UNIVERSITY OF LJUBLJANA
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MASTER THESIS

LIMITED PROGRESS IN HEALTHY LIFE EXPECTANCY AND POSSIBLE SOLUTIONS

Ljubljana, Maj 2024 NINA ABRAHAMSBERG

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e.g. – For example
et al. – and others
etc. – Et cetera
i.e. – That is
ADL - Activities of Daily Living
AI – Artificial intelligence
EU – European Union
HLE – healthy life expectancy
IADL - Instrumental Activities of Daily Living
LE - life expectancy
NCDs – non-communicable diseases
NHS – National Health Statistics
UK – United Kingdom
UN – United Nations
US – United States
WHO – World Health Organization

1 INTRODUCTION

Health, as defined by the World Health Organization, encompasses complete physical, mental, and social well-being, reflecting a dynamic state influenced by aging. While chronological age progresses, the biological age, reflecting one's fitness and health, varies. The conventional threshold of "old age" at 65 overlooks the potential for extended, healthier, and more productive lives beyond this age (WHO, n.d).

Population aging has emerged as a global concern, driven by improved healthcare, better living conditions, and declining birth rates. In the European Union, United States as well as the United Kingdom, significant growth of population aged 65 or older has been recorded in the recent years.

The data indicates a significant increase in the share of older individuals within populations, consequently contributing to a rising presence in the workforce. In the past decade, the proportion of people aged 55 or more in the employed population increased significantly amongst the population in European Union, United States and United Kingdom. Improvements in life expectancy have led to an increase in working life expectancy, reaching an average of 36.0 years in the EU in 2021, compared to 32.3 years in 2001 (Eurostat, 2020).

However, this extension of working life is inconsistent with healthy life expectancy. Despite advancements in healthcare, life expectancy has outpaced the increase in healthy life expectancy. Indicators like health expectancies, focusing on quality rather than just length of life, reveal disparities. The elderly often face health declines, limiting productivity and exacerbating economic challenges. For example, life expectancy at age 65 amongst women and men increased notably more than healthy life expectancy at age 65 alone. As individuals age, they are more likely to rate their health as bad or very bad, indicating a high prevalence of long-standing illnesses and limitations, which further increase significantly with age (Eurostat, 2020). Therefore, the pursuit of longer and healthier lives is a shared goal for individuals, societies, and policymakers alike. As the global population ages, understanding the dynamics of aging becomes increasingly crucial.

Many researchers are for this reason arguing for integration of anti-aging and preventive interventions into healthcare policy to increase the healthy to unhealthy population ratio. This approach aims to delay aging-associated chronic pathologies, resulting in a younger biological age and postponing the onset of disabilities (Vaiserman & Lushchak, 2017). To bridge the gap between healthy life expectancies and life expectancies, this master thesis delves into the multifaceted aspects of aging population, investigating the implications on economy and society and proposes potential solutions.

To comprehend the challenges posed by aging, the thesis initiates with theoretical analysis of scientific papers and secondary statistical data to examine the impact of aging on the health of older populations and its economic consequences. Firstly, the aging population's impact on society is analysed, emphasizing shifts in demographic structures and the consequences of extended life expectancy. The complexity of life spans is explained through metrics like Life Expectancy at 65, Working Life Expectancy, and Healthy Life Expectancy, along with a detailed examination of the health state of older individuals, causes of death, and influential habits, which provides a comprehensive understanding of aging-related health dynamics.

In the second part, using a dual approach of analysing secondary sources on preventive healthcare practices and conducting interviews with longevity companies, the thesis explores strategies to enhance healthy life expectancy. Namely, recognizing the health discrepancies and its implications, the longevity medicine field has gained prominence. Recent scientific breakthroughs have spurred substantial growth in anti-aging biotech companies, developing longevity interventions, including nutritional supplements, therapeutics, genetic manipulation, and data-driven approaches, which are explored alongside an empirical study revealing insights from the field. Firstly, the primary research strives to answer on the first research question: »What is the current status of health and lifestyle choices among populations in different countries?« Then, in the quest for solutions, nine in depth interviews explore the role of longevity companies, aiming to answer the second research question: » How do longevity companies try to contribute to expanding the health spans of the population?«. In addition, the interviews intend to unravel objectives, interventions, challenges, insights and recommendations from industry leaders in the pursuit of healthier life spans, while providing an explanation to the third research question: »What best practices can be identified from the approaches that longevity companies employ?«.

Lastly, the thesis transitions into a comprehensive discussion, interpreting results, proposing policy recommendations, and acknowledging limitations. It underlines the need for targeted interventions to bridge the gap between increasing life expectancy and the limited progress in healthy life expectancy.

