [23]

Body Mass Index

SUMMARY

As of 2017-2018, approximately 42.4% of United States adults were obese, a figure that has seen startling increases from 30.5% since 1999-2000. [24] The prevalence of obesity persists amongst older adults – amongst those aged 65 to 69, 33.9% were obese. [25] This number has increased since 2000, when – according to GBD data, amongst U.S. adults aged 65 to 69 – 25.3% were obese. [26] According to 2019 GBD data, almost 12% of deaths (a 22.9% increase since 1990) and 11.3% of years lived in disability (a 47.5% increase since 1990) amongst adults 70 years and older were attributable to high BMI. [4]

As with smoking, the ill-effects of obesity are well documented, and it is associated with higher rates of death [27], particularly from cardiovascular disease [28] and cancer [29], as well as other comorbidities such as type 2 diabetes, dyslipidemia, hypertension, obstructive sleep apnea and others. [30] A population cohort study of 3.6 million adults found that life expectancy was approximately 4 years shorter in obese adults, [31] whilst life expectancy amongst the severely obese is reduced by an estimated 5-20 years. [32]

Beyond the health and life expectancy impacts, obesity has also been shown to significantly impair mobility, especially amongst women, [33] thus placing a barrier to social engagement, another critical component of healthy aging which is discussed in a subsequent section.

INTERVENTIONS

Physical activity and healthy diet play a role in BMI, and the USPSTF recommends that clinicians offer or refer adults with a body mass index of 30 or higher to intensive, multicomponent behavioral interventions. [34] Weight loss research indicates that holistic programs offering a combination of diet and exercise recommendations lead to the greatest weight loss, as compared with programs focusing solely on diet or exercise. [35,36] (It should be noted that weight loss research has predominantly been focused on middle-aged adults who are moderately obese, measuring short-term interventions. [35]) While most weight loss occurs from caloric restriction, physical activity plays a critical role in the maintenance of weight loss, as well as reducing risk of cardiovascular disease and diabetes beyond that produced solely by weight loss. [37,38]

The benefits of such programs are not limited to weight loss – systematic reviews of six randomized controlled trials in older adults suggested that weight-loss programs combined with comprehensive physical activity programs (aerobic and resistance) also lowered the risk of reduced muscle mass, increased strength, and safeguarded against bone loss. [36] Furthermore, weight loss in obese older adults has been shown to reduce mortality risk by approximately 15%. [39]

Outside of lifestyle improvements, medical and pharmacologic solutions have proven successful as second lines of defense. In particular, bariatric surgery for qualifying individuals has been associated with reductions in mortality risk ranging from 33% to 92%. [40-42] Pharmacologic solutions for weight loss also hold promise, with studies demonstrating the safety and efficacy of such medications for substantial weight loss ($\geq 5\%$ and $\geq 10\%$ of initial weight) in combination with intensive behavior modification, as well as improvements in markers of cardiovascular disease risk. [43,44]

One common criticism of BMI as a biometric assessment is that it does not distinguish between differences in fat mass, lean muscle tissue or percentage of body fat, and – as such – it may be a suboptimal measure of adiposity for the average adult. It may be an even less appropriate measure in the elderly, since it does not take into account the physiological changes that occur as a function of the aging process, including the loss of muscle, fat, and a reduction in height. [45,46] Studies suggest that while BMI is a good predictor of morbidity and mortality in most adults, its value among the oldest old has been debated. [47-49] BMI guidelines may be overly restrictive when applied to the elderly at both ends of the spectrum – high BMI has been shown to be associated with a smaller relative mortality

risk in older adults as compared to younger adults; yet low BMI has been shown to be associated with increased mortality risk, likely due to weight loss due to other comorbidities. Consequently, further research on the appropriateness of using BMI in older adults is required. [50,51]

Metabolic Risks (Fasting Plasma Glucose, Blood Pressure, Cholesterol)

SUMMARY

Amongst U.S. adults 70 years and older, 39.5% of deaths (a 15.6% decrease since 1990) and 25.9% (a 15.9% increase since 1990) of years lived in disability were attributable to metabolic risks. [4] This excess risk is measured against minimum exposure thresholds of 4.8-5.4 mmol/L for glucose, 110-115 mmHg for systolic blood pressure, and 0.7-1.3 mmol/L for LDL cholesterol. [5]

The USPSTF recommends lifestyle changes as the first line of treatment to address elevated metabolic risk factors, including high fasting plasma glucose, high blood pressure, and high cholesterol. [52] These changes can include many of the dimensions discussed in this paper i.e. improving one's diet, achieving a healthy weight, increasing physical activity, and quitting smoking.

If lifestyle changes are not sufficient in controlling risk factors, medication is often prescribed as a second line of defense to help manage these conditions. [53] However, medications are only an effective treatment when taken as prescribed. Poor medication adherence is a major contributor to inadequate chronic disease management and, as noted in Table 2, is a key strategy in blood pressure and diabetes management. [54-57] In fact, Kravitz and Melnikow (2004) referred to patient adherence to physicians' recommendations as "the key mediator between medical practice and patient outcomes." [58] Adherence to antihypertensive medication is associated with a significantly lower risk of cardiovascular disease events among older adults, while adherence to glucose-lowering medications is associated with improved glycemic control and fewer emergency department visits and hospitalizations. [59,60] However, despite the importance of medication adherence, patients with chronic diseases typically only take 50% of their prescribed doses, [61] and are therefore not fully realizing the health benefits and protections these medications are intended to provide.

INTERVENTIONS

Whilst no national guidelines or recommendations for medication adherence have been identified, the USPSTF does provide pharmacologic and non-pharmacologic interventions for hypertension [62,63] and diabetes. [64-66] Furthermore, The Centers for Disease Control and Prevention (CDC) has published general strategies to improve medication adherence for chronic disease management, which range from increased access through lowered costs to utilizing emerging technology like electronic pill bottles with behavioral prompts. [54]

Poor medication adherence behaviors are well understood and stem from a combination of patient, physician, and health system related factors. Amongst individuals, a lack of medical literacy; poor understanding of one's disease and the efficacy of the associated treatment plan; poor historical experiences with prior treatment plans; high medication costs; lack of social support; poor mental health; and lack of access to pharmacies all impact medication adherence. In general, adherence requires a multifaceted approach that incorporates the patient, physician, and health system that addresses the well-known barriers discussed above, amongst others. [67]

On an individual basis, a systematic review of 771 studies of adherence found that the most effective interventions were delivered face-to-face, by pharmacists, and administered directly to patients. This is particularly true of cognitively impaired older adults, where the few studies that do exist on the subject suggest that successful interventions in improving adherence involve frequent human communication as reminder systems rather than nonhuman reminders, such as automated phone messages. [68]

Of course, one cannot simply measure and incentivize medication adherence without facilitating access in the first place. Employers and government can play an important role in ensuring that medications are affordable and accessible. Though the role the employer plays in healthy aging will be discussed later, one large employer's value-based insurance initiative reduced copayments for five chronic conditions, which led to a 7-14% reduction in nonadherence. [69]

Technology is swiftly becoming a powerful enabler of medication adherence, with the largest effect sizes being reported by studies using electronic medication event monitoring and pill count adherence strategies as compared to self-report or pharmacy refill data. [70] Examples include, but are not limited to, smartphone medicine and pill reminder applications. However, the space is rapidly evolving and extends to:

- Smart medication dispensers;
- Hub services, which integrate technology and personal interaction to help patients navigate the complexities of doctor, insurance requirements and pharmacies;
- Telehealth/pre-recorded voice messages from health care providers/integrated appointment scheduling and reminders for medication reviews;
- Increased automation of prescribing and dispensing of medication, allowing pharmacists to spend more time in clinical roles talking to patients about adherence; and
- Mobile tracking and gamification apps.

Dietary Risks

SUMMARY

Amongst U.S. adults 70 years and older, 14.8% of deaths (a 28.9% decrease since 1990) and 5.2% (an 18.4% increase since 1990) of years lived in disability were attributable to dietary risks. [4] Good nutrition is pivotal across all age groups with robust evidence illustrating the role that a healthy diet has on promoting health and reducing risk for chronic diseases. [71-75] This is particularly true amongst older adults who are at greater risk of chronic disease as well as osteoporosis and reduced muscle mass (sarcopenia). [76-78]

A healthy diet is associated with lower rates of coronary heart disease and hypertension and lower mortality rates across the age spectrum. More generally, however, good nutrition improves health-related quality of life by promoting overall health; and preventing malnutrition, which contributes to functional impairment and is associated with increased mortality in older adults. Early evidence has also shown that diet is associated with slower cognitive declines, [79] with one large study finding that participants who adhered most closely to a Mediterranean diet experiencing lower cognitive declines than participants who ate more of a traditional Western diet. [80-82]

With age, several associated nutritional changes may affect quality of life, which makes the provision of a healthy diet even more important. These include reduced thirst and decreased body water, which increase susceptibility to dehydration; age-related changes in nutrient needs [83], which can lead to vitamin deficiency or toxicity; changes in taste, vision and smell [84,85], which can lead to decreased enjoyment of food; broken bones; edentulous, or missing or false teeth [86], which can limit food choices; increased disease incidence, which can lead to changes in nutritional requirements; increased use of over-the-counter or prescription drugs [85], which can lead to changes in appetite, nutrient requirements and increases in possible drug-nutrient interactions.

Of course, for older adults, bone health is a critical concern and, in this regard, diet plays a crucial role where the consumption of sufficient protein, [87] yogurt, [88] and a general Mediterranean diet [89] have all been associated with lower rates of osteoporosis. (Smoking [90] and the failure to maintain muscle mass [91] are associated with higher risk of osteoporosis, again highlighting the importance of smoking cessation and exercise in healthy aging more broadly.)

Beyond the important nutritional aspects of a healthy diet, meals offer a sense of security, independence and often provide structure in a person's day. In general, the social element of meals is a daily pleasure that fosters community, all of which can meaningfully contribute to a person's overall sense of wellbeing. [85,92]

INTERVENTIONS

The Dietary Guidelines for Americans provide a thorough overview of the interventions and key dietary requirements across all age groups. The guidelines recommend: (1) following a healthy dietary pattern at every life stage (for adults, a healthy diet helps meet nutrient needs, achieve a healthy body weight, and reduces the risk of chronic disease); (2) customizing and enjoying nutrient-dense food and beverage choices to reflect personal preferences, cultural traditions and budgetary considerations; (3) focusing on meeting food group needs with nutrient-dense foods and beverages and staying within calorie limits; and (4) limiting food and beverages higher in added sugars, saturated fat and sodium, and limiting alcoholic beverages. [93] While healthy dietary behaviors are consistent at every stage of life (i.e. limit foods and beverages higher in added sugars, saturated fat, and sodium, and limit alcoholic beverages [93]) older adults need to pay special attention to protein consumption to stave off the loss of lean muscle mass and Vitamin B12 since the absorption of this nutrient can decrease with age. Many older adults do not drink enough fluids to stay hydrated, as the sensation of thirst tends to decline with age. [94] Concerns about bladder control or issues with mobility also may hinder intake of fluids among older adults. It is important that older adults drink plenty of water to prevent dehydration and aid in the digestion of food and absorption of nutrients. [95]

There exist myriad barriers to healthy eating, with common reasons including the time necessary to prepare healthy food versus the convenience of fast food, inferior taste, lack of willpower to make healthy choices, the cost of healthy food, and lack of availability of healthy foods. While many of these barriers are common among adults of all ages, older adults also tend to cite social, habitual, or health-related barriers to healthy eating, such as lack of cooking skills; dental and other health issues that impact dietary intake; a change in social support, including eating alone; and impaired mobility or difficulty getting to food sources. [96]

In systematic reviews of healthy eating interventions targeting older adults, dietary education and meal service provision have proven effective in guiding healthier eating habits. [80]

Very old age is associated with increased risks of malnutrition, multimorbidity and disability. Hidden hunger – a term used to describe individuals who have adequate energy consumption, but suboptimal nutrients [97] – becomes more pronounced with many older adults unable to leave their homes and at high risk for falling if they do. As such, home-delivered meal programs, like Meals on Wheels America, are important mechanisms with which to deliver high-nutrient food to homebound older adults. [98]

Whilst the dietary guidelines provide simple and clear recommendations, new research is being conducted to optimize food for the individual's unique needs based on their biological makeup, lifestyle, health conditions, environmental factors and personal preferences. [99]

Physical Activity

SUMMARY

In the United States, 28% of adults aged 50 and over are not meeting physical activity guidelines. [100] According to 2019 GBD data, amongst U.S. adults 70 years and older, 1.6% of deaths (a 46.4% decrease since 1990) and 0.8% (an 8.9% decrease since 1990) of years lived in disability were directly attributable to insufficient physical activity. [4] Regular physical activity is critical for healthy aging, with its benefits well-established, encompassing lower rates of all-cause mortality, coronary heart disease, stroke, hypertension, type 2 diabetes, and some cancers. In fact, when compared with individuals who were insufficiently active (<600 MET (metabolic equivalent) minutes/week), highly

active individuals (exercising the equivalent of 8,000 MET minutes/week) exhibited a risk reduction of 14% for breast cancer; 21% for colon cancer; 28% for diabetes; 25% for ischemic heart disease; and 26% for ischemic stroke. [101] In older adults, physical activity is associated with improved performance of daily activities [102-104], prevention of falls [102-104], improved quality of life in those with arthritis, [105] increased longevity [106], lower risk of cognitive decline [107], and an increased sense of purpose in life. [108] Even light/mild activity has been shown to have positive effects on healthy aging in older adults. [109]

Whilst the Physical Activity Guidelines recommend 150 to 300 minutes of moderate-intensity aerobic activity a week, such as brisk walking, bike riding, or playing tennis, the consensus is that some activity is always better than none, which is particularly relevant for older adults who might not be able to meet the recommended activity criteria, and should be as physically active as their abilities and conditions allow. [110] For frail individuals, water-based exercise programs offer a solution that can reduce joint pain and can help reduce pain and stiffness. [111] Chair-based exercise classes can also allow individuals with balance or mobility issues to exercise with a focus on upper-body movements if full-body movements are not possible. [112] Both water-based and chair-based activities allow frail older adults to be active in a safe, accessible and supported manner, and can help to combat some of the common barriers to physical activity among older adults, including pain and fear of falling [113] and injury. [114]

INTERVENTIONS

According to the Physical Activity Guidelines, adults should do at least 150 minutes (2 hours and 30 minutes) to 300 minutes (5 hours) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) to 150 minutes (2 hours and 30 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Additional health benefits are gained by engaging in physical activity beyond the equivalent of 300 minutes (5 hours) of moderate-intensity physical activity a week. Adults should also do muscle-strengthening activities of moderate or greater intensity and that involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits. [115]

While the guidelines are the same for adults and older adults, given the range of functional ability amongst older adults, physical activity interventions need to be cognizant of an individual's unique context. In general, as part of their weekly physical activity routine, older adults should at least try to incorporate multicomponent physical activity that includes balance training as well as aerobic and muscle-strengthening activities. Most evidence supports a program of exercise with the following characteristics: 3 times per week of balance training and moderate-intensity muscle-strengthening activities for 30 minutes per session, with additional encouragement to participate in moderate-intensity walking activities 2 or more times per week for 30 minutes per session. And, for those unable to meet the physical activity guidelines, increasing activities that involve a combination of standing, walking, and upper body movement may be helpful. [116] Some evidence, albeit less consistent, suggests that tai chi exercises also reduce falls. [117]

Barriers to physical activity can include personal factors (such as lack of time, energy, or motivation and lack of social support), socioeconomic factors (such as lack of access to gym facilities or safe neighborhoods or parks, or knowledge about physical activity), and health factors (such as fear or injury). [118-120] To overcome common barriers among the oldest old, interventions should focus on the overall health benefits of physical activity, individual preferences and social support, and to constraints of the physical environment. Personalized recommendations from health care professionals are also cited as a critical tool in encouraging older adults to participate in physical activity, especially for those who may have hesitations about their ability to exercise safely due to mobility issues or other health concerns. [121]

The literature has shown that interventions combining educational, behavioral, and cognitive-behavioral (including goal setting and tracking) strategies are typically most effective at helping older adults become more active (health education alone has not proven effective). [122-125] A comprehensive meta-analysis found a moderate mean effect size ($d=0.19$) across various interventions designed to increase physical activity among older adults, noting

that behavioral interventions were associated with larger physical activity effect sizes (0.25 vs. 0.17). [126] Behavior change techniques have been found to be effective in promoting physical activity ($d=0.29$) [127] as well as self-efficacy levels [128]. Another meta-analysis looking specifically at older adults with chronic illnesses found that studies using various behavioral strategies to increase physical activity had larger effect sizes (0.51) than studies without behavioral components – for example, a study of patients with chronic obstructive pulmonary disease found that the intervention that used both cognitive and behavioral approaches produced greater physical activity adherence during and after the intervention, as compared to either approach alone. [129] The authors noted that the treatment subjects generally did not achieve 10,000 steps per day; however, there were improvements in physical activity levels above initial sedentary levels. [130]

Systematic reviews have suggested that multi-component interventions can lead to increases in physical activity levels of older adults; however, heterogeneity of interventions make it difficult to assess the precise magnitude of the effects. Further, the effects on maintenance of activity levels beyond 12 months is difficult to assess due to a lack of high-quality longitudinal studies. [131] Older adults' engagement in physical activity may benefit from motivators such as social support and personal enjoyment – as such, group-based activities may be particularly valuable. [132,133]

Technology is playing an increasingly vital role in helping individuals measure and maintain their health and fitness. [134] With the proliferation of wearable devices and mobile applications, individuals can not only track their activity, but also utilize this technology to receive personalized goals and social support. [135] Furthermore, with ever-increasing sophistication, wearable devices can aid in health monitoring more generally, including – but not limited to – fall detection. There are also a wealth of health and fitness programs that cater specifically to older adults which offer in-person and online fitness classes to older adults across the functional spectrum. These types of programs do not only offer classes that cater to unique needs, from strength and yoga to chair-based cardio activity, but also facilitate a sense of community, which is of huge importance to successful aging, as is discussed later in the paper.

Whilst robust programs exist, there are critical individual-level issues centered around access to and compliance with physical activity programs that need to be addressed to reap the benefits fully. This is a multifaceted issue that hinges on elements as varied as socioeconomic status, health status, cognitive ability, [136] and program design. [137] Research has indicated that sustained physical activity compliance is a function of an accessible point of entry into a program (i.e. cost and location); instructor support through proactive encouragement; the feeling of social connectivity and belonging within the program itself; and a sense that the activities are improving an individual's health and wellbeing. All of this leads to a higher likelihood of sustained program enjoyment and thus the evolution of a long-term habit. [137]

NOTE: The following sections are not driven by the GBD framework as described. The rationale for their inclusion is described in the introduction of this paper.

Screenings

SUMMARY

In the United States, cancer is the second leading cause of death, exceeded only by heart disease, with one out of every four deaths in the U.S. due to cancer. [138] The USPSTF notes that mammography screening, [139] cervical cancer screening [140] and colorectal cancer screening [141] are of substantial net benefit for the recommended age ranges, reducing incidence of and mortality from their respective diseases. Despite the well-established benefits of cancer screening, detecting cancer at early stages when it is most easily treated, screening rates remain below the government Healthy People 2020 initiative targets for breast cancer (screening rate: 72.4%, target:

81.1%), cervical cancer (screening rate: 82.9%, target 93.0%) and colorectal cancer screening (screening rate: 66.9%, target: 70.5%). Clear disparities exist as well, with educational attainment, income, sexual orientation, ethnicity, age, race, insurance coverage, access to usual care, and duration of U.S. residence found to be associated with rates of screening. [142]

Literature reviews have demonstrated that cancer prevalence and incidence increase until ages 85-89, after which the rates decrease at the oldest ages. However, the overall number of cases has steadily increased over time due to the rise in population size and longer life expectancies, with cancer mortality continuing to increase after age 85+ years. [143]

Eight percent of all new cancer diagnoses are made in the oldest old, who are at higher risk for melanoma and lung cancer. Amongst this population, cancers are typically only diagnosed in advanced stages. This late-stage detection, paired with lower rates of surgical intervention, leads to considerably lower cancer survival rates amongst individuals 85 and over. While more research is needed on how to treat cancer amongst the oldest old, given their functional and cognitive decline and the presence of multiple comorbidities, [144] cancer screening is a critical tool with which to reduce cancer mortality across cancer types and across ages.