2 UNDERSTANDING AGING POPULATIONS: BACKGROUND AND DEMOGRAPHIC SHIFTS

In recent decades, the world has witnessed a remarkable demographic shift characterized by a significant increase in the proportion of the elderly in the global population. This demographic transformation, commonly referred to as population aging, has far-reaching implications for various aspects of society, including healthcare, social welfare, and economic systems. The limited progress in healthy life expectancy among older adults poses a significant challenge for policymakers and researchers worldwide, as older people

could keep contributing to the society in many ways, if enjoying good health in their later years (WHO, 2015). This chapter aims to provide a comprehensive understanding of the population aging phenomenon, including a definition of aging, the distinction between chronological and biological age, and an elucidation of the aging phenomenon's significance.

2.1 Chronological and biological age

Aging is a natural and irreversible physiological process that occurs in living organisms as they develop over time. It is a universal phenomenon experienced by humans throughout their lives, starting around the fourth decade of life and continuing until death, marking the end of biological life (Dziechciaż & Filip, 2014). The World Health Organization (WHO, n.d.) defines aging as "the process of progressive and intrinsic deterioration of various physiological functions, leading to a decreased ability to adapt to environmental stressors, increasing vulnerability, and an increased risk of disease and death". The aging process is multifaceted, encompassing biological, psychological, and social aspects. While the genetic code is considered a fundamental cause of aging, other factors such as lifestyle choices, medical conditions, and psychosocial elements also play significant roles.

When discussing ageing it is important to distinguish between chronological and biological age. The terms are two distinct but interconnected concepts in understanding the aging process. According to Scott (2021), chronological age is a fundamental concept used to measure the time that has elapsed since an individual's birth. It is a universally recognized and straightforward method of determining an individual's age and is commonly used in administrative, legal, and social contexts. For instance, it serves as a basis for determining eligibility for retirement benefits, legal adulthood, and age-related services.

While chronological age provides a chronological marker for individuals, it does not capture an individual's functional and biological condition. Individuals of the same chronological age may exhibit substantial differences in their physiological and cognitive functions, making chronological age alone an incomplete indicator of overall health status (Han et al., 2019).

Dziechciaż & Filip (2014) emphasize, that biological age, in contrast to chronological age, captures the aspect of the natural, irreversible process of age-related changes in metabolism, physicochemical properties of cells, impaired self-regulation, and structural and functional alterations in tissues and organs. This process involves significant functional changes, including disrupted adaptation and weakened regulatory mechanisms, leading to imbalances in the body's homeostasis. According to Hamczyk et al. (2020) biological age also reflects the physiological condition and functional capabilities of an individual's body. Belsky et al. (2015) further explains that biological age takes into account various biomarkers, which provide insights into an individual's health status and overall well-being. Biomarkers commonly used to assess biological age include

cardiovascular health markers (e.g., blood pressure, cholesterol levels), immune system function, cognitive performance, and indicators of cellular aging, such as telomere length. These biomarkers help determine the rate at which an individual's body is aging and can provide valuable information about their susceptibility to age-related diseases and mortality risk (Belsky et al., 2015).

Biological aging can progress as successful aging, typical aging, or conversely as pathological aging. Successful aging occurs when the aging process is free from disease and influenced by factors that slow down ageing. Typical aging refers to the gradual progression of deficits over time without apparent pathology. Pathological aging, on the other hand, involves the rapid deterioration of vital functions, leading to premature death (Dziechciaż & Filip, 2014).

Han et al. (2019) explains that the difference between biological age and chronological age depends on the type of aging an individual is experiencing. Some individuals may exhibit an accelerated aging process, experiencing physiological decline at a faster rate than expected for their chronological age. This acceleration may result from a combination of genetic predispositions, lifestyle factors (e.g., smoking, poor diet, sedentary behaviour), and exposure to environmental stressors. Conversely, individuals may exhibit a decelerated aging process, where their physiological functions remain preserved despite advanced chronological age. These individuals often have a healthier lifestyle, engage in regular physical activity, and have optimal metabolic and physiological profiles.

Biological age therefore offers a more nuanced and accurate representation of an individual's true age-related health, as it provides a more comprehensive understanding of an individual's health status and can help tailor interventions and healthcare strategies to meet their specific needs. By considering biological age alongside chronological age, healthcare professionals and policymakers can gain insights into the diversity of health trajectories and design targeted interventions to promote healthy aging (Diebel & Rockwood, 2021).