It is well-established that a cancer diagnosis can have substantial quality of life impacts on patients, and health-related quality of life is increasingly being acknowledged as playing a crucial role in patient outcomes. The impacts of cancer and its related treatment on patients' physical and psychosocial functioning and the financial burden cannot be overstated. [145,146] Approximately 42% of patients experience considerable financial burden as a result of their diagnosis and treatment [147] and have been found to be 2.7 times more likely to declare bankruptcy than those without cancer. [148] Adding an additional layer of complexity to navigating life during and after cancer, nearly 20% of cancer survivors report not being able to afford mental health care. [149]

INTERVENTIONS

The USPSTF provides a comprehensive set of cancer screening recommendations both prior to and following retirement, extending across cervical cancer [140], breast cancer [150], and colorectal cancer screening. [141]

The USPSTF guidelines for cervical cancer recommend screening for women ages 21 to 65 years, noting that the benefit of screening does not outweigh the harms for women over 65 years who have had adequate prior screening and are at average risk. [141]

For breast cancer screenings, the USPSTF guidelines recommend biennial screening for women ages 50 to 74 years for women of average risk, noting that women ages 60-69 years are most likely to avoid breast cancer death from mammography screening. They note there is insufficient evidence to weigh the benefits and harms of extending screening beyond age 74 years. [150]

The most recent update to the USPSTF guidelines for colorectal cancer screening recommend that screening begin at age 45 rather than at age 50 to reflect the increase in cases among younger and middle-aged adults. [141] Although colorectal cancer incidence among those 55 years and older has declined over the past two decades, in part due to screening, the incidence among those younger than 50 has been increasing. [151] Evidence suggests that starting colorectal cancer screening at age 45 years can moderately increase life-years gained and decrease cases and deaths compared to starting screening 5 years later at age 50 years. [152] The recommendations remain to discontinue screening for those at average-risk beyond age 75 years who have previously received adequate screening, as on average, few additional life-years are gained when screening in older adults. [152]

At the individual level, invitations and (targeted and tailored) reminders in the form of post cards or letters to eligible individuals, along with small and mass media campaigns have proven effective at increasing screening rates. [153]

For providers, strategies include reminders for physicians to recommend screening to qualifying individuals, in-depth patient education or navigation, and physician incentives. Practice facilitators or coaches, especially those who have appropriate understanding of their patient populations' language and cultural traits [154], have also been used to great effect in increasing colorectal screening rates, for instance. [155-159]

Within the workplace, group discussions, outreach and educational campaigns have illustrated promise.

Naturally, one of the greatest opportunities in screening is expanding access and, in this regard, the possible future for screenings hold promise, encompassing home-based cancer screenings [160]. Given that only about 70% of adults were up-to-date on colorectal cancer screening in 2018, and one-fifth of those 65 to 75 years had not been screened as recommended, [161] home-based colorectal cancer screening offers a convenient solution. The current literature indicates that the leading home-based test is both less effective and more costly than traditional colorectal cancer screening tests, and so – while advancements in home-based screenings hold promise – time will tell whether they serve to augment or replace traditional screening tests. [162]

The future of screenings may also include more targeted risk stratification and precision cancer prevention screenings based on known genomic and environmental factors. [163] The growing interest in personal genomics, coupled with the decreasing costs, has led to a rise in direct-to-consumer genetic testing to detect increased susceptibility toward certain cancers. [164] Today's tests have the ability to analyze specific genes for mutations that are known to increase cancer risk; however, the tests also can lead to confusion when mutations of unknown significance or those without clear clinical management strategies are detected. [164] The convenience of at-home cancer testing and direct-to-consumer genetic testing is clear, and future research will demonstrate whether these emerging trends are making a meaningful difference in the uptake of cancer screening.

Immunizations

SUMMARY

The development of immunizations has been lauded as one of the great public health achievements of all time and is largely responsible for the increase in life expectancy experienced during the 20th century. [165] Several diseases have been eradicated or eliminated as a result of childhood vaccinations, [166] with estimates showing that the vaccination of each U.S. birth cohort delays 33,000 deaths, prevents 14 million cases of disease, and reduces direct health care costs by \$9.9 billion and indirect societal costs by \$33.4 billion. [165]

Each year, nearly 42,000 adults in the U.S. die due to diseases that could have been prevented with an available vaccine. For example, seasonal influenza contributes to more than 200,000 hospitalizations and 36,000 deaths per year. Despite the well-established benefits of regular immunizations, adult immunization rates remain lower than national goals. [167] Among older adults, national influenza vaccination rates were approximately 68% in 2012, compared to Healthy People's 2020 goal of reaching 90% immunization in this age group, while herpes zoster vaccination among older adults was only 20.1%.

It was estimated in 2010 that 4 major vaccine-preventable diseases – influenza, pneumococcal disease, herpes zoster, and pertussis – cost the U.S. health care system \$15 billion dollars, with the cost of influenza hospitalizations alone resulting in \$8.3 billion per year. [167] The COVID-19 pandemic, for which there now exist several effective vaccinations against the disease, has and – at the time that this report was drafted – continues to wreak havoc on the U.S. health care system. It was previously estimated that a single symptomatic case could incur a median direct medical cost of \$3,045 during the infection alone. [168] While the publicly reported number of confirmed cases as of early 2021 was about 25.7 million people, researchers suspect that this number is actually an underestimate, with a machine-learning algorithm calculating estimates closer to 71 million people – about 21.5% of Americans. [169] Earlier estimates predicted that if 20% of the U.S. population were to get infected, there could be 11.2 million

hospitalizations, 2.7 million ICU admissions, 6.23 million hospital bed days, and \$163.4 billion in direct medical costs as a result. [168]

Over 60% of flu-related hospitalizations occur in people 65 years and older, and almost a third of the adult population will develop shingles in their lifetime in the United States. [170] And given that the prevalence of comorbidities rises with age, infection with a vaccine-preventable disease among older adults increases the risk of worse outcomes for this vulnerable population. [167] This holds true for COVID-19's impact on older adults as well – the disease has been more severe in older adults and in those with multiple chronic conditions. [171] As such, immunizations are vital mechanisms with which to reduce incidence of, hospitalization from, and complications from illness.

INTERVENTIONS

The Centers for Disease Control and Prevention recommends that in addition to the influenza vaccine, which all adults should receive annually – and the Td or Tdap vaccine (Tetanus, diphtheria, and pertussis) booster shot every ten years – older adults should obtain a shingles vaccine (50 years and older); a pneumococcal polysaccharide vaccine (PPSV23) (65 years and older); and a pneumococcal conjugate vaccine (PCV13) (for adults with conditions that weaken the immune system, cerebrospinal fluid leak, or cochlear implant). [172]

As with screenings, reducing barriers to immunizations necessitates a combination of education, proactive communication (including telephone, letters, postcards, text messages, or combinations of these strategies) from primary care physicians, [167] and the widespread availability of immunizations. [173-175] Vaccination outreach is particularly important for homebound individuals or those with cognitive impairment who are less likely to have the means to get to a vaccination facility.

Vaccine development has progressed immensely over the years, as the rapid development of several COVID-19 vaccinations has demonstrated. [176] Furthermore, new modes of vaccine delivery are being explored – in the form of patches and sprays, rather than injections – which would make routine immunizations cheaper and more accessible. [176,177]

Not only is the speed of development progressing rapidly, but scientists are also working on cataloguing the immune signatures of different age groups to predict how certain populations would respond to certain vaccines. This means that vaccine formulations could be customized to work best for specific age groups, which was the case with the shingles vaccine, Shingrix. [178]

The COVID-19 pandemic has also brought about new ways of thinking about how best to distribute vaccines to vulnerable older adults. With the centrality of access in vaccine compliance, ensuring that those who might have issues with transportation, those who may not have internet access or are not tech-savvy enough to use an online scheduling system, or those who have mobility or cognitive challenges [179] have simple access to vaccines is imperative. Strategies, which are likely to have broad applicability for vaccine rollouts more generally, included creating pop-up vaccination clinics in convenient locations, such as community centers and places of worship; delivering vaccines to homebound seniors through fire departments and other local agencies; [180] and offering free or discounted rides to vaccination centers. [181]

Social Engagement

SUMMARY

Successful aging is a function of physical, cognitive, and mental health, [182] but also – critically – social engagement, which, according to the Stanford Center on Longevity's Sightlines Project, can have a powerful effect on people's wellbeing, including physical, mental and cognitive health. [183]

In general, researchers note that, over the course of one's life, while the size of one's social network typically decreases, the depth of the remaining relationships are strengthened. [183] This is attributable to the fact that older adults undertake "social pruning". Yet, according to the University of Michigan National Poll on Aging, more than one third of adults aged 50 to 80 report feeling a lack of companionship and nearly one third feel isolated. These findings are consistent with national figures that note that 30% to 40% of older adults report feeling lonely [184].

A lack of social ties, in the form of objective social isolation, subjective feelings of loneliness, or low quality of social relationships, has been found to be a risk factor causing poor physical health [185-190], including higher prevalence of disease [191] and increased likelihood of mortality [192-194]. In fact, a large meta-analysis found that people with stronger relationships had a 50% increased likelihood of survival when compared with those with weaker relationships. [193]

In general, the mental and cognitive benefits of social engagement have started to emerge, though the findings are still primarily centered around correlations rather than strict causation. The research indicates that loneliness is associated with depression [195] and the frequency of an individual's social interactions combined with the size of their social network has been associated with dampening rates of cognitive decline. [196,197]

The impact of loneliness on older adults became highlighted during the COVID-19 pandemic, when social distancing further exacerbated the existing social isolation many older adults already face. Strategies for keeping older adults connected during social distancing restrictions have emerged, encompassing changing perspectives (as discussed below), changing the ways that people connect, and pursuing calming activities encompassing, but not limited to, pleasant sensory experiences like listening to music and looking at art. [198]

INTERVENTIONS

A review of interventions and strategies targeting loneliness and social connectedness for older adults identified nine distinct intervention types, namely:

1. Personal contact, where older adults had scheduled contact with another person;
2. Activity and discussion groups, where they engaged with a new group of people in an activity and/or facilitated discussion;
3. Animal contact, where they had scheduled contact with an animal;
4. Skills courses, where they participated in courses delivered to develop participants' personal skills;
5. Varied/non-specific programs that were multifaceted and did not focus on a single type of intervention;
6. Model of care, in which a new philosophy for care provision was implemented;
7. Reminiscence, where participants recalled and discussed memories and experiences;
8. Support groups, where participants shared personal challenges and received emotional or informational support; and
9. Public broadcast, where participants listened to a generation-specific radio program.

This review found that one-to-one personal contact and activity group interventions were most frequently explored or evaluated. A meta-analysis of interventions targeting a reduction in loneliness found that those designed to change one's frame of thinking about social interactions, including the promotion of positive coping and managing social anxiety, were most effective at reducing loneliness, though future research is needed to advance the evaluation of loneliness and social connectedness interventions. [199]

In general, technology has been a boon to facilitating social engagement amongst older adults. An AARP study found that of the 70% of older adults who are on social media platforms, over 90% use them primarily to keep in touch with family and friends. [200] However, beyond social media, virtual assistants, social robots, [201] video communication platforms, photo-sharing platforms, and senior-specific tablets have all emerged as mechanisms with which to check-in and provide some degree of social connectivity. [202]

Cognitive and Mental Health

SUMMARY

More than 20% of adults over 60 suffer from a mental or neurological disorder, which comprise 6.6% of disability adjusted life years (DALYs) in this population and 17.4% of years lived with disability (YLDs). [203] Dementia and depression are the two most common mental or neurological disorders experienced by older adults, and the links between these conditions and the health behaviors discussed in this paper are well-defined in the scientific literature. Given the close ties between mental health and social and emotional support, which was discussed in the previous section, we instead focus here on cognitive health.

An AARP report noted that “staying mentally sharp” is older adults’ primary health concern, [204] which is not only important for maintaining the functional activities of daily living, but is also a central driver of sustaining a sense of purpose. [205] Even mild cognitive impairment has been shown to be associated with a higher rate of falls in adults over 50, [206] and any state of cognitive impairment – mild, moderate or severe – is associated with increased risk of mortality. [207,208]

INTERVENTIONS

There is a growing body of evidence to suggest that a healthy lifestyle throughout one’s life can help to prevent or delay cognitive impairment. A recent Lancet report highlighted twelve modifiable risk factors that together account for up to 40% of dementia cases worldwide, encompassing: [209]

1. Less education;
2. Hypertension;
3. Hearing impairment;
4. Smoking;
5. Obesity;
6. Depression;
7. Physical inactivity;
8. Diabetes;
9. Low social contact;
10. Excessive alcohol consumption;
11. Traumatic brain injury; and
12. Air pollution.

To a large extent, these risks overlap precisely with the risks and interventions showcased in this document reinforcing the importance of physical activity, improved diet, managing metabolic risks, not smoking, maintaining a healthy body weight and being socially engaged not only for physical health, but cognitive health as well. [210]

An Emerging Evidence Base

Whilst the previously discussed dimensions all have an extensive and well-established evidence base, there is a considerable amount of research being conducted in several new areas pertaining to aging. This is an ever-evolving space and one that is rife with innovation and opportunity. As such, this section seeks to highlight a handful of pillars from the emerging aging Parthenon espoused by the likes of The Sightlines Project [211] and other experts in the space. [212] This encompasses healthy living (e.g. sleep, vision and hearing); social engagement (e.g. purpose); and social infrastructure (e.g. managing activities of daily living and aging in place). These are active areas of inquiry that will evolve considerably over the coming years as a function of advancements in clinical practice, technology, public health, and general health research and development.

SLEEP

It is recommended that adults should sleep 7 – 9 hours per night on a regular basis to promote optimal health (recommendation for adults ages 18-60) [213], whilst older adults should sleep 7-8 hours. [214] Yet, according to the Centers for Disease Control and Prevention, 26.3% of adults aged 65 and over failed to meet this recommendation. [215]

Sufficient sleep is an important dimension of health, and inadequate sleep is associated with adverse health outcomes, including weight gain and obesity, diabetes, hypertension, heart disease and stroke, depression, dementia, [216] and increased risk of death. Mental health and cognitive disorders, such as depression, bipolar disorder, anxiety disorders and attention deficit disorders are associated with sleep problems – not only do individuals afflicted with these conditions experience poor sleep, but poor sleep can further exacerbate these conditions. Interestingly, sleep follows a u-shaped risk trajectory where both long (more than 9 hours) and short (less than 7 hours) sleep duration are associated with increased risk for all-cause mortality. [213,217,218] A cross-country comparative analysis by RAND found that individuals who sleep less than 6 hours per night have a 10% higher mortality risk than those who sleep 7-9 hours, while those who sleep between 6-7 hours per night have a 4% higher mortality [219].

As one ages, there are shifts in one's sleep architecture with an overall decrease in total sleep time, sleep efficiency, slow wave sleep, and rapid eye movement sleep; [220,221] by contrast, there is an increase in time awake after falling asleep, the number of arousals from sleep, and sleep latency. However, such sleep disturbances are not a necessary outcome of aging, but rather common features of the aging process that include but are not limited to comorbidities and psychosocial factors.

In general, the same recommendations for sound sleep in the general population persist for older adults, [222] including, but not limited to, following a consistent sleep schedule, limiting caffeine intake; [223] eating a healthy diet; getting regular physical activity [224] and avoiding electronics prior to bed. [225,226] Randomized controlled trials of older adults with sleep disturbances have found that mindful meditation resulted in significant sleep improvements, [227] while mild to moderate levels of exercise have been found to improve overall quality of sleep. [224,228]

With the mounting evidence of the role of sleep in overall wellbeing, there have been substantial advancements in sleep-related technology, which facilitate the large-scale measurement, diagnosis, and monitoring of sleep disorders. [229] The future of sleep technology will include devices such as:

- Embedded bed sensors, which can collect data on sleep time, breathing, snoring, heart rate, body temperature and other sleep-associated metrics.
- Personal in-ear electroencephalograms (EEG), which have been shown to be able to identify stages of sleep.
- Wearables that use accelerometry and heart rate data to identify when a user is at rest.
- Smartphone sensors placed near a user while sleeping can monitor body movement and snoring using a phone's built-in microphone to monitor sleep patterns.

These technologies have the potential to provide the user with information about their sleep patterns, as well as providing the user's health care provider with clinical information that can be used to inform their care. While many of these products do currently exist on the market, the evidence base for their effectiveness is still in nascent stages. [229]

VISION AND HEARING IMPAIRMENT

Vision and hearing impairment is a common experience amongst older adults in the United States, with 18% of people aged 70 and over experiencing blindness in one or both eyes, whilst 33.2% report problems hearing. [230] As such, it is recommended that adults aged 65 and over receive an eye exam annually, or as recommended. [231] By contrast, screening for hearing loss has not yet been recommended by the United States Preventive Services Task Force, which notes that more research is required before broader recommendation can be made, [232] though the American Speech-Language-Hearing Association recommends that adults be screened by an audiologist once every three years after age 50. [233]

Sensory impairment has a material impact on quality of life, often leading to limitations in communication, which in turn can lead to feelings of social isolation, anxiety, loneliness, depression, and has also been associated with higher rates of cognitive decline and dementia. [234-239]

Dual sensory loss also accounts for greater functional disability with greater risk of falls, [240] increased health-service use, [241,242] and overall worse health and life expectancy with sensory-impaired individuals at a 62% increase in risk of all-cause mortality compared to those with no sensory impairment. [243]

Whilst there are well-defined therapies, the future is centered around technology that leverages the growing sophistication of Bluetooth-powered “hearables” and mobile apps. [244] Future advancements are slated to transform hearing aids from medical instruments into complex AI-driven assistants that might include:

- Smart apps and otoscopes able to diagnose hearing problems with relevant data channeled to otorhinolaryngology specialists who can assist with condition management.
- Hearing aids and cochlear implants that have internet access and can remove background noise or translate languages in real-time.

PURPOSE

Critical to the concept of healthy aging is ensuring that individuals can find and maintain purpose in their lives. [245] Here, purpose is an amalgamation of maintaining goals and the feeling that life is imbued with quality and meaning well into retirement. Naturally, this necessitates that individuals can preserve their physical and mental wellbeing throughout their later years.

The positive manifestations of purpose are being investigated on a more regular basis, though this is – admittedly – a nascent area of inquiry that requires further research. Research to date has illustrated that purpose mirrors broad social inequities with higher levels of purpose clustered around those individuals with means and high degrees of social cohesion (including, but not limited to, higher socio-economic status, employment, and marriage status). [246]

For those who do find purpose, the benefits are manifest, [245] including positive associations with psychological and mental wellbeing including mitigating cognitive decline [246-248]; improved physical health including associations with reduced stroke incidence; [249] lower odds of myocardial infarction; [250] improved maintenance of physical function [251,252]; and lower mortality risk. [253,254] Recent research has also highlighted the bidirectional between a sense of purpose and physical activity. [108]

Unfortunately, with few exceptions, the literature demonstrates that purpose typically declines with age. Nevertheless, the potential to experience purpose persists across the life span and should be actively promoted amongst older adults. This includes, but is by no means limited to, providing opportunities for older adults to continue in contributing roles (whether in family life, ongoing careers, or beyond); participate in meaningful activities and sustain their social value and sense of relevance, [251] including volunteering opportunities;

maintaining connections with family and friends; setting manageable goals; and spending time on activities they enjoy or cultivating new skills altogether.

Volunteer organizations like AmeriCorps Seniors offer programs for older adults, like the Foster Grandparent Program, which places older adults in neighborhood public schools where they can help children learn to read or provide tutoring, and the RSVP program, which helps older adults find volunteer opportunities in their communities. [255] AARP's Senior Plant initiative offers a variety of courses, programs and activities to help older adults learn technology skills, covering topics such as basic computer skills, using social media, and learning online banking. [256]

However, older age need not be focused solely on ongoing learning or volunteering. With older adults working well into traditional retirement age, furthering their careers and the expertise they have honed over a lifetime, there is an opportunity for organizations to embrace the virtues of a multigenerational workforce. Such a strategy can serve in the interests of the company (deep expertise and mentoring of younger staff members) and the individual. The successful adoption of a multigenerational workforce will necessitate thoughtful interventions by companies, including, but not limited to, the elimination of ageism in the workforce and creating a workplace that acknowledges, celebrates, and accommodates the unique needs of its diverse teams. [257]

MANAGING ACTIVITIES OF DAILY LIVING

As one ages, the functional ability that people possess to care for themselves – referred to as activities of daily living (ADLs), and centered around mobility, eating, dressing, bathing, toileting, and continence – has a material impact on quality of life. (From an actuarial standpoint, this is particularly relevant for long-term care.)

The maintenance of ADLs is important in helping guard against a cycle of rapidly deteriorating physical and mental health outcomes, ranging from malnutrition to increased risk of falls, and even a higher mortality risk. [258] Whilst higher socioeconomic status and quality of life play a role in mitigating ADL impairment, modifiable lifestyle habits, including vigorous physical activity and not smoking have been found to have a significant association with lower risk of ADL impairment. Other significant safeguards included cognitive decline (poor memory), cardiovascular disease, arthritis, diabetes, and depression. [259]

The adoption of a proactive approach to managing and reducing risk for ADL deterioration, closely tied to the interventions outlined in this paper, helps ensure that older adults have the care they need today to prevent or delay the need for institutional care at a later stage. This not only facilitates an enhanced quality of life for the individual, but also helps manage health care costs.

If one can maintain a high functional status, there is a higher likelihood that one may age in place, which, as the next section illustrates, is becoming increasingly desirable and realistic as a function of an ever-evolving technological landscape.

AGING IN PLACE

Aging in place has received increasing attention over the past several decades, in part due to growing concerns that the U.S. health system will be unable to meet the needs of older adults, particularly in the demand for long-term care services. [260] However, this is not simply a push, but a pull – older adults want to remain in their homes, with AARP studies suggesting that 75% of adults 50 years and older and 90% of adults over 65 would prefer to stay in their homes and communities as they age. [261]

Aging in place has been linked to social engagement, identity, purpose, meaning, routine, security and familiarity, and independence, all of which have been shown to be vital components of successful aging. [262,263] The ability to remain at home ensures older adults can maintain the personal connections they have developed, whilst also maintaining the routines which help imbue their lives with a sense of purpose. [264]

Of course, homes need to be provisioned to ensure that individuals can safely age in place as their requirements change over time, and organizations, such as Meals on Wheels America, offer financial assistance to implement critical home repairs and modifications to help older adults continue living in their own homes. [98] Doorways may need to be widened and countertops lowered to accommodate a wheelchair user. Bathrooms may need grip bars and walk-in showers as opposed to shower-bathtub combinations, which can be challenging to use safely. [265] Upstairs bedrooms may need to be located to the first level for easier accessibility. An AARP survey found that 36% of adults 50 years and older anticipate modifying their homes to enable them to stay as they age. [261] This investment has material health and health care spending ramifications – it has been estimated that for every \$1 invested in home modifications returns \$1.50 in reduced medical spending for falls and hospitalizations for older adults over 75 years. [266]

The built environment also plays an important role in the ability to age in place. Streets need to be safe for crossing and sidewalks must exist to connect residential areas with retail areas and grocery stores, keeping in mind the needs of all who may use them, including those with limited mobility. (Pedestrian safety is an important topic, as an older pedestrian is 61% more likely to die when hit by a motor vehicle than a younger one.) Public transportation is also a key factor in the ability to age in place, as many older individuals can no longer drive themselves. [262]

As the tech-savvy middle-aged adults of today move into retirement, they are more likely to embrace the flurry of promising digital tools – from voice-activated assistants to automatic sensors – that will transform the future of aging in place. Technology can address the physical needs of an older adult at home – with capabilities like smart lights, thermometers, and doorbells, as well as the emotional needs of an older adult at risk for loneliness and isolation – through companies that are creating online communities to help keep older adults engaged or social companion robots. Personal assistants can remind users to take their medication, make phone calls, and hail a ride-sharing service car to take the user to an appointment. Even everyday services like grocery delivery and telemedicine, which experienced a surge during the COVID-19 pandemic, will help keep older adults in their homes as they age. [267]

THE ACCELERATION OF DIGITAL ADOPTION AMONG OLDER ADULTS

As novel interventions are developed, moribund notions of technological literacy amongst older adults need to be revisited. A January 2020 survey by AARP reported a narrowing in the generation gap in smartphone usage, with smartphone usage among older adults up from just over 50% in 2014 to 77% in 2019 – 81% of people aged 60-69 and 62% of people aged 70+. This increased adoption of technology was not limited to smartphones, as older adults were also increasingly purchasing wearables, home assistants and smart home technology at the same rate as adults 18-49 years. Older adults are also embracing technology for education purposes, with 23% taking online classes for certificates or degrees. [344]

Whilst older adults were already adopting new technology at fairly high rates, the COVID-19 pandemic accelerated digital adoption, as forced social isolation required developing new ways to connect with loved ones and take care of household tasks. Over 90% of older adults have claimed that their devices and the internet helped them a lot during the COVID-19 pandemic, whether through social connections or household shopping or accessing health care. [345] In an April 2021 AARP survey, older adults reported using technology in new ways since the pandemic:

- 70% of older adults used video chat, with one in three using video chat on a weekly basis.
- One third of older adults reported currently using or being interested in social media livestreams.
- One third of older adults have attended a virtual event such as an exercise class in the past year.
- Older adults reported a large increase in smartphone use for online grocery ordering (from 6% pre-pandemic to 24%) and for communicating with health care providers through telehealth visits and ordering prescriptions (from 28% to 40%). [346]
- Nearly half of older adults had used the internet to purchase medical supplies online and about 20% had increased this behavior. [345]

While there has been an encouraging acceleration in technology adoption for many older adults, barriers still exist, including cost (60%), lack of technological literacy (40%), and privacy concerns (83%). Overcoming these obstacles through accessible design, well-funded technology (through private or public initiatives), and products that incorporate data privacy by design will be essential for ensuring that all individuals have equal opportunity to benefit from the remarkable and ongoing advances in the digital realm. [345,346]

The Role of Inequity

Any discussion on health is wholly incomplete without an examination of health care discrepancies – differences in health and health care that relate to social, economic, and environmental disadvantage. Any successful interventions need to be keenly aware of the vastly different health experiences and opportunities experienced both within the United States itself and across multiple countries around the world. In the United States, despite material advancements in health care, geographic disparities in life expectancy grew from 1980 to 2014. [268]

Figure 6

WIDENING INEQUALITY IN LIFE EXPECTANCY FOR WOMEN IN THE UNITED STATES

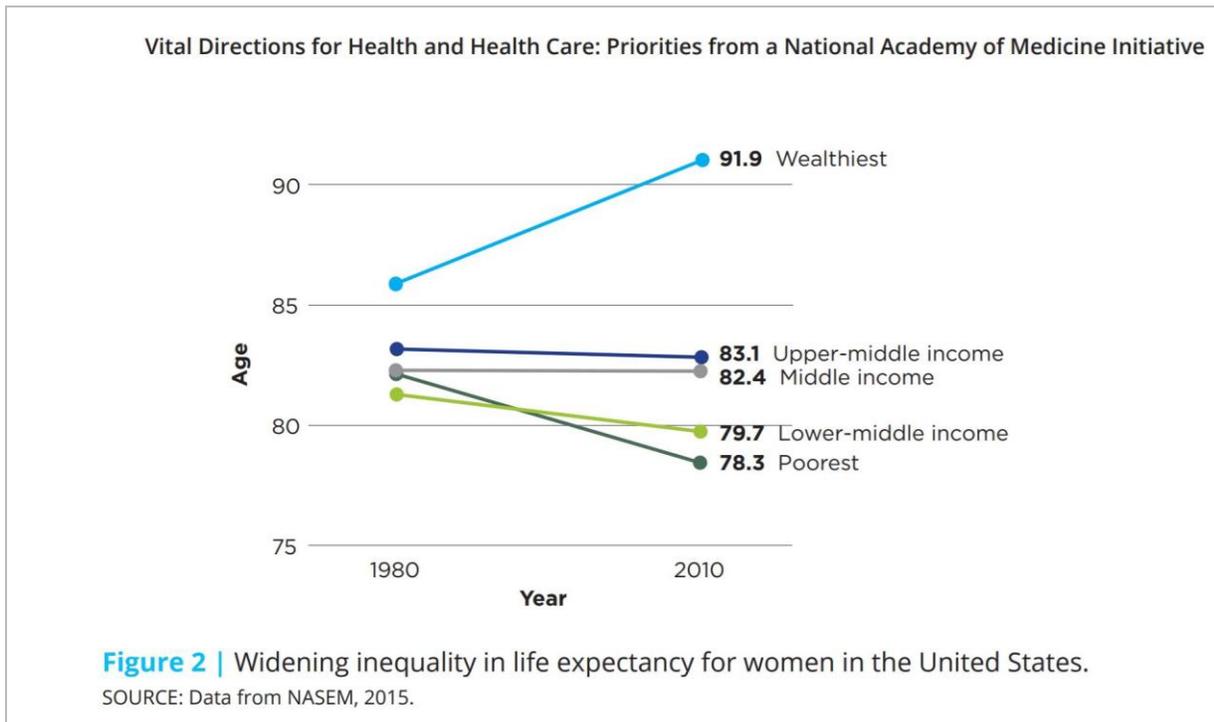


Figure sourced from National Academy of Medicine. “Vital Directions for Health and Health Care: Priorities from a National Academy of Medicine Initiative” (March 21, 2017).

Whilst health inequities are covered in detail in other papers, [269-276] the prevalence of and ability to ameliorate the various health conditions and habits contained in this paper is inextricably tied to racial and ethnic, gender, and geographic dimensions.

Cost is a primary barrier to quality health care and lifestyle choices, since this informs access, which becomes a particularly acute problem when considering access to healthy diets [277-284], or parks and outdoor areas to engage in physical activity. [285-289] Health literacy is similarly important when it comes to medication adherence [290,291], screenings [292-299], and vaccinations. [300-304]

Researchers are continuing to document and study health inequities with a view towards minimizing them in the health care system, whilst also ensuring that the next generation of health interventions serve society broadly.

The Role of the Employer in Influencing Healthy Lifestyles

In the 1990s John Elkington emphasized the need to move away from a narrow focus on the financial bottom line to focus on a broader triple bottom line. [305] Within that framework, he argues that true sustainability can only be achieved at the intersection of environmental (planet), social (people), and economic performance (profit). Businesses are not automatically granted a license to operate in perpetuity. To achieve this, they serve their long-term interests by tackling issues that are material to their progress.

Central to this vision is human capital. Health, one of the principal components of human capital, has traditionally been confined to the domain of occupational safety and health. This component can be expanded as health spans the gamut from internal employee wellbeing to the ramifications that a potential product or service has on the

health of others. With strong correlations between employee health and productivity, absenteeism, and presenteeism, there is a natural financial incentive for corporations to maintain an interest in the health of their population. In addition, commitment to health improvements can be part of an overall goal of broader corporate social responsibility.

Despite the importance of health, employee health continues to deteriorate in the workplace, with Stanford University professor Jeffrey Pfeffer finding that companies are the fifth largest cause of death in the United States in his book “Dying for a Paycheck”. [306]

THE WORKPLACE CAN BE A SETTING FOR HEALTH PROMOTION

The Affordable Care Act (ACA) recognized that the workplace carries opportunities to make an impact on the health of both the population and the economy. [307] In the past, employer-provided health care coverage primarily emphasized treatment, but in part due to changes introduced by the ACA, some employers have adopted programs to promote health and non-communicable disease (NCD) prevention. Incentives to change habits that increase risk for NCDs and to establish healthier behaviors have been core to such initiatives.

It is well established that a healthy lifestyle (including not smoking, maintaining a healthy weight, being physically active, drinking alcohol moderately, and eating a good quality diet) during one’s working years is associated with not only longer life expectancy, but also with more years lived free of disability from major disease, including cancer, cardiovascular disease, and diabetes. [308] Given the role that noncommunicable diseases play in productivity, absenteeism, and the economy more broadly, the World Health Organization has highlighted the health promotion potential that workplaces possess when deploying a comprehensive strategic and integrated approach to workplace health and wellness. [309]

Individuals learn and acquire experience through work, but work environments impact a person’s ability to perform, particularly through the relationships between work and mental and physical health. [310]

INCENTIVES CAN HAVE A MATERIAL IMPACT ON HEALTH BEHAVIORS, AND UTILIZE WELL-ESTABLISHED BEHAVIORAL SCIENCE AND BEHAVIORAL ECONOMIC PRINCIPLES

Incentives are central to economics and are used across the public and private sectors to influence behavior. There is literature that supports the impact and use of financial incentives to impact health behavior, and the employer is generally well-positioned to utilize these. [311] Thirumurthy, Asch and Volpp summarize the need for such incentives well, noting that: [312]

“If intrinsic motivations alone were enough to influence health behaviors, individuals would not smoke, all drivers would wear seat belts, and patients with chronic conditions would take their medications. Yet approximately half of patients prescribed single-drug therapy for hypertension discontinue their medications within a year, even though presumably they want to avoid strokes and hopefully know that taking their medication is one way to reduce health risks.”

Organizations can educate staff, help create healthy choice architectures (e.g. healthy canteen options and onsite exercise facilities), and to incentivize generally healthy habits with or without the assistance of effective wellness programs. [313] They can report on and measure improvements in employee health over time.

Table 3 below provides an overview of some of the interventions in the workplace.

Table 3
EXAMPLES OF WORKPLACE HEALTH INTERVENTIONS

| Risk Factor | Intervention |
|----------------------|---|
| Nutrition | Access to fruit and vegetables; [314] healthy canteens; [315] nutrition counseling; healthy food policies at meetings or employee events |
| Physical Activity | Workplace physical activity interventions, [316] including steps challenges, access to on-site gyms, and flexible work schedules to allow for physical activity during the day |
| Tobacco Cessation | Monetary incentives; [317] tobacco cessation programs; [318] tobacco-free workplace policies |
| BMI | Weight management programs; [319] employee health surveys with follow-up counseling; stress management programs; increased job control [320]; addressing long work hours; [321] healthy canteens [322] |
| Medication Adherence | Reduced copayment [323] |
| Screenings | Group discussions, outreach, and educational campaigns; [324,325] offering incentives; on-site screenings |
| Immunizations | Onsite vaccinations [326,327] and incentives [328] to receive immunizations; education campaigns; reminders |
| Mental Health | Implement primary, secondary, and tertiary work-related mental health interventions (including increasing employee control and promoting physical activity; stress management reduction programs; and cognitive behavioral therapy-based programs focused on the workplace, respectively) [329]; onsite physical activity and yoga; [330] subsidized counseling; host seminars; dedicated in-office quiet space for relaxation; offer health insurance with no or low out-of-pocket costs for depression medications and mental health counseling; allow employee participation in decisions on issues that affect job stress [331]; reduce work-related risk factors for mental health problems (job stress, work environment, etc.); develop worker strengths and positive aspects of work. [332] |
| Sleep | Educational programs, modifying workplace environmental characteristics such as lighting and screening, and referral for sleep disorder treatment; [333] dedicated breaks in schedule; napping rooms; reduction in acute and chronic stress; stress management programs. [219] |

With older Americans working longer than in previous generations, either through desire or necessity, employers will need to hone their understanding of how to effectively utilize a multigenerational workforce. This means

creating a welcoming workplace, devoid of ageism and accommodating of variations in workplace habits and consideration of health needs. The workplace remains an important setting for deploying services that facilitate health promotion given the prominence of the workplace in an adult's life. [334-336] While considerably more research needs to be conducted concerning the efficacy of workplace health promotion programs on older adults in particular, there is an emerging evidence base suggesting that positive outcomes can potentially be garnered through high-quality workplace interventions. [337]

The Role of Government in Influencing Healthy Lifestyles

Health and health choices are underpinned by issues of access, which hinge critically on government schemes. Questions around policy, equity, and individual empowerment all fall under government purview, which influences health through a variety of ways – including its role in funding clinical research, [338] using that research to inform national guidelines, [95] providing federal programming, performing public health surveillance [339,340] and creating evidence-based policy to help make communities healthier. [115,338] With 74 million U.S. adults projected to be over the age of 65 by 2030, the question around sound policies for this growing population is an area of great importance.

Federal programs like Medicare and Social Security serve as the foundational elements of health and wellbeing in later life in the U.S. Beyond these core programs exist opportunities for the government to continue to influence the health and wellbeing of older Americans. The National Prevention Council, which was created under the Affordable Care Act to serve as a central coordinating force for the various executive agencies focused on health, published the National Prevention Strategy in 2011. The National Prevention Strategy identified four Strategic Directions where the government can serve a critical role in facilitating healthy aging – health and safe community environments; clinical and community preventive services; empowered people; and elimination of health disparities. [182]

Health and Safe Community Environments focuses on increasing access to and the affordability of adaptable housing, creating more walkable communities, improving older driver safety, enhancing public transportation options, promoting access to healthy food, developing plans to address potential vulnerability to natural disasters, protecting against elder mistreatment, and recruiting and retaining a multidisciplinary workforce.

Clinical and Community Preventive Services seeks to increase access to preventive services, dental services and behavioral health care, developing falls prevention programs, training health care providers on age-related issues, expanding availability of home- and community-based services, and supporting caregivers.

Empowered People provides individuals with more information about healthy options, increasing access and use of technology to support health and other needs, creating opportunities for employment, education and volunteering activities, supporting and empowering informal caregivers to promote healthy aging, and combating ageism.

Elimination of Health Disparities educates professionals to identify and address disparities, collecting community-wide data to identify health care disparities, and distributing information and implementing programs that address age-related health issues.