Old age, defined by biologists and physicians, represents the final stage of aging that culminates in death. The determination of the beginning of old age is challenging due to the individualized nature of the aging process. Therefore, the convention of using a specific chronological age as a threshold is commonly followed. Although there is no universally recognized standard, various researchers have proposed different ages for the start of old age. A detailed analysis of the threshold used by various institutions and researchers is provided in review by Dziechciaż & Filip (2014). For example, a German psychologist, L. Aschoffa, suggests that aging begins at 45, while Russian gerontology indicates 80 as the starting age. In contrast, the WHO has adopted the age of 65 as the threshold for old age, which is also accepted in Europe. However, the United Nations (UN) defines old age as starting at 60, a criterion used in the United States (US) and United Kingdom (UK).

2.2 Aging Population

Increased life expectancy (LE) is considered a remarkable achievement of human development, primarily driven by improvements in nutrition, sanitation, medical advancements, healthcare access, education, and economic well-being. While it reflects one of humanity's greatest accomplishments, it poses new challenges related to the health and well-being of aging populations to the societies around the world (UNFPA and HelpAge International, 2012).

The population ageing refers to the global trend of increasing proportions of older individuals in the population, accompanied by changes in their health status and healthcare needs. This phenomenon arises primarily from two factors: declining fertility rates and increasing life expectancy. Decreased birth rates and improved healthcare have led to the increasing share of older adults in the population, resulting in an unprecedented demographic shift (United Nations, 2023). Namely, fertility for the world as whole has fallen from an average of five births per woman in 1950 to more than half less, 2.3 births per woman in 2021. The overall fertility is projected to fall to 2.1 births per woman by 2050 (United Nations Population Fund, 2023).

As of 2022, 1 in 10 people globally were aged 65 or over compared to 1 in 20 in 1950. The same age group may account for 1 in 6 people globally in 2050 (United Nations, 2022). Population aging is a widespread phenomenon observed in all regions, independently of their stage of development (WHO, 2015), though developing countries are experiencing more rapid population ageing than developed countries did historically. The proportion of the population aged 65 or above in developed regions rose from 7 to 14% in the last 40 to 120 years and will take another 20 to 50 years to increase further from 14 to 21%. On the other hand, developing countries will see an increase of older persons from 7 to 14% in only 15 to 35 years and a further increase to 21% in just 10 to 30 years (United Nations, 2023).

Furthermore, a common global trend is an increasing share of oldest-old individuals. The proportion of oldest-old individuals (aged 85 years or more) in the EU is growing at a faster pace than of any other age group. The share of oldest-old people in the EU population was 3.0% in 2022, with differences across member states. France, Portugal, Spain, Greece, and Italy had higher shares of oldest-old people, while Ireland, Cyprus, and Slovakia had lower shares. The number of oldest-old people in the EU is projected to more than double, increasing by 103.0% between 2022 and 2050. The number of individuals aged 85 years, or more is expected to rise from 13.2 million in 2022 (13.0 mil in 2021) to 26.8 million by 2050, and the number of centenarians (aged 100 years or more) is projected to grow to half a million by 2050 (Eurostat, 2023a).

2.2.1 Global changes in demographic structure

The process of population aging has been observed in Europe for several decades and is driven by low fertility rates, increased life expectancy, and migration patterns in some cases. According to Eurostat's population projections (2023a), the aging of the European Union's population will accelerate in the coming decades, with a significant rise in the number and proportion of older individuals. The population of older people, defined as those aged 65 years or more, in the European Union (EU) is projected to increase substantially, from 94.3 million in 2022 (93.2. in 2021) to 129.8 million by 2050.

As of 2022, the European Union's population comprised 446.7 million individuals, with 15.0% falling within the age group of 0 to 14 years, 63.9% in the working age range of 15 to 64 years, and the remaining 21.1% consisting of individuals aged 65 or above. In Slovenia alone, there were 21.1% of people aged 65 and above. According to Eurostat's projections for the year 2050, the proportion of people aged 65 or above is expected to increase significantly to 29.5% of the EU's population (Eurostat, 2023a).

Likewise, US data from the World Bank (2023a) indicates that 64.9% of the population belonged to the working-age group (15-64 years), while 17.1% were aged 65 or above in 2022. Projections for 2050 suggest that the share of older individuals will rise to 23.6%, while the working age population will shrink to 60.8% of the total population.