Individuals retiring today can, on average, look forward to 19 further years of life. [341] A strong coalition of individuals, corporations, and governments can together work towards a goal that these years of life are not only extended over time, but that they are imbued with good health. This means expanding access to, building the evidence of, and broadly championing the best interventions and strategies to help individuals maximize their health span. In doing so, all stakeholders can potentially share in the value that is created. [182]

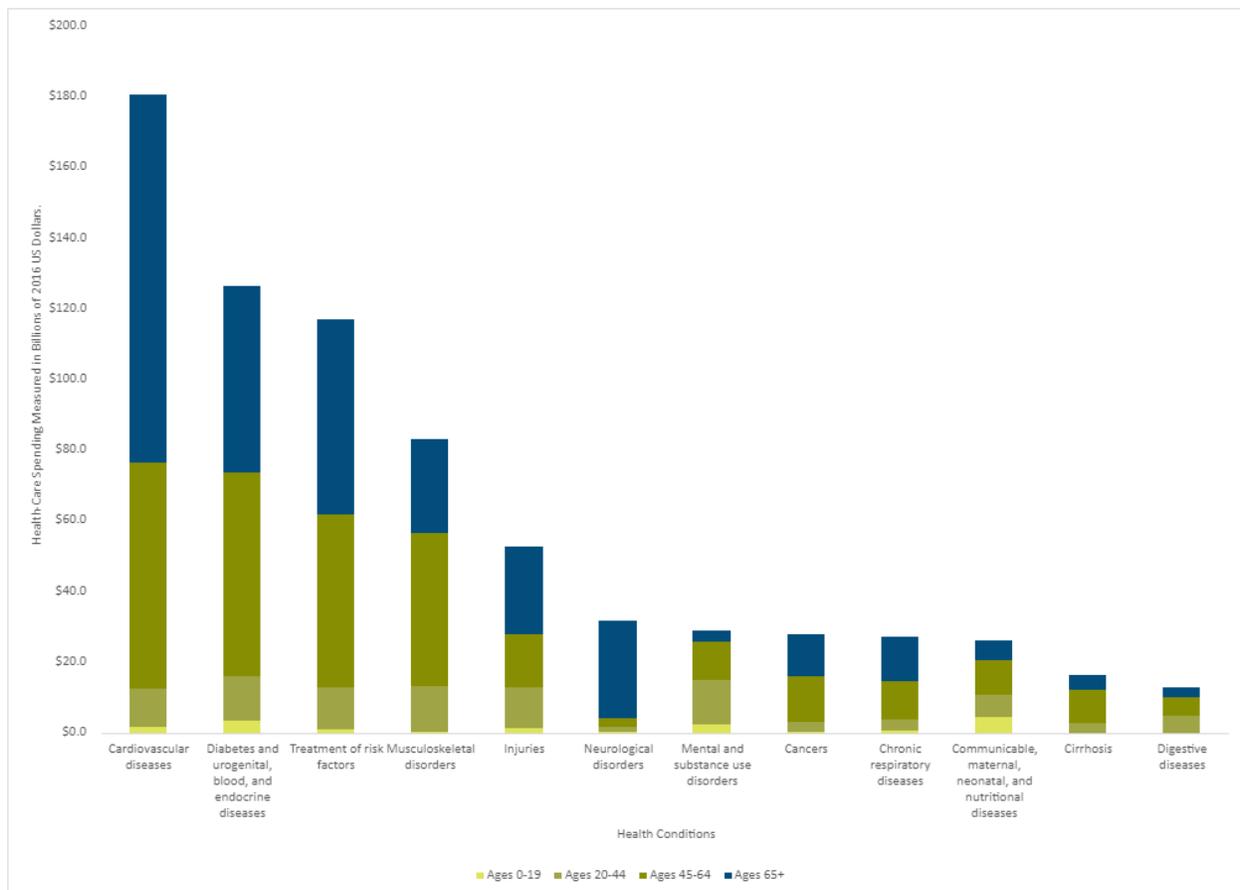
U.S. Health Care Costs Associated with Modifiable Behavior in Retirement

The cost implications of health on retirement are well known, but – until recently – the individual and combined effects of modifiable risk factors on health care spending have not received as much attention.

Utilizing the Global Burden of Diseases Studies, researchers found that in 2016 \$730.4 billion, or 27%, of U.S. health care spending was attributable to modifiable risk factors, which increases to 34.9% among those 65 years and older. [342] The attributable spend was centered around the five key risk areas discussed previously, namely: tobacco use, high body-mass index, high fasting plasma glucose, dietary risks, and high blood pressure, with attributable spend skewed heavily towards older adults, highlighting the importance of healthy lifestyle interventions to individuals, providers and payers. This framework provides a clear quantification of the health care costs associated with the improvement and management of health both prior to and following retirement. This then serves as a roadmap towards minimizing the cost burden of health on retirement.

Figure 7

ATTRIBUTABLE HEALTH SPENDING BY MEDICAL CONDITION AND AGE CATEGORY



Source: Bolnick HJ, Bui AL, Bulchis A, Chen C, Chapin A, Lomsadze L, et al. "Health-care spending attributable to modifiable risk factors in the USA: an economic attribution analysis." *Lancet*. 2020;5(10):e525–35. [342]

Whilst younger individuals comprise a smaller portion of the attributable health care spend, it is precisely during these earlier ages that lifestyle behaviors are cemented with material long-term health and cost implications. For older adults, a multi-pronged effort may be undertaken to help individuals measure, learn about, manage and mitigate risk. That is, individuals could have access to ongoing biometric measurement and, for those with elevated

risks, ready access could be provided to robust interventions that encourage them to improve their lifestyle. (If necessary, medication should be prescribed.)

Table 4

| | Ages 0-19 | Ages 20-44 | Ages 45-64 | Ages 65+ | Total |
|--|------------|------------|-------------|-------------|------------|
| Total Spending (in billions) | \$288.30 | \$564.00 | \$902.80 | \$950.40 | \$2,705.60 |
| Total Attributable Spending | \$14.70 | \$94.60 | \$289.00 | \$ 332.10 | \$730.40 |
| Attributable Spending as Percentage of Total | 5.1% | 16.8% | 32.0% | 34.9% | 27.0% |
| Spending per Capita | \$3,521.01 | \$5,333.79 | \$10,786.01 | \$19,988.64 | \$8,484.99 |
| Attributable Spending per Capita | \$179.53 | \$894.64 | \$3,452.77 | \$6,984.67 | \$2,290.60 |

Source: Bolnick HJ, Bui AL, Bulchis A, Chen C, Chapin A, Lomsadze L, et al. "Health-care spending attributable to modifiable risk factors in the USA: an economic attribution analysis." *Lancet*. 2020;5(10):e525–35. [342]

Potential Areas for Future Research

There is general recognition that the past is not necessarily a reliable indicator of the future, but it is a valuable starting point. In the case of healthy lifestyle in retirement, there is evidence on the causal relationships between the primary modifiable risks and health outcomes. Table 2 further highlights the need for additional evidence on emerging risk factors.

Similarly, while the solutions (interventions) seem simple on paper, they are challenging in practice, often seen through take-up or adherence rates. As such, the biggest gap in evidence does not relate to the risk factors, but rather the efficacy of interventions to address the primary and emerging risks. This is further complicated by the multifaceted nature of potential interventions ranging from public health and socioeconomic programs to individual decision making.

Furthermore, with the proliferation of technology, and increasing adoption amongst older adults, there is renewed opportunity for private entities and medical care providers to think about how best to engage, facilitate, and measure health and health improvements amongst older adults. This trend is of relevance to insurers as a mechanism with which to proactively measure and manage risk amongst their policyholders. [343]

An aging population comes with immense challenges around access, equity, and helping individuals not only lead a long life, but one imbued with good health. Ongoing research in this space continues with the goal that this growing segment of society is able to maximize their health span and, in so doing, lead a healthier life – ideally one filled with more purpose throughout their later years.

Healthy aging is a rich topic with an assortment of important research areas that the Society of Actuaries may consider further exploration to inform actuaries on these areas. This research report, focused on the existing literature in this space, is a first step towards future research. While there are myriad elements of healthy aging and many institutions with this topic on their research agendas, there may be projects that will benefit from an actuarial perspective. To stimulate discussion among Society of Actuaries staff and volunteers, a brief list of questions with material actuarial content include:

- What issues and challenges are there for leading a healthy lifestyle later in life, and how do they compare to earlier stages of retirement? How can people maintain a reasonable quality of life when they confront late in life health challenges?
- Which are the most effective causal relationships between healthy lifestyles and activities of daily living (ADLs)?
- The differences between life expectancy and healthy life expectancy are years lived in poor health. An important research question arises as to whether or not years lived in poor health have decreased with time (compression of morbidity). What are current trends in this health measure and what are the most effective tactics to enhance a compression of morbidity?
- How do lifestyle behavioral changes made prior to retirement impact the retirement period? Furthermore, what are the perceptions on health in retirement for individuals leading up to and during retirement?
- What are the natural limits on life expectancy and healthy life expectancy, and to what degree can modifiable behaviors drive improvements in both these regards?
- What is the role of genetic research on advancing healthy aging, including, but not limited to, genome sequencing amongst supercentenarians and gene-editing via CRISPR?
- The further exploration of social connectivity, both in form, function and impact.
- How quality of life may be improved for individuals with hearing, sight, mobility and cognitive decline, and how this decline may best be managed.
- The role of incentives and built environment on facilitating a healthy retirement.



Give us your feedback!

Take a short survey on this report.

[Click Here](#)

SOA
Research
INSTITUTE

Acknowledgments

The researchers extend their deepest gratitude to the Project Oversight Group, who generously offered their keen insights into the multiple facets of the robust healthy aging agenda. Furthermore, the researchers also thank the Society of Actuaries for seamlessly stewarding the research process and providing valuable feedback on drafts of the manuscript.

Project Oversight Group

Ian Duncan
Jeanne de Cervens
Kelly Moore
John O’Leary
Anna Rappaport
Bruce Stahl
Sandra Timmermann
Steve Vernon

Society of Actuaries

Achilles Natsis, Health Research Actuary
Barbara Scott, Senior Research Administrator
Steve Siegel, Senior Practice Research Actuary

References

- [1] N. St. Fleur, C. Williams and C. Wood, "Can We Live to 200?," *The New York Times*, 27 April 2021.
- [2] M. Mather, P. Scommegna and L. Kilduff, "Fact Sheet: Aging in the United States," Population Reference Bureau, Washington, D.C., 2019.
- [3] T. R. Frieden, "A Framework for Public Health Action: The Health Impact Pyramid," *American Journal of Public Health*, vol. 100, no. 4, pp. 590-595, 2010.
- [4] Institute for Health Metrics and Evaluation (IHME), "GBD Compare Data Visualization," IHME; University of Washington, Seattle, 2020.
- [5] GBD 2019 Risk Factors Collaborators, "Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019," *The Lancet*, vol. 396, no. 10258, pp. 1223-1249, 2020.
- [6] Institute for Health Metrics and Evaluation (IHME), "Tobacco Visualization," IHME, University of Washington, Seattle, 2017.
- [7] P. Jha, C. Ramasundarahettige, V. Landsman, B. Rostron, M. Thun, R. N. Anderson, T. McAfee and R. Peto, "21st-Century Hazards of Smoking and Benefits of Cessation in the United States," *The New England Journal of Medicine*, vol. 368, pp. 341-350, 2013.
- [8] S. H. Nash, L. M. Liao, T. B. Harris and N. D. Freedman, "Cigarette Smoking and Mortality in Adults Aged 70 Years and Older: Results From the NIH-AARP Cohort," *American Journal of Preventive Medicine*, vol. 52, no. 3, pp. 276-283, 2017.
- [9] T. Ostbye, D. H. Taylor and S.-H. Jung, "A Longitudinal Study of the Effects of Tobacco Smoking and Other Modifiable Risk Factors on Ill Health in Middle-Aged and Old Americans: Results from the Health and Retirement Study and Asset and Health Dynamics among the Oldest Old Survey," *Preventive Medicine*, vol. 34, no. 3, pp. 334-345, 2002.
- [10] A. Z. LaCroix and G. S. Omenn, "Older Adults and Smoking," *Clinics in Geriatric Medicine*, vol. 8, no. 1, pp. 69-88, 1992.
- [11] Y. Cao, S. Kenfield, Y. Song, B. Rosner, W. Qiu, H. D. Sesso, J. M. Gaziano and J. Ma, "Cigarette Smoking Cessation and Total and Cause-Specific Mortality: A 22-Year Follow-up Study Among US Male Physicians," *Archives of Internal Medicine*, vol. 171, no. 21, pp. 1959-1960, 2011.
- [12] D. H. Taylor, Jr., V. Hasselblad, S. J. Henley, M. J. Thun and F. A. Sloan, "Benefits of Smoking Cessation for Longevity," *American Journal of Public Health*, vol. 92, no. 6, pp. 990-996, 2002.
- [13] S. J. Henley, K. Asman, B. Momin, M. S. Gallaway, M. B. Culp, K. R. Ragan, T. B. Richards and S. Babb, "Smoking cessation behaviors among older U.S. adults," *Preventive Medicine Reports*, vol. 16, 2019.

- [14] Agency for Healthcare Research and Quality, "Clinical Guidelines and Recommendations: Older Smokers," Agency for Healthcare Research and Quality, Rockville, 2012.
- [15] F. A. van den Brand, G. E. Nagelhout, B. Winkens, N. H. Chavannes and O. C. P. van Schayck, "Effect of a workplace-based group training programme combined with financial incentives on smoking cessation: a cluster-randomised controlled trial," *The Lancet Public Health*, vol. 3, no. 11, pp. e536-e544, 2018.
- [16] P. DeCicca and L. McLeod, "Cigarette taxes and older adult smoking: Evidence from recent large tax increases," *Journal of Health Economics*, vol. 27, no. 4, pp. 918-929, 2008.
- [17] J. C. MacLean, A. S. Kessler and D. S. Kenkel, "Cigarette Taxes and Older Adult Smoking: Evidence from the Health and Retirement Study," *Health Economics*, vol. 25, no. 4, pp. 424-438, 2015.
- [18] V. Lemmens, A. Oenema, I. K. Knut and J. Brug, "Effectiveness of smoking cessation interventions among adults: a systematic review of reviews," *European Journal of Cancer Prevention*, vol. 17, no. 6, pp. 535-544, 2008.
- [19] U.S. Preventive Services Task Force, "Final Recommendation Statement: Interventions for Tobacco Smoking Cessation in Adults, Including Pregnant Persons," U.S. Preventive Services Task Force, Rockville, 2021.
- [20] U.S. Preventive Services Task Force, "Final Recommendation Statement: Lung Cancer Screening," U.S. Preventive Services Task Force, Rockville, 2021.
- [21] S. Babb, A. Malarcher, G. Schauer, K. Asman and A. Jamal, "Quitting Smoking Among Adults - United States, 2000-2015.," *MMWR Morbidity and Mortality Weekly Report*, vol. 65, no. 52, pp. 1457-1464, 2017.
- [22] A. Jamal, B. A. King, L. J. Neff, J. Whitmill, S. D. Babb and C. M. Graffunder, "Current Cigarette Smoking Among Adults - United States, 2005 - 2015," *Morbidity and Mortality Weekly Report (MMWR)*, vol. 65, no. 44, 2016.
- [23] M. Gajewski, "Visions for the future: Quitting smoking," *Cancer Research UK*, 10 March 2015.
- [24] Global Burden of Disease Collaborative Network, "Global Burden of Disease Study 2015 (GBD 2015): Obesity and Overweight Prevalence 1980-2015," Institute for Health Metrics and Evaluation (IHME), Seattle, 2017.
- [25] Centers for Disease Control and Prevention, "Adult Obesity Facts," 2021.
- [26] K. M. Flegal, M. D. Carroll, C. L. Ogden and C. L. Johnson, "Prevalence and Trends in Obesity Among US Adults, 1999-2000," *JAMA*, vol. 288, no. 14, pp. 1723-1727, 2002.
- [27] D. Aune, A. Sen, M. Prasad, T. Norat, I. Janszky, S. Tonstad, P. Romundstad and L. J. Vatten, "BMI and all cause mortality: systematic review and non-linear dose-response meta-analysis of 230 cohort studies with 3.74 million deaths among 30.3 million participants," *BMJ*, vol. 353, no. i2156, 2016.
- [28] G. Whitlock, S. Lewington, P. Sherliker, R. Clarke, J. Emberson, J. Halsey, N. Qizilbash, R. Collins and R. Peto, "Body-mass index and cause-specific mortality in 900,000 adults: collaborative analyses of 57 prospective studies," *Lancet*, vol. 373, no. 9669, pp. 1083-1096, 2009.
- [29] A. Berrington de Gonzalez, P. Hartge, J. R. Cerhan, A. J. Flint, L. Hannan, R. J. MacInnis, S. C. Moore, G. S. Tobias, H. Anton-Culver, L. B. Freeman, W. L. Beeson, S. L. Clipp, D. R. English, A. R. Folsom, D. M. Freedman,

- G. Giles, N. Hakansson, K. D. Henderson, J. Hoffman-Bolton, J. A. Hoppin, K. L. Koenig, I. M. Lee, M. S. Linet, Y. Park, G. Pocobelli, A. Schatzkin, H. D. Sesso, E. Weiderpass, B. J. Willcox, A. Wolk, A. Zeleniuch-Jacquotte, W. C. Willett and M. J. Thun, "Body-mass index and mortality among 1.46 million white adults," *New England Journal of Medicine*, vol. 363, no. 23, pp. 2211-2219, 2010.
- [30] D. W. Haslam and W. P. James, "Obesity," *Lancet*, vol. 366, no. 9492, pp. 1197-1209, 2005.
- [31] K. Bhaskaran, I. dos-Santos-Silva, D. A. Leon, I. J. Douglas and L. Smeeth, "Association of BMI with overall and cause-specific mortality: a population-based cohort study of 3.6 million adults in the UK," *The Lancet Diabetes & Endocrinology*, vol. 6, no. 12, pp. 944-953, 2018.
- [32] K. R. Fontaine, D. T. Redden, C. Wang, A. O. Westfall and D. B. Allison, "Years of life lost due to obesity," *JAMA*, vol. 289, no. 2, pp. 187-193, 2003.
- [33] A. Kingston, J. Byles, K. Kiely, K. Anstey and C. Jagger, "The impact of smoking and obesity on disability-free life expectancy in older Australians," *The Journals of Gerontology: Series A*, no. glaa290, 2020.
- [34] US Preventive Services Task Force, "Behavioral Weight Loss Interventions to Prevent Obesity-Related Morbidity and Mortality in Adults: US Preventive Services Task Force Recommendation Statement," *JAMA*, vol. 320, no. 11, pp. 1163-1171, 2018.
- [35] W. C. Miller, D. M. Kocaja and E. J. Hamilton, "A meta-analysis of the past 25 years of weight loss research using diet, exercise or diet plus exercise intervention," *International Journal of Obesity-related Metabolic Disorders*, vol. 21, no. 10, pp. 941-947, 1997.
- [36] J. A. Batsis, L. E. Gill, R. K. Masutani, A. M. Adachi-Mejia, H. B. Blunt, P. J. Bagley, F. Lopez-Jimenez and S. J. Bartels, "Weight Loss Interventions in Older Adults with Obesity: A Systematic Review of Randomized Controlled Trials Since 2005," *Journal of the American Geriatric Society*, vol. 65, no. 2, pp. 257-268, 2017.
- [37] Centers for Disease Control and Prevention, "Why is physical activity important?," 2020.
- [38] C. E. Cox, "Role of Physical Activity for Weight Loss and Weight Maintenance," *Diabetes Spectrum*, vol. 30, no. 3, pp. 157-160, 2017.
- [39] S. B. Kritchevsky, K. M. Beavers, M. E. Miller, M. K. Shea, D. K. Houston, D. W. Kitzman and B. J. Nicklas, "Intentional weight loss and all-cause mortality: a meta-analysis of randomized clinical trials," *PLoS One*, vol. 10, no. 3, 2015.
- [40] L. Sjostrom, K. Narbro, D. Sjostrom, K. Karason, B. Larrson, H. Wedel, T. Lystig, M. Sullivan, C. Bouchard, B. Carlsson, C. Bengtsson, S. Dahlgren, A. Gummesson, P. Jacobson, J. Karlsson, A. K. Lindroos, H. Lonroth, I. Naslund, T. Olbers, K. Stenlof, J. Torgerson, G. Agren, L. M. Crlsson and Swedish Obese Subjects Study, "Effects of bariatric surgery on mortality in Swedish obese subjects," *New England Journal of Medicine*, vol. 357, no. 8, pp. 741-752, 2007.
- [41] T. D. Adams, R. E. Gress, S. C. Smith, R. C. Halverson, S. C. Simper, W. D. Rosamond, M. J. Lamonte, A. M. Stroup and S. C. Hunt, "Long-term mortality after gastric bypass surgery," *New England Journal of Medicine*, vol. 357, no. 8, pp. 753-761, 2007.

- [42] D. R. Flum and E. P. Dellinger, "Impact of gastric bypass operation on survival: a population-based analysis," *Journal of the American College of Surgeons*, vol. 199, no. 4, pp. 543-551, 2004.
- [43] T. A. Wadden, J. P. Foreyt, G. D. Foster, J. O. Hill, S. Klein, P. M. O'Neil, M. G. Perri, F. X. Pi-Sunyer, C. L. Rock, J. S. Erickson, H. N. Maier, D. D. Kim and E. Dunayevich, "Weight Loss with Naltrexone SR/Bupropion SR Combination Therapy as an Adjunct to Behavior Modification: The COR-BMOD Trial," *Obesity*, vol. 19, no. 1, pp. 110-120, 2011.
- [44] G. A. Bray, P. Hollander, S. Klein, R. Kushner, B. Levy, M. Fitchet and B. H. Perry, "A 6-Month Randomized, Placebo-Controlled, Dose-Ranging Trial of Topiramate for Weight Loss in Obesity," *Obesity*, vol. 11, no. 6, pp. 722-733, 2003.
- [45] A. S. Ryan, "Exercise in aging: its important role in mortality, obesity and insulin resistance," *Aging & Health*, vol. 6, no. 5, pp. 551-563, 2010.
- [46] J. A. Batsis and A. B. Zagaria, "Addressing Obesity in Aging Patients," *Medical Clinics of North America*, vol. 102, no. 1, pp. 65-85, 2018.
- [47] J. E. Winter, R. J. MacInnis, N. Wattanapenpaiboon and C. A. Nowson, "BMI and all-cause mortality in older adults: a meta-analysis," *The American Journal of Clinical Nutrition*, vol. 99, no. 4, pp. 875-890, 2014.
- [48] J. A. Batsis, T. A. Mackenzie, S. J. Bartels, K. R. Sahakyan, V. K. Somers and F. Lopez-Jimenez, "Diagnostic Accuracy of Body Mass Index to Identify Obesity in Older Adults: NHANES 1999-2004," *International Journal of Obesity (London)*, vol. 40, no. 5, pp. 761-767, 2016.
- [49] K. J. Rothman, "BMI-related errors in the measurement of obesity," *Internal Journal of Obesity (London)*, vol. 32, no. 3, pp. S56-59, 2008.
- [50] A. Heiat, V. Vaccarino and H. Krumholz, "An Evidence-Based Assessment of Federal Guidelines for Overweight and Obesity as They Apply to Elderly Persons," *Archives of Internal Medicine*, vol. 161, no. 9, pp. 1194-1203, 2001.
- [51] I. Janssen, "Morbidity and Mortality Risk Associated with an Overweight BMI in Older Men and Women," *Obesity*, vol. 15, no. 7, pp. 1827-1840, 2007.
- [52] E. A. O'Connor, C. V. Evans, M. C. Rushkin, N. Redmond and J. S. Lin, "Behavioral Counseling to Promote a Healthy Diet and Physical Activity for Cardiovascular Disease Prevention in Adults with Cardiovascular Risk Factors: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force," *JAMA*, vol. 324, no. 20, pp. 2076-2094, 2020.
- [53] National Heart, Lung and Blood Institute, "Metabolic Syndrome".
- [54] A. B. Neiman, T. Ruppert, M. Ho, L. Garber, P. J. Weidle, Y. Hong, M. G. George and P. G. Thorpe, "CDC Grand Rounds: Improving Medication Adherence for Chronic Disease Management - Innovations and Opportunities," *Morbidity and Mortality Weekly Report (MMWR)*, vol. 66, no. 45, pp. 1248-1251, 2017.
- [55] M. C. Sokol, K. A. McGuigan, R. R. Verbrugge and R. S. Epstein, "Impact of medication adherence on hospitalization risk and healthcare cost," *Medical Care*, vol. 43, no. 6, pp. 521-530, 2005.

- [56] J. A. Cramer, "A systematic review of adherence with medications for diabetes," *Diabetes Care*, vol. 27, no. 5, pp. 1218-1224, 2004.
- [57] J. A. Cramer, A. Benedict, N. Muszbek, A. Keskinaslan and Z. M. Khan, "The significance of compliance and persistence in the treatment of diabetes, hypertension and dyslipidaemia: a review," *International Journal of Clinical Practice*, vol. 62, no. 1, pp. 76-87, 2008.
- [58] R. L. Kravitz and J. Melnikow, "Medical Adherence Research: Time for a Change in Direction?," *Medical Care*, vol. 42, no. 3, pp. 197-199, 2004.
- [59] Q. Yang, A. Chang, M. D. Ritchey and F. Loustalot, "Antihypertensive Medication Adherence and Risk of Cardiovascular Disease Among Older Adults: A Population-Based Cohort Study," *Journal of the American Heart Association*, vol. 6, 2017.
- [60] K. Capoccia, P. S. Odegard and N. Letassy, "Medication Adherence with Diabetes Medication: A Systematic Review of the Literature," *The Diabetes Educator*, vol. 42, no. 1, pp. 34-71, 2015.
- [61] B. Kocurek, "Promoting Medication Adherence in Older Adults ... and the Rest of Us," *Diabetes Spectrum*, vol. 22, no. 2, pp. 80-84, 2009.
- [62] U.S. Preventive Services Task Force, "Screening for High Blood Pressure in Adults: U.S. Preventive Services Task Force Recommendation Statement," *Annals of Internal Medicine*, vol. 163, pp. 778-786, 2015.
- [63] P. K. Whelton, R. M. Carey and W. S. Aronow, "2017 Guideline for the Prevention, Detection, Evaluation and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines," *Journal of the American College of Cardiology*, vol. 71, pp. e127-e248, 2018.
- [64] U.S. Preventive Services Task Force, "Screening for Abnormal Blood Glucose and Type 2 Diabetes Mellitus: U.S. Preventive Services Task Force Recommendation Statement," *Annals of Internal Medicine*, vol. 163, pp. 861-868, 2015.
- [65] American Diabetes Association, "Pharmacologic Approaches to Glycemic Treatment: Standards of Medical Care in Diabetes - 2021," *Diabetes Care*, vol. 44, pp. S111-S124, 2021.
- [66] American Diabetes Association, "Older Adults: Standard of Medical Care in Diabetes - 2021," *Diabetes Care*, vol. 44, pp. S168-S179, 2021.
- [67] M. T. Brown and J. K. Bussell, "Medication Adherence: WHO Cares?," *Mayo Clinic Proceedings*, vol. 86, no. 4, pp. 304-314, 2011.
- [68] N. L. Campbell, M. A. Boustani, E. N. Skopelja, S. Gao, F. W. Unverzagt and M. D. Murray, "Medication Adherence in Older Adults with Cognitive Impairment: A Systematic Evidence-Based Review," *The American Journal of Geriatric Pharmacotherapy*, vol. 10, no. 3, pp. 165-177, 2012.
- [69] M. E. Chernew, M. R. Shah, A. Wegh, S. N. Rosenberg, I. A. Juster, A. B. Rosen, M. C. Sokol, K. Yu-Isenberg and A. M. Fendrick, "Impact of Decreasing Copayments on Medication Adherence Within a Disease Management Environment," *Health Affairs*, vol. 27, no. 1, 2006.

- [70] V. S. Conn and T. M. Ruppap, "Medication adherence outcomes of 771 intervention trials: Systematic review and meta-analysis," *Preventive Medicine*, vol. 99, pp. 269-276, 2017.
- [71] T. T. Fung, S. E. Chiuve, M. L. McCullough, K. M. Rexrode, G. Logroscino and F. B. Hu, "Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women," *Archives of Internal Medicine*, vol. 168, no. 7, pp. 713-720, 2008.
- [72] P. N. Mitrou, V. Kipnis, A. C. Thiebaut, J. Reedy, A. F. Subar, E. Wirfalt, A. Flood, T. Mouw, A. R. Hollenbeck, M. F. Leitzmann and A. Schatzkin, "Mediterranean dietary pattern and prediction of all-cause mortality in a US population: results from the NIH-AARP Diet and Health Study," *Archives of Internal Medicine*, vol. 167, no. 22, pp. 2461-2468, 2007.
- [73] A. Trichopoulou, C. Bamia and D. Trichopoulos, "Mediterranean diet and survival among patients with coronary heart disease in Greece," *Archives of Internal Medicine*, vol. 165, no. 8, pp. 929-935, 2005.
- [74] N. Graudal, G. Jurgens, B. Baslund and M. H. Alderman, "Compared with usual sodium intake, low- and excessive-sodium diets are associated with increased mortality: a meta-analysis," *American Journal of Hypertension*, vol. 27, no. 9, pp. 1129-1137, 2014.
- [75] M. O'Donnell, A. Mente, S. Rangarajan, M. J. McQueen, X. Wang, L. Liu, H. Yan, S. F. Lee, P. Mony, A. Devanath, A. Rosengren, P. Lopez-Jaramillo, R. Diaz, A. Avezum, F. Lanas, K. Yusoff, R. Iqbal, R. Ilow, N. Mohammadifard, S. Gulec, A. H. Yusufali, L. Kruger, R. Yusuf, J. Chifamba, C. Kabali, G. Dagenais, S. A. Lear, K. Teo and S. Yusuf, "Urinary Sodium and Potassium Excretion, Mortality and Cardiovascular Events," *The New England Journal of Medicine*, vol. 371, pp. 612-623, 2014.
- [76] M. Bernstein and N. Munoz, "Position of the Academy of Nutrition and Dietetics: Food and Nutrition for Older Adults: Promoting Health and Wellness," *Journal of the Academy of Nutrition and Dietetics*, vol. 112, no. 8, pp. 1255-1277, 2012.
- [77] J. Shlisky, D. E. Bloom, A. R. Beaudreault, K. L. Tucker, H. H. Keller, Y. Freund-Levi, R. A. Fielding, F. W. Cheng, G. L. Jensen, D. Wu and S. N. Meydani, "Nutritional Considerations for Healthy Aging and Reduction in Age-Related Chronic Disease," *Advances in Nutrition*, vol. 8, no. 1, pp. 17-26, 2017.
- [78] K. T. Knuops, L. C. de Groot, D. Kromhout, A.-E. Perrin, O. Moreiras-Varela, A. Menotti and W. A. van Staveren, "Mediterranean diet, lifestyle factors, and 10-year mortality in elderly European men and women: the HALE project," *JAMA*, vol. 292, no. 12, pp. 1433-1439, 2004.
- [79] J. Zheng, R. Zhou, F. Li, L. Chen, K. Wu, J. Huang, H. Liu, Z. Huang, L. Xu, Z. Yuan, C. Mao and X. Wu, "Association between dietary diversity and cognitive impairment among the oldest-old: Findings from a nationwide cohort study," *Clinical Nutrition*, vol. 40, no. 4, pp. 1452-1462, 2021.
- [80] X. Zhou, F. J. Perez-Cueto, Q. Dos Santos, E. Monteleone, A. Giboreau, K. M. Appleton, T. Bjorner, W. L. Bredie and H. Hartwell, "A Systematic Review of Behavioural Interventions Promoting Healthy Eating among Older People," *Nutrients*, vol. 10, no. 2, 2018.
- [81] P. Agarwal, K. Dhana, L. L. Barnes, T. M. Holland, Y. Zhang, D. A. Evans and M. C. Morris, "Unhealthy foods may attenuate the beneficial relation of a Mediterranean diet to cognitive decline," *Alzheimer's & Dementia*, 2021.

- [82] B. S. Klinedinst, S. T. Le, B. Larsen, C. Pappas, N. J. Hoth, A. Pollpeter, Q. Wang, Y. Wang, S. Yu, L. Wang, K. Allenspach, J. P. Mochel, D. A. Bennett and A. A. Willette, "Genetic Factors of Alzheimer's Disease Modulate How Diet is Associated with Long-Term Cognitive Trajectories: A UK Biobank Study," *Journal of Alzheimer's Disease*, vol. 78, no. 3, pp. 1245-1257, 2020.
- [83] G. J. Goodwin, "Social, psychological and physical factors affecting the nutritional status of elderly subjects: separating cause and effect," *American Journal of Clinical Nutrition*, vol. 50, pp. 1201-1209, 1989.
- [84] J. Blumberg, "Nutrition needs of seniors," *Journal of the American College of Nutrition*, vol. 16, pp. 517-523, 1997.
- [85] F. Ott, T. Readman and C. Backman, "Mealtimes of the institutional elderly: a literature review," *Canadian Journal of Occupational Therapy*, vol. 57, pp. 261-267, 1990.
- [86] S. L. Silverman and A. Cranney, "Quality-of-life measurement in osteoporosis," *Journal of Rheumatology*, vol. 24, pp. 1218-1221, 1997.
- [87] I. Groenendijk, L. den Boeft, L. J. van Loon and L. C. de Groot, "High Versus Low Dietary Protein Intake and Bone Health in Older Adults: a Systematic Review and Meta-Analysis," *Computational and Structural Biotechnology Journal*, vol. 17, pp. 1101-1112, 2019.
- [88] E. Laird, A. M. Molloy, H. McNulty, M. Ward, K. McCarroll, L. Hoey, C. F. Hughes, C. Cunningham, J. J. Strain and M. C. Casey, "Greater yogurt consumption is associated with increased bone mineral density and physical function in older adults," *Osteoporosis International*, vol. 28, pp. 2409-2419, 2017.
- [89] M. C. Savanelli, L. Barrea, P. E. Macchia, S. Savastano, A. Falco, A. Renzullo, E. Scarano, I. C. Nettore, A. Colao and C. Di Somma, "Preliminary results demonstrating the impact of Mediterranean diet on bone health," *Journal of Translational Medicine*, vol. 15, 2017.
- [90] P. K. K. Wong, J. J. Christie and J. D. Wark, "The effects of smoking on bone health," *Clinical Science (London)*, vol. 113, no. 5, pp. 233-241, 2007.
- [91] M. Locquet, C. Beaudart, O. Bruyere, J. A. Kanis, L. Delandsheere and J. Y. Reginster, "Bone health assessment in older people with or without muscle health impairment," *Osteoporosis International*, vol. 29, pp. 1057-1067, 2018.
- [92] E. Amarantos, A. Martinez and J. Dwyer, "Nutrition and Quality of Life in Older Adults," *Journals of Gerontology: Series A*, vol. 56A, no. Special Issues II, pp. 54-64, 2001.
- [93] U.S. Department of Agriculture and U.S. Department of Health and Human Services, "Dietary Guidelines for Americans, 2020-2025. 9th Edition," 2020.
- [94] C. A. Zizza, K. J. Ellison and C. M. Wernette, "Total Water Intakes of Community-Living Middle-Old and Oldest-Old Adults," *The Journals of Gerontology: Series A*, vol. 64A, no. 4, pp. 481-486, 2009.
- [95] U.S. Department of Health and Human Services and U.S. Department of Agriculture, "Dietary Guidelines for Americans 2020-2025," U.S. Department of Health and Human Services and U.S. Department of Agriculture, Washington, D.C., 2021.

- [96] A. Miller and N. Steinle, "Barriers to Healthy Eating in the Elderly; a National and Global Perspective," *Journal of Human Nutrition & Food Science*, vol. 8, no. 1, 2020.
- [97] M. Eggersdorfer, U. Akobundu, R. L. Bailey, J. Shlisky, A. R. Beaudreault, G. Bergeron, R. B. Blancato, J. B. Blumberg, M. W. Bourassa, F. Gomes, G. Jensen, M. A. Johnson, D. Mackay, K. Marshall, S. N. Meydani and K. L. Tucker, "Hidden Hunger: Solutions for America's Aging Populations," *Nutrients*, vol. 10, no. 9, 2018.
- [98] Meals on Wheels America, "Meals on Wheels America," 2021. [Online]. Available: <https://www.mealsonwheelsamerica.org/>. [Accessed 27 April 2021].
- [99] Deloitte, "Future of Food: personalised, responsible and healthy".
- [100] Centers for Disease Control and Prevention, "Adults Need More Physical Activity," 2019.
- [101] H. H. Kyu, V. F. Bachman, L. T. Alexander, J. E. Mumford, A. Afshin, K. Estep, J. L. Veerman, K. Delwiche, M. L. Iannarone, M. L. Moyer, K. Cercy, T. Vos, C. J. Murray and M. H. Forouzanfar, "Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013," *BMJ*, vol. 354, 2016.
- [102] W. J. Chodzko-Zajko, D. N. Proctor, M. A. F. Singh, C. T. Minson, C. R. Nigg, G. J. Salem and J. S. Skinner, "Exercise and Physical Activity for Older Adults: American College of Sports Medicine Position Stand," *Medicine and Science in Sports & Exercise*, vol. 41, no. 7, pp. 1510-1530, 2009.
- [103] D. I. Miller, V. Taler, P. S. Davidson and C. Messier, "Measuring the impact of exercise on cognitive aging: methodological issues," *Neurobiology of Aging*, vol. 33, pp. e29-43, 2012.
- [104] M. Snowden, L. Steinman, K. Mochan, F. Grodstein, T. R. Prohaska, D. J. Thurman, D. R. Brown, J. N. Laditka, J. Soares, D. J. Zweiback, D. Little and L. A. Anderson, "Effect of exercise on cognitive performance in community-dwelling older adults: review of intervention trials and recommendations for public health practice and research," *Journal of the American Geriatric Society*, vol. 59, no. 4, pp. 704-716, 2011.
- [105] Centers for Disease Control and Prevention, "Physical Activity for Arthritis," 2018.
- [106] V. Gremeaux, M. Gayda, R. Lepers, P. Sosner, M. Juneau and A. Nigam, "Exercise and longevity.," *Maturitas*, vol. 73, no. 4, pp. 312-317, 2012.
- [107] M. Angevaren, G. Aufdemkampe, J. Verhaar, A. Aleman and L. Vanhees, "Physical activity and enhanced fitness to improve cognitive function in older people without known cognitive impairment," *Cochrane Database Systematic Reviews*, vol. 2, 2008.
- [108] A. Yemiscigil and I. Vlaev, "The bidirectional relationship between sense of purpose in life and physical activity: a longitudinal study," *Journal of Behavioral Medicine*, 2021.
- [109] E. Fuzeki, T. Engeroff and W. Banzer, "Health Benefits of Light-Intensity Physical Activity: A Systematic Review of Accelerometer Data of the National Health and Nutrition Examination Survey (NHANES)," *Sports Medicine*, vol. 47, pp. 1769-1793, 2017.