As of 2022, the demographic distribution in the UK revealed a population composition of 17.5% of individuals falling within the age range of 0-14 years, the majority of the population (63.4%) belonging to the age group of 15-64 years and 19.1% of the population aged 65 and above. Projections for 2050 suggest a shift in this demographic landscape, with a substantial increase in the percentage of individuals aged 65 and over, reaching 25%. Meanwhile, the proportion of individuals aged 15-64 years is expected to decrease to 58.5% (Leeson et al., 2013).

Additionally, there is a rising trend of older individuals among employed. For instance, between 2004 and 2022, the percentage of individuals aged 55 years or more in the total employed population within the EU increased from 12% to 28%. There was an increase from 9.3% to 18.5% of employed persons aged 55 or more in Slovenia, as reported by Eurostat (2023b). In the US, the US bureau of labour statistics (2023) reported that the proportion of older individuals in the labour force grew from 14.4% in 2014 to 38.8% in 2022. Moreover, in the UK, the Office for National Statistics (2022) revealed that individuals aged 50 and above have been the primary contributors to the growth in economic activity in recent years.

In 2022 the median age of the EU population was 44.4 years, varying across member states. The median age of the EU population is projected to increase by 3.8 years in the next three decades, reaching 48.2 years by 2050 (Eurostat, 2023c). The pace of change varies across countries, with Poland, Slovakia, and Malta experiencing significant

increases in median age, while France, Belgium, the Netherlands, and Denmark are projected to have slower changes. To compare, by 2050, the median age of the world population is projected to reach 36.2 years (Eurostat, 2020a).

2.2.2 Impact of increased life expectancy on society

On one hand, increased life expectancy signifies progress in medical advancements and improved living conditions. Many people have reasons to look forward to later life and further contribute to the society, especially if they can enjoy these additional years in good health. Many researchers (Didino et al., 2016; Eskhoor et al., 2015; Angelini et al., 2011) have revealed that older individuals often report higher life satisfaction and feel more connected to their families, friends, and local communities. Good at al. (2011) especially pointed out the positive impact of daily activities of life and state of independence on the level of life satisfaction. Moreover, the level of life satisfaction was in multiple studies proved to be directly and significantly correlated with health status of the individual (Papi & Cheraghi, 2021; Góngora & Solano, 2014; Jafari et al., 2010). Multiple studies have shown that older adults' life satisfaction levels decrease with the loss of physical health capabilities that advance with age (Borg et al. 2006; Baird et al., 2010; Chen, 2001).

Unfortunately, there are also many challenges of the growing number and proportion of older people in the society. Namely, the increase in life expectancy did not come with an increase in healthy life expectancy (HLE), meaning that people experience a large portion of their later life in poor health (Brown, 2015). Some researchers (Axelrad, 2018; Van Rijn et al., 2013; Brown, 2015) argue that population aging is likely to pressure downward economic growth by reducing the available labour supply, increasing age-related social costs, and affecting the sustainability of government finances. This negative coefficient might be explained by high rates of exiting the workforce or low productivity; both mechanisms affected by poor health and disability. A disability refers to any physical or mental condition (impairment) that hinders an individual’s ability to perform specific activities (activity limitation) and engage with their surroundings (Centers for Disease Control and Prevention, 2024).

These concerns are centred around the assumption that the old-age dependency ratio, which refers to the number of older people relative to the working-age population, will continue to rise. As this ratio increases, there is a decline in the size of the workforce available to care for the older generations. This has already led to increased financial burdens on governments, changes in retirement age policies, and lower levels of pension benefits (Eurostat, 2020a).

3 MEASURING LIFE SPANS

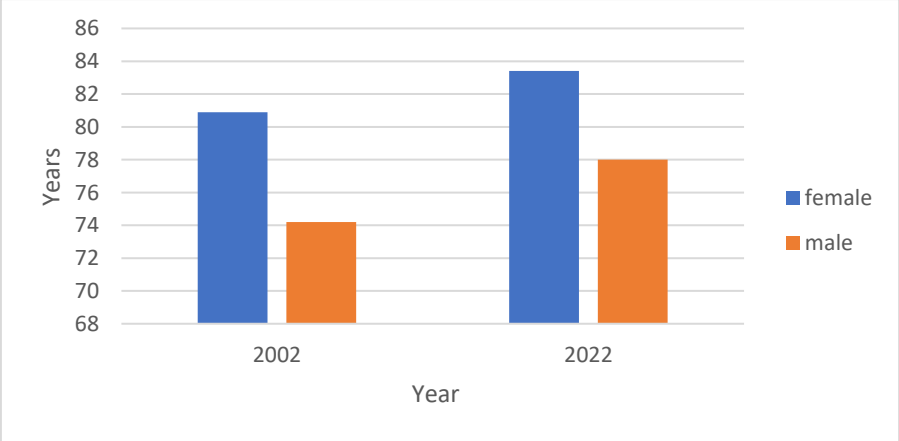
The extended lifespan can be attributed to a range of factors, including the reduction in child mortality, advancements in public health and medical technologies, greater awareness of the benefits associated with maintaining a healthy lifestyle, the transition from physically demanding occupations to service-oriented jobs, and overall enhancements in living conditions (European Commission, 2010).

According to Eurostat (2020a), the concept of life expectancy refers to the average additional years an individual at a specific age can anticipate living, assuming exposure to the prevailing mortality conditions observed during the given period. Life expectancy is calculated by considering age-specific death rates, which reflect the probabilities of dying at different ages. When life expectancy is discussed in terms of various age groups, starting from birth, life expectancy at birth represents the average number of years a newborn can anticipate living if exposed to the current mortality conditions throughout their entire life.

In the EU, life expectancy at birth has exhibited a noteworthy increase over a significant duration. Eurostat (2020a) indicates that, on average, life expectancy has risen by more than two years per decade for both genders since the 1960s. Furthermore, the gender gap in life expectancy at birth, wherein women historically had higher life expectancy than men, has gradually narrowed during the examined period as male life expectancy has increased at a faster pace.

According to Eurostat (2023d), between 2002 and 2022, there was an increase in life expectancy at birth for both males and females in the examined population. In 2002, the average life expectancy at birth for males was recorded at 74.5 years, which subsequently rose to 78.0 years in 2022. Similarly, females had a life expectancy at birth of 80.9 years in 2002, which increased to 83.4 years in 2022. Figure 1 shows the increase in life expectancy at birth for both genders during the observed period.

Figure 1: Life expectancy at birth, by gender, EU (2002, 2022)



Source: Eurostat (2023d).

3.1 Life Expectancy at 65

When studying aging populations, an important concept to consider is life expectancy at the age of 65. Eurostat (2020a) defines this measure as the average number of additional years that an individual of age 65 can anticipate living, assuming the current mortality rates remain constant. In the EU, this indicator has been increasing over time, reflecting improvements in longevity.

According to the Eurostat data (2023d), within the EU, a woman aged 65 could expect to live an additional 19.5 years, while a man of the same age had a considerably lower figure of 15.8 years in 2002. Life expectancy at the age of 65 increased to 21.2 for females and 17.8 for males in 2022. In the same year, among the EU Member States, Lichtenstein had the highest life expectancy at age 65, with women expecting to live 22.1 more years and men 21.6 more years. In Slovenia, life expectancy at age 65 for females accounted for 21.5 years, while for males 3.7 years less (17.8 years). Notably, women aged 65 generally had higher life expectancies than men across all EU Member States.

3.2 Working life expectancy

Improvements in life expectancy are driving the increase in working life expectancy, i.e. the number of years people are expected to be economically active (Loichinger & Weber, 2016). The increasing life expectancy and aging population worldwide have led to worsening dependency ratios, which, in turn, have driven the extension of working life through higher retirement ages (Parker et al., 2020).

Retirement constitutes a significant aspect in the discussion on aging, encompassing both the withdrawal from the workforce and the subsequent phase of life. However, it was only during the 20th century that retirement emerged as a distinct life chapter. The age at which individuals retire has undergone substantial changes throughout history (Majmundar & Hayward, 2018). In the past, it was normal to continue working even at older ages. For instance, Costa (1998) reports that in 1880, the labour force participation rate of US men aged 65 and older exceeded 75%. Over the following century, this rate steadily declined, dropping to below 20% by 1990, a trend mirrored in France, Germany, and the United Kingdom. With increased life expectancy, most workers today can anticipate a retirement period spanning two decades (Majmundar & Hayward, 2018).

Eurostat's statistics (2023e) show that as of 2022, young men aged 15 in the EU could expect to be part of the labour force for approximately 38.6 years, while their female counterparts could anticipate 34.2 years of active working life. Notably, the discrepancy between the two genders can be largely attributed to a higher proportion of women interrupting their careers to attend to family needs and the existence of different pension ages for men and women in certain EU Member States. Countries like the Netherlands, Sweden, Denmark, Germany, Malta, Ireland, and Cyprus displayed longer expected

working lives for young men, surpassing 40 years. Sweden was the only EU Member State where young women could expect to work for an equivalent duration of 40 years. Conversely, young women in Italy and Greece had relatively shorter anticipated active working lives, amounting to less than 30 years. In Slovenia, females could expect to work for about 35.5 years, while their male counterparts could expect to work 2.4 years more (37.9). Over the period from 2002 to 2022, the average duration of working life experienced an upward trend for both men and women across the EU countries. During this period, women's working lives increased by an additional 5.3 years on average, while men's increased by 2.9 years.