- [110] K. L. Piercy, R. P. Troiano, R. M. Ballard, S. A. Carlson, J. E. Fulton, D. A. Gulaska, S. M. George and R. D. Olson, "The Physical Activity Guidelines for Americans," *JAMA*, vol. 320, no. 19, pp. 2020-2028, 2018.
- [111] P. G. Lee, E. A. Jackson and C. R. Richardson, "Exercise Prescriptions in Older Adults," *American Family Physician*, vol. 95, no. 7, pp. 425-432, 2017.
- [112] National Council on Aging, "Exercise Programs That Promote Senior Fitness," *National Council on Aging*, 1 January 2021.
- [113] N. A. Cavill and C. E. M. Foster, "Enablers and barriers to older people's participation in strength and balance activities: A review of reviews," *Journal of Frailty, Sarcopenia and Falls*, vol. 3, no. 2, pp. 105-113, 2018.
- [114] J. M. Heath and M. R. Stuart, "Prescribing Exercise for Frail Elders," *Journal of the American Board of Family Practitioners*, vol. 15, pp. 218-228, 2002.
- [115] U.S. Department of Health and Human Services, "Physical Activity Guidelines for Americans, 2nd edition," U.S. Department of Health and Human Services, Washington, DC, 2018.
- [116] C. K. Blair, M. C. Morey, R. A. Desmond, H. J. Cohen, R. Sloane, D. C. Snyder and W. Demark-Wahnefried, "Light-Intensity Activity Attenuates Functional Decline in Older Cancer Survivors," *Medical Science & Sports Exercise*, vol. 46, no. 7, pp. 1375-1383, 2014.
- [117] Physical Activity Guidelines Advisory Committee., "Physical Activity Guidelines Advisory Committee Report," U.S. Department of Health and Human Services, Washington, DC, 2008.
- [118] M. Rasinaho, M. Hirvensalo, R. Leinonen, T. Lintunen and T. Rantanen, "Motives for and Barriers to Physical Activity among Older Adults with Mobility Limitations," *Journal of Aging and Physical Activity*, vol. 15, no. 1, pp. 90-102, 2007.
- [119] P. M. Gray, M. H. Murphy, A. M. Gallagher and E. E. Simpson, "Motives and Barriers to Physical Activity Among older Adults of Different Socioeconomic Status," *Journal of Aging and Physical Activity*, vol. 24, no. 3, pp. 419-429, 2016.
- [120] Centers for Disease Control and Prevention, "Overcoming Barriers to Physical Activity," 2020.
- [121] V. Baert, E. Gorus, T. Mets and I. Bautmans, "Motivators and Barriers for Physical Activity in Older Adults with Osteoporosis," *Journal of Geriatric Physical Therapy*, vol. 38, no. 3, pp. 105-114, 2015.
- [122] B. H. Marcus, D. M. Williams, P. M. Dubbert, J. F. Sallis, A. C. King, A. K. Yancey, B. A. Franklin, D. Buchner, S. R. Daniels and R. P. Claytor, "Physical Activity Intervention Studies. What We Know and What We Need to Know: A Scientific Statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism," *Circulation*, vol. 114, no. 24, 2006.
- [123] V. S. Conn, J. C. Valentine and H. M. Cooper, "Interventions to increase physical activity among aging adults: a meta-analysis," *Annals of Behavioral Medicine*, vol. 24, no. 3, pp. 190-200, 2002.
- [124] R. K. Dishman and J. Buckworth, "Increasing physical activity: a quantitative synthesis," *Medicine & Science in Sports & Exercise*, vol. 28, no. 6, pp. 706-719, 1996.

- [125] A. C. King, "Interventions to Promote Physical Activity by Older Adults," *The Journals of Gerontology: Series A*, vol. 56, pp. 36-46, 2001.
- [126] V. S. Conn, A. R. Hafdahl and D. R. Mehr, "Interventions to Increase Physical Activity Among Healthy Adults: Meta-Analysis of Outcomes," *American Journal of Public Health*, vol. 101, no. 4, pp. 751-758, 2011.
- [127] N. O'Brien, S. McDonald, V. Araujo-Soares, J. Lara, L. Errington, A. Godfrey, T. D. Meyer, L. Rochester, J. C. Mathers, M. White and F. F. Sniehotta, "The features of interventions associated with long-term effectiveness of physical activity interventions in adults aged 55-70 years: a systematic review and meta-analysis," *Health Psychology Review*, vol. 9, no. 4, pp. 417-433, 2015.
- [128] D. P. French, E. K. Olander, A. Chisholm and J. McSharry, "Which behavior change techniques are most effective at increasing older adults' self-efficacy and physical activity behavior? A systematic review," *Annals of Behavioral Medicine*, vol. 48, no. 2, pp. 225-234, 2014.
- [129] C. J. Atkins, R. M. Kaplan, R. M. Timms, S. Resinch and K. Lofback, "Behavioral exercise programs in the management of chronic obstructive pulmonary disease," *Journal of Consulting and Clinical Psychology*, vol. 52, no. 4, pp. 591-603, 1984.
- [130] V. S. Conn, A. R. Hafdahl, S. A. Brown and L. M. Brown, "Meta-Analysis of Patient Education Interventions to Increase Physical Activity among Chronically Ill Adults," *Patient Education and Counseling*, vol. 70, no. 2, pp. 157-172, 2008.
- [131] A. Zubala, S. MacGillivray, H. Frost, T. Kroll, D. A. Skelton, A. Gavine, N. M. Gray, M. Toma and J. Morris, "Promotion of physical activity interventions for community dwelling older adults: A systematic review of reviews," *PLoS One*, vol. 12, no. 7, 2017.
- [132] M. M. van Stralen, H. De Vries, A. N. Mudde, C. Bolman and L. Lechner, "Determinants of initiation and maintenance of physical activity among older adults: a literature review," *Health Psychology Review*, vol. 3, no. 2, pp. 147-207, 2009.
- [133] M. R. Franco, A. Tong, K. Howard, C. Sherrington, P. H. Ferreira, R. Z. Pinto and M. L. Ferreira, "Older people's perspectives on participation in physical activity: a systematic review and thematic synthesis of qualitative literature," *British Journal of Sports Medicine*, vol. 49, pp. 1268-1276, 2015.
- [134] Deloitte Insights, "Are consumers already living the future of health? Findings from the Deloitte 2020 Survey of US Health Care Consumers," Deloitte, 2021.
- [135] A. Kononova, L. Li, K. Kamp, M. Bowen, R. V. Rikard, S. Cotten and W. Peng, "The Use of Wearable Activity Trackers Among Older Adults: Focus Group Study of Tracker Perceptions, Motivators, and Barriers in the Maintenance Stage of Behavior Change," *JMIR Mhealth and UHealth*, vol. 7, no. 4, 2019.
- [136] S. Rivera-Torres, T. D. Fahey and M. A. Rivera, "Adherence to Exercise Programs in Older Adults: Informative Report," *Gerontology and Geriatric Medicine*, vol. 5, 2019.
- [137] C. Farrance, F. Tsofliou and C. Clark, "Adherence to community based group exercise interventions for older people: A mixed-methods systematic review," *Preventive Medicine*, vol. 87, pp. 155-166, 2016.

- [138] U.S. Cancer Statistics Working Group, "U.S. Cancer Statistics Data Visualization Tool, based on 2019 submission data (1999-2017)," U.S. Department of Health and Human Services, Centers for Disease Control and Prevention and National Cancer Institute, 2020.
- [139] U.S. Preventive Services Task Force, "Final Recommendation Statement: Breast Cancer Screening," 2016.
- [140] U.S. Preventive Services Task Force, "Final Recommendation Statement: Cervical Cancer: Screening," U.S. Preventive Services Task Force, Rockville, 2018.
- [141] U.S. Preventive Services Task Force, "Final Recommendation Statement: Screening for Colorectal Cancer," U.S. Preventive Services Task Force, Rockville, 2021.
- [142] S. A. Sabatino, T. D. Thompson, M. C. White, J. A. Shapiro, J. de Moor, V. P. Doria-Rose, T. Clarke and L. C. Richardson, "Cancer Screening Test Receipt - United States, 2018," *Morbidity and Mortality Weekly Report (MMWR)*, vol. 70, no. 2, pp. 29-35, 2021.
- [143] S. C. Nolen, M. A. Evans, A. Fischer, M. M. Corrada, C. H. Kawas and D. A. Bota, "Cancer - Incidence, Prevalence and Mortality in the Oldest-Old: A Comprehensive Review," *Mechanisms of Ageing and Development*, vol. 164, pp. 113-126, 2017.
- [144] B. Di Capua, A. Bellieni, D. Fusco, M. A. Gambacorta, L. Tagliaferri, E. R. Villani, R. Bernabei, V. Valentini and G. F. Colloca, "Perspectives and limits of cancer treatment in an oldest old population," *Ageing, Clinical and Experimental Research*, 2021.
- [145] A. Sitlinger and S. Y. Zafar, "Health-Related Quality of Life: The Impact on Morbidity and Mortality," *Surgical Oncology Clinics of North America*, vol. 27, no. 4, pp. 675-684, 2018.
- [146] M. Delgado-Guay, J. Ferrer, A. G. Rieber, W. Rhondali, S. Tayjasanant, J. Ochoa, H. Cantu, G. Chisholm, J. Williams, S. Frisbee-Hume and E. Bruera, "Financial Distress and Its Associations With Physical and Emotional Symptoms and Quality of Life Among Advanced Cancer Patients," *Oncologist*, vol. 20, no. 9, pp. 1092-1098, 2015.
- [147] S. Y. Zafar, J. M. Peppercorn, D. Schrag, D. H. Taylor, A. M. Goetzinger, X. Zhong and A. P. Abernethy, "The financial toxicity of cancer treatment: a pilot study assessing out-of-pocket expenses and the insured cancer patient's experience," *Oncologist*, vol. 18, no. 4, pp. 381-390, 2013.
- [148] S. Ramsey, D. Blough, A. Kirchoff, K. Kreizenbeck, C. Fedorenko, K. Snell, P. Newcomb, W. Hollingworth and K. Overstreet, "Washington State cancer patients found to be at greater risk for bankruptcy than people without a cancer diagnosis," *Health Affairs (Millwood)*, vol. 32, no. 6, pp. 1143-1152, 2013.
- [149] K. E. Hoffman, E. P. McCarthy, C. J. Recklitis and A. K. Ng, "Psychological Distress in Long-term Survivors of Adult-Onset Cancer: Results From a National Survey," *Archives of Internal Medicine*, vol. 169, no. 14, pp. 1274-1281, 2009.
- [150] U.S. Preventive Services Task Force, "Final Recommendation Statement: Breast Cancer: Screening," U.S. Preventive Services Task Force, Rockville, 2016.

- [151] R. L. Siegel, S. A. Fedewa, W. F. Anderson, K. D. Miller, J. Ma, P. S. Rosenberg and A. Jemal, "Colorectal Cancer Incidence Patterns in the United States, 1974-2013," *Journal of the National Cancer Institute*, vol. 109, no. 8, 2017.
- [152] A. B. Knudsen, C. M. Rutter and E. F. Peterse, "Colorectal Cancer Screening: A Decision Analysis for the U.S. Preventive Services Task Force," Agency for Healthcare Research and Quality, Rockville, 2020.
- [153] R. C. Baron, B. K. Rimer, R. A. Breslow, R. J. Coates, J. Kemer, S. Melillo, N. Habarta, G. P. Kalra, S. Chattopadhyay, K. M. Wilson, N. C. Lee, P. D. Mullen, S. S. Coughlin and P. A. Briss, "Client-directed interventions to increase community demand for breast, cervical and colorectal cancer screening: a systematic review," *American Journal of Preventive Medicine*, vol. 35, no. 1, pp. S34-55, 2008.
- [154] M. Sarfaty, M. Doroshenk, J. Hotz, D. Brooks, S. Hayashi, T. C. Davis, D. Joseph, D. Stevens, D. L. Weaver, M. B. Potter and R. Wender, "Strategies for expanding colorectal cancer screening at community health centers," *CA: A Cancer Journal for Clinicians*, vol. 63, no. 4, pp. 221-231, 2013.
- [155] J. Christie, S. Itzkowitz, I. Lihau-Nkanza, A. Castillo, W. Redd and L. Jandorf, "A randomized controlled trial using patient navigation to increase colonoscopy screening among low-income minorities," *Journal of the National Medical Association*, vol. 100, no. 3, pp. 278-284, 2008.
- [156] K. E. Lasser, J. Murillo, S. Lisboa, A. N. Casimir, L. Valley-Shah, K. M. Emmons, R. H. Fletcher and J. Z. Ayanian, "Colorectal cancer screening among ethnically diverse, low-income patients: a randomized controlled trial," *Archives of Internal Medicine*, vol. 171, no. 10, pp. 906-912, 2011.
- [157] B. Lebowohl, A. I. Neugut, E. Stavsky, S. Villegas, C. Meli, O. Rodriguez, C. Franco, M. S. Krauskopft and R. Rosenberg, "Effect of a patient navigator program on the volume and quality of colonoscopy," *Journal of Clinical Gastroenterology*, vol. 45, no. 5, pp. e47-53, 2011.
- [158] E. D. Paskett, J. P. Harrop and K. J. Wells, "Patient navigation: an update on the state of the science," *CA: A Cancer Journal for Clinicians*, vol. 61, no. 4, pp. 237-249, 2011.
- [159] R. E. Myers, T. Hyslop, R. Sifri, H. Bittner-Fagan, N. C. Katurakes, J. Cocroft, M. Dicarlo and T. Wolf, "Tailored navigation in colorectal cancer screening," *Medical Care*, vol. 46, pp. S123-131, 2008.
- [160] S. N. Sheinfeld Gorin, M. Jimbo, R. Heizelman, K. M. Harmes and D. M. Harper, "The future of cancer screening after COVID-19 may be at home," *Cancer*, vol. 127, no. 4, pp. 498-503, 2020.
- [161] D. A. Joseph, J. B. King, N. F. Dowling, C. C. Thomas and L. C. Richardson, "Vital Signs: Colorectal Cancer Screening Test Use - United States, 2018," *Morbidity and Mortality Weekly Report (MMWR)*, vol. 69, no. 10, pp. 253-259, 2020.
- [162] S. K. Naber, A. B. Knudsen, A. G. Zauber, C. M. Rutter, S. E. Fischer, C. J. Pabinniak, B. Soto, K. M. Kuntz and I. Lansdorp-Vogelaar, "Cost-effectiveness of a multitarget stool DNA test for colorectal cancer screening of Medicare beneficiaries," *PLoS One*, 2019.
- [163] H. A. Loomans-Kropp and A. Umar, "Cancer prevention and screening: the next step in the era of precision medicine," *NPJ Precision Oncology*, vol. 3, no. 3, 2019.

- [164] M. K. Kilbride and A. R. Bradbury, "Evaluating Web-Based Direct-to-Consumer Genetic Tests for Cancer Susceptibility," *JCO Precision Oncology*, pp. 161-169, 2020.
- [165] HealthyPeople.gov, "Immunization and Infectious Diseases," 2020.
- [166] Centers for Disease Control and Prevention, "Achievements in Public Health, 1900-1999: Impact of Vaccines Universally Recommended for Children - United States, 1990-1998," *Morbidity & Mortality Weekly Reports*, vol. 48, no. 12, pp. 243-248, 1999.
- [167] L. Tan, "Adult vaccination: Now is the time to realize an unfulfilled potential," *Human Vaccines & Immunotherapeutics*, vol. 11, no. 9, pp. 2158-2166, 2015.
- [168] S. M. Bartsch, M. C. Ferguson, J. A. McKinnell, K. J. O'Shea, P. T. Wedlock, S. S. Siegmund and B. Y. Lee, "The Potential Health Care Costs and Resource Used Associated with COVID-19 in the United States," *Health Affairs*, vol. 39, no. 6, 2020.
- [169] J. Noh and G. Danuser, "Estimation of the fraction of COVID-19 infected people in U.S. states and countries worldwide," *PLoS One*, vol. 16, no. 2, 2021.
- [170] Centers for Disease Control and Prevention, "What Vaccines are Recommended for You," 2019.
- [171] A. T. Isik, "COVID-19 Infection in Older Adults: A Geriatrician's Perspective," *Clinical Interventions in Aging*, vol. 15, pp. 1067-1069, 2020.
- [172] Centers for Disease Control and Prevention, "Recommended Vaccines for Adults," Centers for Disease Control and Prevention, Atlanta, 2019.
- [173] J. C. Jacobson Vann, R. M. Jacobson, T. Coyne-Beasley, J. K. Asafu-Adjei and P. G. Szilagyi, "Patient reminder and recall interventions to improve immunization rates," *Cochrane Database of Systematic Reviews*, 2018.
- [174] N. Y. Loskutova, C. Smail, E. Callen, E. W. Staton, N. Nazir, B. Webster and W. Pace, "Effects of multicomponent primary care-based intervention on immunization rates and missed opportunities to vaccinate adults," *BMC Family Practice*, vol. 21, 2020.
- [175] C. J. Herman, T. Speroff and R. D. Cebul, "Improving Compliance with Immunization in the Older Adult: Results of a Randomized Cohort Study," *Journal of the American Geriatrics Society*, vol. 42, no. 11, pp. 1154-1159, 1994.
- [176] Wellcome Trust, "The future of vaccines: Three innovations from around the world," *Medical Xpress*, 27 April 2020.
- [177] The History of Vaccines, "The Future of Immunizations," *History of Vaccines*, 10 January 2018.
- [178] A. Keener, "Tailoring vaccines for older people and the very young," *Nature*, 27 November 2019.
- [179] Centers for Disease Control and Prevention, "Guidance for Vaccinating Older Adults and People with Disabilities: Ensuring Equitable COVID-19 Vaccine Access," 2021.

- [180] Illinois Department of Public Health, "Protect Chicago Homebound," Chicago, 2021.
- [181] J. Bergal, "Without a Ride, Many in Need Have No Shot at COVID-19 Vaccine," *Pew Trusts*, 1 February 2021.
- [182] National Prevention, Health Promotion, and Public Health Council, "Healthy Aging in Action: Advancing the National Prevention Strategy," U.S. Department of Health and Human Services, Washington, DC, 2016.
- [183] J. L. Streeter, S. Raposo and H.-W. Liao, "Sightlines Project Special Report: Social Engagement. Chapter 1: The Importance of Social Relationships for Longevity," Stanford Center on Longevity, Stanford , 2018.
- [184] N. Abedini, E. Solway, J. Piette and P. Malani, "Cross-Sector Collaborations to Decrease Loneliness and Social Isolation in Older Adults," *Health Affairs Blog*, 20 June 2019.
- [185] J. S. House, K. R. Landis and D. Umberson, "Social relationships and health," *Science*, vol. 241, no. 4865, pp. 540-545, 1988.
- [186] B. N. Uchino, J. T. Cacioppo and J. K. Kiecolt-Glaser, "The relationship between social support and physiological processes: a review with emphasis on underlying mechanisms and implications for health," *Psychological Bulletin*, vol. 119, no. 3, pp. 488-531, 1996.
- [187] S. Cohen, "Social Relationships and Health," *American Psychologist*, vol. 59, no. 8, pp. 676-684, 2004.
- [188] J. K. Kiecolt-Glaser and T. L. Newton, "Marriage and health: his and hers," *Psychological Bulletin*, vol. 127, no. 4, pp. 472-503, 2001.
- [189] E. Y. Cornwell and L. J. Waite, "Social Disconnectedness, Perceived Isolation, and Health among Older Adults," *Journal of Health and Social Behavior*, vol. 50, no. 1, pp. 31-48, 2009.
- [190] C. E. Coyle and E. Dugan, "Social isolation, loneliness and health among older adults," *Journal of Aging & Health*, vol. 24, no. 8, pp. 1346-1363, 2012.
- [191] S. Cohen, W. J. Doyle, D. P. Skoner, B. S. Rabin and J. M. Gwaltney, Jr., "Social ties and susceptibility to the common cold," *JAMA*, vol. 277, no. 24, pp. 1940-1944, 1997.
- [192] L. F. Berkman and S. L. Syme, "Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents," *American Journal of Epidemiology*, vol. 109, no. 2, pp. 186-204, 1979.
- [193] J. Holt-Lunstad, T. B. Smith and J. B. Layton, "Social Relationships and Mortality Risk: A Meta-analytic Review," *PLoS Medicine*, 2010.
- [194] J. Holt-Lunstad, T. B. Smith, M. Baker, T. Harris and D. Stephenson, "Loneliness and social isolation as risk factors for mortality: a meta-analytic review," *Perspectives on Psychological Science*, vol. 10, no. 2, pp. 227-237, 2015.
- [195] Y. Luo, L. C. Hawkey, L. J. Waite and J. T. Cacioppo, "Loneliness, Health, and Mortality in Old Age: A National Longitudinal Study," *Social Science & Medicine*, vol. 74, no. 6, pp. 907-914, 2012.