The decision regarding retirement has long attracted the interest of analysts and policymakers due to its profound impact on individual well-being and broader societal aspects. Choosing to extend one's working years allows for the accumulation of more savings and shortens the period of retirement spending, even though resulting in fewer years of leisure. At the societal level, alterations in retirement age influence taxes, transfers, labour force size, and the overall economy. Given that increased longevity often leads to a greater share of societal resources being directed toward the elderly, raising the retirement age can serve as a countermeasure to this trend (Majmundar & Hayward, 2018).

OECD Economics Department prioritizes the efforts addressing barriers in hiring and retaining older workers, as many policymakers are now pushing for a later retirement. This involves the removal of mandatory retirement ages and pension regulations that potentially discourage prolonged work engagement. In the current landscape, there exists a deficiency in both governmental and corporate investment in retraining initiatives for older individuals. Relying solely on initial education to equip individuals with skills for lifelong careers is becoming less feasible, particularly within the context of lengthened careers in a rapidly evolving world. There is a pressing need to enhance training tailored specifically to the requirements of senior employees, particularly in adapting to digital tools within the workplace. Enterprises can provide valuable assistance by enabling older workers to access retraining and upskilling opportunities, introducing more adaptable contracts with reduced working hours or remote work possibilities, and facilitating transitions to less physically demanding roles (Rouzet et al., 2019).

Most importantly, health problems and limitations can affect working life expectancy, as individuals may face difficulties in maintaining employment due to declining health or disabilities (Majmundar & Hayward, 2018). Studies by Department for Work and pensions (2017), Performance and innovation unit (2000), and van den Berg et al. (2010) have highlighted functional limitations caused by physical or mental health conditions, insufficient provision of workplace accommodations, a lack of suitable employment opportunities such as access to jobs with low physical demands, and caring responsibilities as the main reasons for premature exit from the workforce and absenteeism.

The influence of health on work participation is particularly significant for individuals aged 50 years and above, and it must be considered when aiming for prolonged and sustainable working lives (Parker et al., 2020). Eurostat (2020b) further supports that claim, as it was found that in 2019, 15.9% of the EU workforce aged 55-64 years opted for early retirement, among them, 15.8% cited reasons of illness or disability, and 14.2% mentioned dismissal or redundancy as the main factors for leaving work. Only 31.6% of people in this age group left their last job at a normal retirement age.

The UK Health Foundation's analysis (2022) reveals the population distribution by age of those who were economically inactive from 2014 to 2022. The number of individuals aged 50–69 who reported ill health as the cause of their inactivity experienced a gradual increase, rising from 22.3% to 27.3% between 2014 and 2022.

Parker et al. (2020) stresses the challenges to extending working lives if individuals are expected to continue working until a later age without considering their health problems and work-related disabilities. Therefore, the success of policies designed to delay retirement greatly depends on population health.

3.3 Healthy life expectancy

Given the global phenomenon of aging populations, it is crucial to ensure that the additional years of life are accompanied by good health to adequately address healthcare, social care, and pension needs. Healthy life expectancy, often referred to as healthy life expectancy or disability-free life expectancy, represent the projected number of years an individual is expected to live in a healthy state without severe disability or illness. Though healthy life expectancy has been used for many years, discrepancies in the definition of 'disability' and the methods of calculation have made it challenging to compare across different countries (Jagger, 2015).

As described by Jagger et al. (2007), the measurement of disability was previously established based on a hierarchy of basic Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL), and the concept of an interval of need. ADLs are basic self-care tasks like bathing, grooming, dressing and toileting, while IADLs are activities one does on a daily basis to take care of oneself and one's home, such as shop groceries, cook, clean, etc. (Jagger et al., 2001). The concept of an interval of need is a measure of disability and its severity according to the intervals that elapsed between the periods of necessary help (Isaacs & Neville, 1976). Participants in the study (Jagger et al., 2007) were considered moderately to severely disabled if they required human assistance to perform at least one of the following five ADLs: transferring to and from a chair, putting on shoes and socks, preparing a hot meal, moving around outside, and bathing or washing themselves. To measure diseases, participants at baseline were asked if they had ever experienced various conditions, including heart attack, diabetes, bronchitis, asthma, arthritis, stroke, hearing problems, and eyesight problems.

According to Eurostat's (2015) explanation, healthy life expectancy is separately computed for both men and women, at birth, and at ages 50 and 65, using the Sullivan method. The method uses on one hand data from period life table and from cross-sectional survey providing prevalence of given health condition (e.g. disability) on the other hand. Healthy life expectancy therefore relies on age-specific data concerning the prevalence of the population in healthy and unhealthy conditions, as well as age-specific mortality data. A healthy condition is characterized by the absence of functioning limitations and disabilities.

Since 2005, the EU has been reporting healthy life expectancy, a disability-free life expectancy derived from the annual Statistics on Income and Living Conditions (EU-SILC) survey, which has seen improved harmonization and comparability since 2008. To calculate this indicator, the widely used Sullivan method is employed. It takes into account the proportion of the population at different ages with and without disabilities, combined with mortality data. One of the main advantages of the indicator lies in its simplicity, utilization of readily available data, and independence from the population's size and age structure (Eurostat, 2020a).

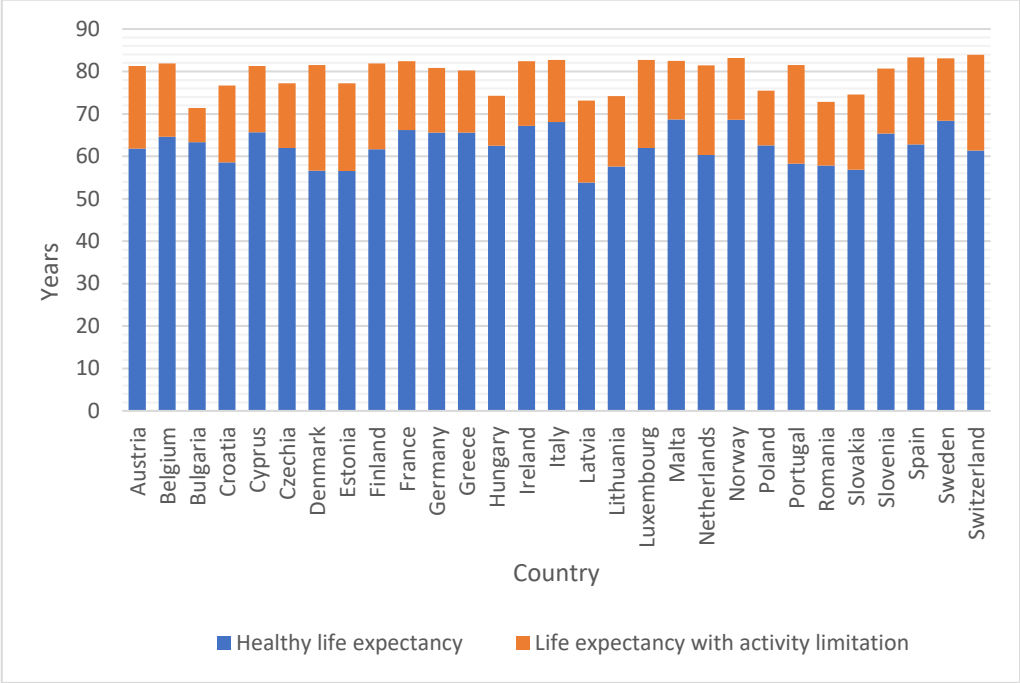
Brown (2015) emphasizes that unlike conventional life expectancy, healthy life expectancy considers both the duration and quality of life. For this reason, Jagger (2015) stresses the importance of monitoring trends in life expectancy and healthy life expectancy for guiding policy reforms aimed at compressing the period of ill health and dependence and avoiding the opposite scenario of increased years lived in ill health or dependence.

Determining healthy life expectancy has caught attention from both health and economic stakeholders as the presence of additional years spent in an unhealthy state, characterized by limitations in functioning or disability, may lead to a higher demand for supplementary healthcare and long-term care services. In fact, life expectancy, population morbidity, and extensions to working life are exhibiting inconsistent patterns when compared to healthy life expectancy (Jagger, 2015). Brown (2015) shows that life expectancy within the EU is rising at a faster rate than healthy life expectancy, leading to a gradual expansion of morbidity, which refers to the average number of years lived in poor health.