- [196] R. E. Holtzman, G. W. Rebok, J. S. Saczynski, A. C. Kouzis, K. W. Doyle and W. W. Eaton, "Social network characteristics and cognition in middle-aged and older adults," *The Journals of Gerontology: Series B, Psychological Sciences and Social Sciences*, vol. 59, no. 6, pp. 278-284, 2004.
- [197] P. A. Thomas, "Trajectories of Social Engagement and Limitations in Late Life," *Journal of Health and Social Behavior*, vol. 52, no. 4, pp. 430-443, 2011.
- [198] K. A. Van Orden, E. Bower, J. Lutz, C. Silva, A. M. Gallegos, C. A. Podgorski, E. J. Santos and Y. Conwell, "Strategies to Promote Social Connections Among Older Adults During "Social Distancing" Restrictions," *American Journal of Geriatric Psychiatry*, 2020.
- [199] H. M. O'Rourke, L. Collins and S. Sidani, "Interventions to address social connectedness and loneliness for older adults: a scoping review," *BMC Geriatrics*, vol. 18, 2018.
- [200] G. O. Anderson, "Getting Connected: Older Americans Embrace Technology to Enhance Their Lives," *AARP Research: Technology*, February 2018.
- [201] C. Lee, M. F. Hosseini, J. Miller, T. R. Patskanick and J. F. Coughlin, "The Oldest Olds' Perceptions of Social Robots," in *HCI 2019: Human Aspects of IT for the Aged Population. Social Media, Games and Assistive Environments*, Orlando, 2019.
- [202] AARP Foundation, "Using Technology to Make Meaningful Connections," *Connect 2 Affect*, 2021.
- [203] World Health Organization, "Mental health of older adults," 2017.
- [204] J. Hagerty, "2016 AARP Member Opinion Survey," AARP, Washington, DC, 2016.
- [205] J. C. Millan-Calenti, J. Tubio, S. Pita-Fernandez, S. Rochette, T. Lorenzo and A. Maseda, "Cognitive impairment as predictor of functional dependence in an elderly sample," *Archives of Gerontology and Geriatrics*, vol. 54, no. 1, pp. 197-201, 2012.
- [206] S. Tyrovolas, A. Koyanagi, E. Lara, Z. I. Santini and J. M. Haro, "Mild cognitive impairment is associated with falls among older adults: Findings from the Irish Longitudinal Study on Ageing (TILDA)," *Experimental Gerontology*, vol. 75, pp. 42-47, 2016.
- [207] K. B. Rajan, N. T. Aggarwal, R. S. Wilson, S. A. Everson-Rose and D. A. Evans, "Association of Cognitive Functioning, Incident Stroke, and Mortality in Older Adults," *Stroke*, vol. 45, no. 9, pp. 2563-2567, 2014.
- [208] T. E. Stump, C. M. Callahan and H. C. Hendrie, "Cognitive Impairment and Mortality in Older Primary Care Patients," *Journal of the American Geriatrics Society*, vol. 49, no. 7, pp. 934-940, 2001.
- [209] G. Livingston, J. Huntley, A. Sommerlad, D. Ames, C. Ballard, S. Banerjee, C. Brayne, A. Burns, J. Cohen-Mansfield, C. Cooper, S. G. Costafreda, A. Dias, N. Fox, L. N. Gitlin, R. Howard, H. C. Kales, M. Kivimaki, E. B. Larson, A. Ogunniyi, V. Orgeta, K. Ritchie, K. Rockwood, E. L. Sampson, Q. Samus, L. S. Schneider, G. Selbaek, L. Teri and N. Mikadam, "Dementia prevention, intervention and care: 2020 report of the Lancet Commission," *The Lancet*, vol. 396, no. 10248, pp. 413-446, 2020.

- [210] D. G. Blazer, K. Yaffe and J. Karlawish, "Cognitive Aging: A Report from the Institute of Medicine," *JAMA*, vol. 313, no. 21, pp. 2121-2122, 2015.
- [211] Stanford Center on Longevity, "The Sightlines Project," [Online]. Available: <https://longevity.stanford.edu/the-sightlines-project/>.
- [212] J. Graham, "What the 2020s Have In Store for Aging Boomers," *KHN.org*, 16 January 2020.
- [213] N. F. Watson, M. S. Badr, G. Belenky, D. L. Bliwise, O. M. Buxton, D. Buysse, D. F. Dinges, J. Gangwisch, M. A. Grandner, C. Kushida, R. K. Malhotra, J. L. Martin, S. R. Patel, S. F. Quan and E. Tasali, "Recommended Amount of Sleep for a Healthy Adult: A Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society," *Sleep*, vol. 38, no. 6, pp. 843-844, 2015.
- [214] M. Hirshkowitz, K. Whiton, S. M. Albert, C. Alessi, O. Bruni, L. DonCarlos, N. Hazen, J. Herman, P. J. Adams Hillard, E. S. Katz, L. Kheirandish-Gozal, D. N. Neubauer, A. E. O'Donnell, M. Ohayon, J. Peever, R. Rawding, R. C. Sachdeva, B. Setters, M. V. Vitiello and J. C. Ware, "National Sleep Foundation's updated sleep duration recommendations: final report," *Sleep Health*, vol. 1, no. 4, pp. 233-243, 2015.
- [215] Centers for Disease Control and Prevention, "Short Sleep Duration Among US Adults," 2017.
- [216] S. Sabia, A. Fayosse, J. Dumurgier, V. T. van Hees, C. Paquet, A. Sommerlad, M. Kivimaki, A. Dugravot and A. Singh-Manoux, "Association of sleep duration in middle and old age with incidence of dementia," *Nature Communications*, vol. 12, 2021.
- [217] L. Gallicchio and B. Kalesan, "Sleep duration and mortality: a systematic review and meta-analysis," *Journal of Sleep Research*, vol. 18, no. 2, pp. 148-158, 2009.
- [218] A. Alves da Silva, R. Gorga Bandeira de Mello, C. Wohlgemuth Schaan, F. D. Fuchs, S. Redline and S. C. Fuchs, "Sleep duration and mortality in the elderly: a systematic review with meta-analysis," *BMJ Open*, vol. 6, no. 2, 2016.
- [219] M. Hafner, M. Stepanek, J. Taylor, W. M. Troxel and C. Van Stolk, "Why sleep matters - the economic costs of insufficient sleep," RAND Corporation, Santa Monica, 2016.
- [220] B. Miner and M. H. Kryger, "Sleep in the Aging Population," *Sleep Medicine Clinics*, vol. 12, no. 1, pp. 31-38, 2017.
- [221] Y.-L. Huang, R.-Y. Liu, Q.-S. Wang, E. J. Van Someren, H. Xu and J.-N. Zhou, "Age-associated difference in circadian sleep - wake and rest-activity rhythms," *Physiology & Behavior*, vol. 76, no. 4-5, pp. 597-603, 2002.
- [222] National Institute on Aging, "A Good Night's Sleep," 2020.
- [223] C. Drake, T. Roehrs, J. Shambroom and T. Roth, "Caffeine effects on sleep taken 0, 3, or 6 hours before going to bed," *Journal of Clinical Sleep Medicine*, vol. 9, no. 11, 2013.
- [224] M. A. Kredlow, M. C. Capozzoli, B. A. Hearon, A. W. Calkins and M. W. Otto, "The effects of physical activity on sleep: a meta-analytic review," *Journal of Behavioral Medicine*, vol. 38, pp. 427-449, 2015.

- [225] M. A. Christensen, L. Bettencourt, L. Kaye, S. T. Moturu, K. T. Nguyen, J. E. Olgin, M. J. Pletcher and G. M. Marcus, "Direct Measurements of Smartphone Screen-Time: Relationships with Demographics and Sleep," *PLoS One*, vol. 11, no. 11, 2016.
- [226] T. Nuutinen, C. Ray and E. Roos, "Do computer use, TV viewing, and the presence of the media in the bedroom predict school-aged children's sleep habits in a longitudinal study?," *BMC Public Health*, vol. 13, 2013.
- [227] D. S. Black, G. A. O'Reilly, R. Olmstead, E. C. Breen and M. R. Irwin, "Mindfulness Meditation and Improvement in Sleep Quality and Daytime Impairment Among Older Adults with Sleep Disturbances: A Randomized Clinical Trial," *JAMA Internal Medicine*, vol. 175, no. 4, pp. 494-501, 2015.
- [228] A. C. King, L. A. Pruitt, S. Woo, C. M. Castro, D. K. Ahn, M. V. Vitiello, S. H. Woodward and D. L. Bliwise, "Effects of Moderate-Intensity Exercise on Polysomnographic and Subjective Sleep Quality in Older Adults with Mild to Moderate Sleep Complaints," *The Journals of Gerontology: Series A*, vol. 63, no. 9, pp. 997-1004, 2008.
- [229] I. Perez-Pozuelo, B. Zhai, J. Palotti, R. Mall, M. Aupetit, J. M. Garcia-Gomez, S. Taheri, Y. Guan and L. Fernandez-Luque, "The future of sleep health: a data-driven revolution in sleep science and medicine," *NPJ Digital Medicine*, vol. 3, 2020.
- [230] J. E. Crews and V. A. Campbell, "Vision Impairment and Hearing Loss Among Community-Dwelling Older Americans: Implications for Health and Functioning," *American Journal of Public Health*, vol. 94, no. 5, pp. 823-829, 2004.
- [231] American Optometric Association, "Comprehensive Eye Exams".
- [232] U.S. Preventive Services Task Force, "Final Recommendation Statement: Screening for Hearing Loss in Older Adults," Rockville, 2021.
- [233] American Speech-Language-Hearing Association, "Preferred Practice Patterns for the Profession of Audiology," 2006.
- [234] V. Bernabei, V. Morini, F. Moretti, A. Marchiori, B. Ferrari, E. Dalmonte, D. De Ronchi and A. R. Atti, "Vision and hearing impairments are associated with depressive-anxiety syndrome in Italian elderly," *Aging & Mental Health*, vol. 14, no. 4, pp. 467-474, 2011.
- [235] S. Pardhan, L. Smith, R. Bourne, A. David, N. Leveziel, L. Jacob, A. Koyanagi and G. F. Lopez-Sanchez, "Combined Vision and Hearing Difficulties Results in Higher Levels of Depression and Chronic Anxiety: Data From a Large Sample of Spanish Adults," *Frontiers in Psychology*, vol. 11, 2021.
- [236] B. K. Keller, J. L. Morton, V. S. Thomas and J. F. Potter, "The Effect of Visual and Hearing Impairments on Functional Status," *Journal of the American Geriatrics Society*, vol. 47, no. 11, pp. 1319-1325, 1999.
- [237] V. R. Cimarolli, D. S. Jopp, K. Boerner and J. Minahan, "Depressive symptoms in the oldest-old: The role of sensory impairments," *Archives of Gerontology and Geriatrics*, vol. 78, pp. 249-254, 2018.

- [238] J. G. S. Davidson and D. M. Guthrie, "Older Adults with a Combination of Vision and Hearing Impairment Experience Higher Rates of Cognitive Impairment, Functional Dependence, and Worse Outcomes Across a Set of Quality Indicators," *Journal of Aging and Health*, vol. 31, no. 1, pp. 85-108, 2017.
- [239] T. R. Patskanick, J. Miller, L. A. D'Ambrosio, C. Lee and J. F. Coughlin, "Mapping the Future of Hearables: Lessons from Online and the "Oldest Old" Consumers," in *HCI 2019: Human Aspects of IT for the Aged Population. Design for the Elderly and Technology Acceptance*, Orlando, 2019.
- [240] B. Gopinath, C. M. McMahon, G. Burlutsky and P. Mitchell, "Hearing and vision impairment and the 5-year incidence of falls in older adults," *Age and Ageing*, vol. 45, no. 3, pp. 409-414, 2016.
- [241] M. Brennan, "Impairment of Both Vision and Hearing Among Older Adults: Prevalence and Impact on Quality of Life," *Generations*, vol. 1, no. 5, pp. 52-56, 2003.
- [242] M. I. Tareque, A. Chan, Y. Saito, S. Ma and R. Malhotra, "The Impact of Self-Reported Vision and Hearing Impairment on Health Expectancy," *American Geriatrics Society*, vol. 67, no. 12, pp. 2528-2536, 2019.
- [243] B. Gopinath, J. Schneider, C. M. McMahon, G. Burlutsky, S. R. Leeder and P. Mitchell, "Dual Sensory Impairment in Older Adults Increases the Risk of Mortality: A Population-Based Study," *PLoS One*, vol. 8, no. 3, 2013.
- [244] The Medical Futurist, "The Future of Hearing: How Technology Might Turn Us Into Superheroes," 2019.
- [245] S. Musich, S. S. Wang, S. Kraemer, K. Hawkins and E. Wicker, "Purpose in Life and Positive Health Outcomes Among Older Adults," *Population Health Management*, vol. 21, no. 2, pp. 139-147, 2018.
- [246] M. Pinquart, "Creating and maintaining purpose in life in old age: A meta-analysis," *Ageing International*, vol. 27, pp. 90-114, 2002.
- [247] G. Kim, S. H. Shin, M. A. Scicolone and P. Parmelee, "Purpose in Life Protects Against Cognitive Decline Among Older Adults," *The American Journal of Geriatric Psychiatry*, vol. 27, no. 6, pp. 593-601, 2019.
- [248] G. T. Reker, "Personal meaning, optimism, and choice: Existential predictors of depression in community and institutional elderly," *The Gerontologist*, vol. 37, pp. 709-716, 1997.
- [249] E. S. Kim, J. K. Sun, N. Park and C. Peterson, "Purpose in life and reduced incidence of stroke in older adults: The Health and Retirement Study," *Journal of Psychosomatic Research*, vol. 74, no. 5, pp. 427-432, 2013.
- [250] E. S. Kim, J. K. Sun, N. Park, L. D. Kubzansky and C. Peterson, "Purpose in life and reduced risk of myocardial infarction among older U.S. adults with coronary heart disease: a two-year follow-up," *Journal of Behavioral Medicine*, vol. 36, pp. 124-133, 2013.
- [251] E. S. Kim, I. Kawachi, Y. Chen and L. D. Kubzansky, "Association Between Purpose in Life and Objective Measures of Physical Function in Older Adults," *JAMA Psychiatry*, vol. 74, no. 10, pp. 1039-1045, 2017.
- [252] N. Krause, "Stressors in highly valued roles, meaning in life, and the physical health status of older adults," *Journal of Gerontology: Series B*, vol. 59B, pp. S287-S297, 2004.

- [253] B. P. O'Connor and R. J. Vallerand, "Psychological adjustment variables as predictors of mortality among nursing home residents," *Psychology and Aging*, vol. 13, pp. 368-374, 1998.
- [254] N. Krause, "Meaning in Life and Mortality," *The Journals of Gerontology*, vol. 64B, no. 4, pp. 517-527, 2009.
- [255] AmeriCorps Seniors, "AmeriCorps".
- [256] AARP, "Senior Planet".
- [257] P. Irving, "When No One Retires," *Harvard Business Review*, 7 November 2018.
- [258] J. C. Millan-Calenti, J. Tubio, S. Pita-Fernandez, I. Gonzalez-Abraldes, T. Lorenzo, T. Fernandez-Arruty and A. Maseda, "Prevalence of functional disability in activities of daily living (ADL), instrumental activities of daily living (IADL) and associated factors, as predictors of morbidity and mortality," *Archives of Gerontology and Geriatrics*, vol. 50, no. 3, pp. 306-310, 2010.
- [259] E. d'Orsi, A. J. Xavier, A. Steptoe, C. de Oliveira, L. R. Ramos, M. Orrell, P. Demakakos and M. G. Marmot, "Socioeconomic and Lifestyle Factors Related to Instrumental Activity of Daily Living Dynamics: Results from the English Longitudinal Study of Ageing," *Journal of the American Geriatrics Society*, vol. 62, no. 9, pp. 1630-1639, 2014.
- [260] S. Vasunilashorn, B. A. Steinman, P. S. Liebig and J. Pynoos, "Aging in Place: Evolution of a Research Topic Whose Time Has Come," *Journal of Aging Research*, vol. 2012, 2012.
- [261] J. Binette, K. Vasold and AARP Research, "2018 Home and Community Preferences: A National Survey of Adults Ages 18-Plus," AARP, 2018.
- [262] N. Farber and D. Shinkle, "Aging in Place: A State Survey of Livability Policies and Practices. A Research Report by the National Conference of State Legislatures and the AARP Public Policy Institute," AARP, Washington, DC, 2011.
- [263] J. L. Wiles, A. Liebing, N. Guberman, J. Reeve and R. E. S. Allen, "The Meaning of "Aging in Place" to Older People," *The Gerontologist*, vol. 52, no. 3, pp. 357-366, 2012.
- [264] K. Konig, M. Raue, L. A. D'Ambrosio and J. F. Coughlin, "Physical and Emotional Support of the Neighborhood for Older Adults: A Comparison of the United States and Germany," *Journal of Environmental Psychology*, vol. 62, 2019.
- [265] N. McGill, "As senior population grows, aging in place gains popularity: Communities conducting outreach," *The Nation's Health*, vol. 43, no. 8, pp. 1-16, 2013.
- [266] M. D. Eriksen, N. Greenhalgh-Stanley and G. V. Engelhardt, "Home safety, accessibility, and elderly health: Evidence from falls," *Journal of Urban Economics*, vol. 87, no. C, pp. 14-24, 2015.
- [267] K. Hanss, M. Zweig and C. Stotz, "We've entered an unprecedented market for aging in place," *RockHealth*, 8 September 2020.

- [268] E. J. Tan, "How Growing Geographic and Racial Disparities Inhibit the Ability to Live Longer and Healthier Lives - Report 1: National Level Analysis," AARP Thought Leadership, Washington, DC, 2020.
- [269] National Academies of Sciences, Engineering and Medicine; Health and Medicine Division; Board on Population Health and Public Health Practice; Committee on Community-Based Solutions to Promote Health Equity in the United States, *Communities in Action: Pathways to Health Equity*, Washington, DC: National Academies Press (US), 2017.
- [270] Agency for Healthcare Research and Quality, "2019 National Healthcare Quality and Disparities Report," Agency for Healthcare Research and Quality, Rockville, 2020.
- [271] R. Ahuja and C. Levy, "Better Brain Health through Equity: Addressing Health and Economic Disparities in Dementia for African Americans and Latinos," The Milken Institute, 2021.
- [272] Centers for Disease Control and Prevention, "CDC Health Disparities & Inequalities Report - United States, 2013," 2013.
- [273] J. J. Escarce, "Health Inequity in the United States: A Primer," University of Pennsylvania, Philadelphia, 2019.
- [274] S. Artiga, K. Orgera and O. Pham, "Disparities in Health and Health Care: Five Key Questions and Answers," KFF, 2020.
- [275] S. Kubendran, R. DeVol and A. Chatterjee, "The Price Women Pay for Dementia: Strategies to Ease Gender Disparity and Economic Costs," Milken Institute, 2019.
- [276] W. H. Frist, "Overcoming Disparities in U.S. Health Care," *Health Affairs*, vol. 24, no. 2, 2005.
- [277] K. Giskes, M. Avendano, J. Brug and A. E. Kunst, "A systematic review of studies on socioeconomic inequalities in dietary intakes associated with weight gain and overweight/obesity conducted among European adults," *Obesity Reviews*, vol. 11, pp. 413-429, 2010.
- [278] K. Giskes, F. van Lenthe, M. Avendano-Pabon and J. Brug, "A systematic review of environmental factors and obesogenic dietary intakes among adults: are we getting closer to understanding obesogenic environments?," *Obesity Reviews*, vol. 12, pp. e95-106, 2011.
- [279] S. Cummins and S. Macintyre, "Food environments and obesity - neighbourhood or nation?," *International Journal of Epidemiology*, vol. 35, pp. 100-104, 2006.
- [280] A. Drewnowski and S. E. Specter, "Poverty and obesity: the role of energy density and energy costs," *The American Journal of Clinical Nutrition*, vol. 79, no. 1, pp. 6-16, 2004.
- [281] C. Rehm, J. L. Penalvo, A. Afshin and D. Mozaffarian, "Dietary Intake Among US Adults, 1999-2012," *JAMA*, vol. 315, no. 23, pp. 2542-2553, 2016.
- [282] J. P. Ziliak, C. Gundersen and M. Haist, "The Causes, Consequences, and Future of Senior Hunger in America," University of Kentucky, Center for Poverty Research, Lexington, 2008.

- [283] J. S. Lee and E. A. Frongillo, Jr., "Factors Associated with Food Insecurity Among U.S. Elderly Persons: Importance of Functional Impairments," *The Journals of Gerontology: Series B*, vol. 56, no. 2, pp. S94-S99, 2001.
- [284] J. S. Lee and E. A. Frongillo, Jr., "Nutritional and Health Consequences Are Associated with Food Insecurity among U.S. Elderly Persons," *The Journal of Nutrition*, vol. 131, no. 5, pp. 1503-1509, 2001.
- [285] C. Gidlow, L. H. Johnston, D. Crone, N. J. Ellis and D. James, "A systematic review of the relationship between socioeconomic position and physical activity," *Health Education Journal*, vol. 65, pp. 338-367, 2006.
- [286] K. Ball, J. Salmon, B. Giles-Corti and D. Crawford, "How can socioeconomic differences in physical activity among women be explained? A qualitative study.," *Women & Health*, vol. 41, pp. 93-113, 2006.
- [287] K. Ball, A. Timperio, J. Salmon, B. Giles-Corti, R. Roberts and D. Crawford, "Personal, social and environmental determinants of educational inequalities in walking: a multilevel study.," *Journal of Epidemiology and Community Health*, vol. 61, pp. 108-114, 2007.
- [288] D. Crawford, A. Timperio, B. Giles-Corti, K. Ball, C. Hume and R. Roberts, "Do features of public open spaces vary according to neighbourhood socio-economic status?," *Health & Place*, vol. 14, pp. 889-893, 2008.
- [289] A. Rigolon, "A complex landscape of inequity in access to urban parks: A literature review," *Landscape and Urban Planning*, vol. 153, pp. 160-169, 2016.
- [290] R. Chowdhury, H. Khan, E. Heydon, A. Shroufi, S. Fahimi, C. Moore, B. Stricker, S. Mendis, A. Hofman, J. Mant and O. H. Franco, "Adherence to cardiovascular therapy: a meta-analysis of prevalence and clinical consequences," *European Heart Journal*, vol. 34, no. 38, pp. 2940-2948, 2013.
- [291] A. D. Bowry, W. H. Shrank, J. L. Lee, M. Stedman and N. K. Choudhry, "A Systematic Review of Adherence to Cardiovascular Medications in Resource-Limited Settings," *Journal of General Internal Medicine*, vol. 26, pp. 1479-1491, 2011.
- [292] D. T. Liss and D. W. Baker, "Understanding current racial/ethnic disparities in colorectal cancer screening in the United States: the contribution of socioeconomic status and access to care," *American Journal of Preventive Medicine*, vol. 46, no. 3, pp. 228-236, 2014.
- [293] J. Wardle, K. McCaffery, M. Nadel and W. Atkin, "Socioeconomic differences in cancer screening participation: comparing cognitive and psychosocial explanations," *Social Science & Medicine*, vol. 59, no. 2, pp. 249-261, 2004.
- [294] J. Niederdeppe and A. G. Levy, "Fatalistic beliefs about cancer prevention and three prevention behaviors," *Cancer Epidemiology, Biomarkers and Prevention*, vol. 16, no. 5, pp. 998-1003, 2007.
- [295] J. Wardle and A. Steptoe, "Socioeconomic differences in attitudes and beliefs about healthy lifestyles," *Journal of Epidemiology & Community Health*, vol. 57, no. 6, pp. 440-443, 2003.
- [296] S. J. Katz and T. P. Hofer, "Socioeconomic disparities in preventive care persist despite universal coverage. Breast and cervical cancer screening in Ontario and the United States," *JAMA*, vol. 272, no. 7, pp. 530-534, 1994.

- [297] H. Y. Lee and H. Im, "Colorectal cancer screening among Korean American immigrants: unraveling the influence of culture," *Journal of Health Care for the Poor and Underserved*, vol. 24, no. 2, pp. 579-598, 2013.
- [298] W. Born, K. Engelman, K. A. Greiner, S. B. Bhattacharya, S. Hall, Q. Hou and J. S. Ahluwalia, "Colorectal cancer screening, perceived discrimination, and low-income and trust in doctors: a survey of minority patients," *BMC Public Health*, vol. 9, 2009.
- [299] D. Steinwachs, J. D. Allen, W. E. Barlow, R. P. Duncan, L. E. Egede, L. S. Friedman, N. L. Keating, P. Kim, J. R. Lave, T. A. Laveist, R. B. Ness, R. J. Optican and B. A. Virnig, "National Institutes of Health state-of-the-science conference statement: Enhancing use and quality of colorectal cancer screening," *Annals of Internal Medicine*, vol. 152, no. 10, pp. 663-667, 2010.
- [300] M. C. Rangel, V. J. Shoenbach, K. A. Weigle, V. K. Hogan, R. P. Strauss and S. I. Bangdiwala, "Racial and ethnic disparities in influenza vaccination among elderly adults," *Journal of General Internal Medicine*, vol. 20, pp. 426-431, 2005.
- [301] M. M. Hughes, N. S. Saiyed and T. S. Chen, "Local-Level Adult Influenza and Pneumococcal Vaccination Disparities: Chicago, Illinois, 2015-2016," *American Journal of Public Health*, vol. 108, no. 4, pp. 517-523, 2018.
- [302] P.-j. Lu, A. O'Halloran, W. W. Williams, M. C. Lindley, S. Farrall and C. B. Bridges, "Racial and ethnic disparities in vaccination coverage among adult populations in the U.S.," *Vaccine*, vol. 33, no. 4, pp. D83-D91, 2015.
- [303] A. S. O'Malley and C. B. Forrest, "Immunization Disparities in Older Americans: Determinants and Future Research Needs," *American Journal of Preventive Medicine*, vol. 31, no. 2, pp. 150-158, 2006.
- [304] P.-j. Lu, A. Rodriguez-Lainz, A. O'Halloran, S. Greby and W. W. Williams, "Adult Vaccination Disparities Among Foreign-Born Populations in the US, 2012," *American Journal of Preventive Medicine*, vol. 47, no. 6, pp. 722-733, 2014.
- [305] J. Elkington, "Enter the Triple Bottom Line," in *The Triple Bottom Line: Does it All Add Up?*, London, Earthscan, 2013.
- [306] J. Pfeffer, *Dying for a Paycheck: How Modern Management Harms Employee Health and Company Performance and What We Can Do About It*, HarperCollins Publishers, 2018.
- [307] L. Anderko, J. S. Roffenbender, R. Z. Goetzel, F. Millard, K. Wildenhaus, C. DeSantis and W. Novelli, "Promoting Prevention Through the Affordable Care Act: Workplace Wellness," *Preventing Chronic Disease*, vol. 9, 2012.
- [308] Y. Li, J. Schoufour, D. D. Wang, K. Dhana, A. Pan, X. Liu, M. Song, G. Liu, H. J. Shin, Q. Sun, L. Al-Shaar, M. Wang, E. B. Rimm, E. Herzmark, M. J. Stempfer, W. C. Willett, O. H. Franco and F. B. Hu, "Healthy lifestyle and life expectancy free of cancer, cardiovascular disease, and type 2 diabetes: prospective cohort study," *BMJ*, vol. 368, 2020.
- [309] World Health Organization, "Policy Brief: Promoting and Creating an Enabling Environment for Healthy Behaviours Among Workers," World Health Organization, 2014.

- [310] M. Stepanek, K. Jahanshahi and F. Millard, "Individual, Workplace, and Combined Effects Modeling of Employee Productivity Loss," *Journal of Occupational and Environmental Medicine*, vol. 61, no. 6, pp. 469-478, 2019.
- [311] M. Hafner, J. Pollard and C. Van Stolk, "Incentives and physical activity: An assessment of the association between Vitality's Active Rewards with Apple Watch benefit and sustained physical activity improvements," RAND Corporation, Santa Monica, 2018.
- [312] H. Thirumurthy, D. A. Asch and K. G. Volpp, "The Uncertain Effect of Financial Incentives to Improve Health Behaviors," *JAMA*, vol. 321, no. 15, pp. 1451-1452, 2019.
- [313] S. Mattke, H. Liu, J. Caloyeras, C. Y. Huang, K. R. Van Busum, D. Khodyakov and V. Shier, "Workplace Wellness Programs Study: Final Report," *RAND Health Quarterly*, vol. 3, no. 2, 2013.
- [314] D. H. Bandoni, K. C. de Moura Bombem, D. M. L. Marchioni and P. C. Jaime, "The influence of the availability of fruits and vegetables in the workplace on the consumption of workers," *Nutrition & Food Science*, vol. 40, no. 1, 2010.
- [315] F. Geaney, J. Harrington, A. P. Fitzgerald and I. J. Perry, "The impact of a workplace catering initiative on dietary intakes of salt and other nutrients: a pilot study," *Public Health Nutrition*, vol. 14, no. 8, 2011.
- [316] J. L. Reed, S. A. Prince, C. G. Elliott, K.-A. Mullen, H. E. Tulloch, S. Hiremath, L. M. Cotie, A. L. Pipe and R. D. Reid, "Impact of Workplace Physical Activity Interventions on Physical Activity and Cardiometabolic Health Among Working-Age Women," *Circulation: Cardiovascular Quality and Outcomes*, vol. 10, no. 2, 2017.
- [317] K. G. Volpp, A. B. Troxel, M. V. Pauly, H. A. Glick, A. Puig, D. A. Asch, R. Galvin, J. Zhu, F. Wan, J. DeGuzman, E. Corbett, J. Weiner and J. Audrain-McGovern, "A Randomized, Controlled Trial of Financial Incentives for Smoking Cessation," *New England Journal of Medicine*, vol. 360, pp. 699-709, 2009.
- [318] N. A. Rigotti, J. H. Kelley, S. Regan, E. Inman, S. Kalkhoran, A. Flaster and S. K. Chaguturu, "Enhancing employer coverage of smoking cessation treatment: A randomized trial of the Partners in Helping You Quit (PIHQ) program," *Preventive Medicine*, vol. 140, 2020.
- [319] J. Davis, B. Clark, G. Lewis and I. Duncan, "The Impact of a Worksite Weight Management Program on Obesity: A Retrospective Analysis," *Population Health Management*, vol. 17, no. 5, 2014.
- [320] A. Kouvonen, M. Kivimaki, S. J. Cox, T. Cox and J. Vahtera, "Relationship Between Work Stress and Body Mass Index Among 45,810 Female and Male Employees," *Psychosomatic Medicine*, vol. 67, no. 4, pp. 577-583, 2005.
- [321] M. A. Cook and J. Gazmararian, "The association between long work hours and leisure-time physical activity and obesity," *Preventive Medicine Reports*, vol. 10, pp. 271-277, 2018.
- [322] A. Naicker, A. Shrestha, C. Joshi, W. Willett and D. Spiegelman, "Workplace cafeteria and other multicomponent interventions to promote healthy eating among adults: A systematic review," *Preventive Medicine Reports*, vol. 22, 2021.

- [323] B. Clark, J. DuChane, J. Hou, E. Rubinstein, J. McMurray and I. Duncan, "Evaluation of increased adherence and cost savings of an employer value-based benefits program targeting generic antihyperlipidemic and antidiabetic medications," *Journal of Managed Care in Pharmacy*, vol. 20, no. 2, pp. 141-150, 2014.
- [324] J. D. Allen, A. M. Stoddard, J. Mays and G. Sorensen, "Promoting breast and cervical cancer screening at the workplace: results from the Woman to Woman Study," *American Journal of Public Health*, vol. 91, no. 4, pp. 584-590, 2001.
- [325] G. X. Ma, L. Yin, W. Gao, Y. Tan, R. Liu, C. Fang and X. S. Ma, "Workplace-Based Breast Cancer Screening Intervention in China," *Cancer Epidemiology, Biomarkers & Prevention*, vol. 21, no. 2, 2012.
- [326] X. Yue, C. Black, S. Ball, S. Donahue, M. A. De Perio, A. S. Laney and S. Greby, "Workplace interventions associated with influenza vaccination coverage among health care personnel in ambulatory care settings during the 2013-2014 and 2014-2015 influenza seasons," *American Journal of Infection Control*, vol. 45, no. 11, pp. 1243-1248, 2017.
- [327] X. Yue, C. Black, S. Ball, S. Donahue, M. A. de Perio, A. S. Laney and S. Greby, "Workplace Intervention and Vaccination-Related Attitudes Associated with Influenza Vaccination Coverage Among Healthcare Personnel Working in Long-Term Care Facilities, 2015-2016 Influenza Season," *Journal of the American Medical Directors Association*, vol. 20, no. 6, pp. 718-724, 2019.
- [328] M. P. Nowalk, C. J. Lin, S. L. Toback, M. D. Rousculp, C. Eby, M. Raymund and R. K. Zimmerman, "Improving Influenza Vaccination Rates in the Workplace: A Randomized Trial," *American Journal of Preventive Medicine*, vol. 38, no. 3, pp. 237-246, 2010.
- [329] S. Joyce, M. Modini, H. Christensen, A. Mykletun, R. Bryant, P. B. Mitchell and S. B. Harvey, "Workplace interventions for common mental disorders: a systematic meta-review," *Psychological Medicine*, vol. 46, pp. 683-697, 2016.
- [330] A. H. Chu, D. Koh, F. M. Moy and F. Muller-Riemenschneider, "Do workplace physical activity interventions improve mental health outcomes?," *Occupational Medicine*, vol. 64, no. 4, pp. 235-245, 2014.
- [331] Centers for Disease Control and Prevention, "Mental Health Disorders and Stress Affecting Working-Age Americans," 2019.
- [332] A. D. LaMontagne, A. Martin, K. M. Page, N. J. Reavley, A. J. Noblet, K. T. Milner and P. M. Smith, "Workplace mental health: developing an integrated intervention approach," *BMC Psychiatry*, vol. 14, 2014.
- [333] N. S. Redeker, C. C. Caruso, S. D. Hashmi, J. M. Mullington, M. Grandner and T. I. Morgenthaler, "Workplace Interventions to Promote Sleep Health and an Alert, Healthy Workforce," *Journal of Clinical Sleep Medicine*, vol. 15, no. 4, 2019.
- [334] C. Pegus, T. L. Bazarre, J. S. Brown and J. Menzin, "Effect of the Heart at Work program on awareness of risk factors, self-efficacy, and health behaviors," *Journal of Occupational & Environmental Medicine*, vol. 44, no. 3, pp. 228-236, 2002.

- [335] S. G. Aldana, R. Greenlaw, H. A. Diehl, H. Englert and R. Jackson, "Impact of the coronary health improvement project (CHIP) on several employee populations," *Journal of Occupational & Environmental Medicine*, vol. 44, no. 9, pp. 831-839, 2002.
- [336] M. J. Bloch, D. S. Armstrong, L. Dettling, A. Hardy, K. Caterino and S. Barrie, "Partners in lowering cholesterol: comparison of a multidisciplinary educational program, monetary incentives, or usual care in the treatment of dyslipidemia identified among employees," *Journal of Occupational & Environmental Medicine*, vol. 48, no. 7, pp. 675-681, 2006.
- [337] A. Poscia, U. Moscato, D. I. La Milia, S. Milovanovic, J. Stojanovic, A. Borghini, A. Collamati, W. Ricciardi and N. Magnavita, "Workplace health promotion for older workers: a systematic literature review," *BMC Health Services Research*, vol. 16, 2016.
- [338] L. P. Whitsel, "Government's Role in Promoting Healthy Living," *Progress in Cardiovascular Diseases*, vol. 59, no. 5, pp. 492-497, 2017.
- [339] National Center for Health Statistics, "National Health and Nutrition Examination Survey (NHANES)," National Center for Health Statistics, 2021.
- [340] Centers for Disease Control and Prevention, "Behavioral Risk Factor Surveillance System (BRFSS)," Centers for Disease Control and Prevention, 2020.
- [341] Social Security Administration, "Actuarial Life Table," 2017.
- [342] H. J. Bolnick, A. L. Bui, A. Bulchis, C. Chen, A. Chapin, L. Lomsadze, A. H. Mokdad, F. Millard and J. L. Dieleman, "Health-care spending attributable to modifiable risk factors in the USA: an economic attribution analysis," *The Lancet Public Health*, vol. 5, no. 10, pp. 525-35, 2020.
- [343] J. Maroba, F. Millard and D. Kotzen, "Changing the Status Quo Bias: Applying Behavioral Science as a Win-Win for Insurers and Clients," *Society of Actuaries Marketing & Distribution Section: News Direct*, pp. 4-6, May 2018.
- [344] AARP, "2020 Tech and the 50+ Survey," AARP, 2019.
- [345] P. Rinderud, "Seniors and technology during COVID-19: the latest insights," Ericsson, 2021.
- [346] AARP, "2021 Tech Trends and the 50-Plus: Top 10 Biggest Trends," AARP, 2021.

About The Society of Actuaries Research Institute

Serving as the research arm of the Society of Actuaries (SOA), the SOA Research Institute provides objective, data-driven research bringing together tried and true practices and future-focused approaches to address societal challenges and your business needs. The Institute provides trusted knowledge, extensive experience and new technologies to help effectively identify, predict and manage risks.

Representing the thousands of actuaries who help conduct critical research, the SOA Research Institute provides clarity and solutions on risks and societal challenges. The Institute actuaries, academics, employers, the insurance industry, regulators, research partners, foundations and research institutions, sponsors and non-governmental organizations, building an effective network which provides support, knowledge and expertise regarding the management of risk to benefit the industry and the public.

Managed by experienced actuaries and research experts from a broad range of industries, the SOA Research Institute creates, funds, develops and distributes research to elevate actuaries as leaders in measuring and managing risk. These efforts include studies, essay collections, webcasts, research papers, survey reports, and original research on topics impacting society.

Harnessing its peer-reviewed research, leading-edge technologies, new data tools and innovative practices, the Institute seeks to understand the underlying causes of risk and the possible outcomes. The Institute develops objective research spanning a variety of topics with its [strategic research programs](#): aging and retirement; actuarial innovation and technology; mortality and longevity; diversity, equity and inclusion; health care cost trends; and catastrophe and climate risk. The Institute has a large volume of [topical research available](#), including an expanding collection of international and market-specific research, experience studies, models and timely research.

Society of Actuaries
475 N. Martingale Road, Suite 600
Schaumburg, Illinois 60173
www.SOA.org