Figure 2 compares healthy life expectancy at birth and life expectancy at birth with activity limitation for both males and females within European countries in 2021. According to the data from Eurostat (2023f), there has been an observable increase in healthy life expectancy at birth for both women and men in the EU over the period from 2004 to 2021. For women, healthy life expectancy at birth rose from 63.7 years to 64.2 years, representing a gain of 0.5 years. Yet, during the same period, life expectancy at birth for women increased from 81.5 to 82.9 years, yielding a gain of 1.4 years, meaning that for women, just over 1/3 of the increase in life expectancy is spent in good health. Similarly, in this period, men experienced an improvement in their healthy life expectancy at birth for 1.1 years (from 62.0 years to 63.1 years), while total life expectancy increased for 2.2

years, from 75.0 to 77.2 years. Therefore, men spent only a half of the increase in their life expectancy in good health.

Figure 2: Life expectancy and healthy life expectancy at birth, by country, 2021



Source: Eurostat(2023f).

Furthermore, Office for National Statistics (2024) reports that in 2004, in the UK, the life expectancy for females was 81 years, with a healthy life expectancy of 63 years, while for males in the same year the life expectancy was 76.6. years and healthy life expectancy stood at 61.5 years. Moving forward to 2021, there was a slight increase in life expectancy figures. For males, the life expectancy rose to 78.6 years and healthy life expectancy followed a slight increase to 61.84 years, comprising 79% of their total lifespan. Similarly, for females, the life expectancy increased to 82.6 years, while healthy life expectancy decreased to 62.1 years, representing 75% of their total lifespan.

Based on data by WHO (2020), in the year 2000, female life expectancy stood at 79.2 years and a healthy life expectancy of 67 years. During the same year, male life expectancy was slightly lower at 74.1 years and a healthy life expectancy of 64.6 years. In 2019, there was an increase in life expectancy for both genders. Male life expectancy rose to 76.3 years, with a healthy life expectancy of 65.2 years, accounting for 85% of the total lifespan. Similarly, female life expectancy increased to 80.7 years, with healthy life expectancy remaining at 67 years, constituting 83% of the total lifespan.

Table 1: Life expectancy and healthy life expectancy across global regions

year	region	life expectancy	healthy life expectancy	% of healthy years
2000	US	76.65	65.8	85.90%
2019	US	78.5	66.1	84.25%
2004	EU	78.25	62.82	80.45%
2021	EU	80.05	63.65	79.55%
2004	UK	78.8	62.25	79.05%
2021	UK	80.6	61.9	76.90%

Source: Eurostat (2023f); Office for National Statistics (2024); WHO (2020)

Table 1 presents global data for life expectancy, healthy life expectancy and proportion of healthy years within total lifespan in the EU, UK, and US. Nonetheless, a direct comparison between regions is not feasible as data for same years of reporting could not be found.

Observed trends across regions clearly indicate that the increase in healthy life expectancy has not fully kept pace with the overall extension of life expectancy. This question of whether morbidity would expand or be compressed as average lifespan increases has been a topic of debate in the past. Only decreasing death rates while not considering reducing age-specific morbidity rates will unavoidably increase overall morbidity, including cognitive decline and severe disability. Crimmins et al. (2010) have defined the morbidity process concerning populations as a health change due to aging, which starts with physiological dysregulation evidenced by various biological risk factors. This is followed by the diagnosis of diseases, functional loss, disability, frailty, and ultimately, mortality. The term mortality pertains to the number of deaths resulting from the specific health event in question. It is typically expressed as a rate, denoted as the death rate, which is commonly presented per 1000 individuals. This rate is determined by dividing the total number of deaths within a defined timeframe and population by the overall population size (Hernandez & Kim, 2022).

According to Jagger et al. (2007), the most substantial differences in life expectancy between participants with and without diseases were observed in men with stroke (4.8 years) and diabetes (4.4 years), and in women with stroke (4.6 years) and diabetes (5.6 years). All conditions, except arthritis and hearing impairment for both men and women, and visual impairment for men, resulted in a significant reduction in life expectancy. The author additionally found that stroke had the most profound effect on healthy life expectancy at age 65, leading to 6.5 years decrease in healthy life expectancy for men and 5.8 years for women. Interestingly, the years of disability-free life years gained without stroke, cognitive impairment, arthritis, or visual impairment exceeded the life expectancy, indicating that eliminating these disorders would compress the period of disability.

Evidently, the increase in healthy life expectancy is primarily attributed to the reduction in mortality rates rather than a decrease in the number of years lived with disability. Thus, while extra years are being added to our lifespan, the quality of life during these additional years is compromised as these additional years are predominantly characterized by poor health and reduced well-being. The remarkable increase in life expectancy has led to a higher risk of various health issues, disabilities, dementia, and advanced aging before death. In the past, people tended to pass away at a relatively young age, often from acute conditions, while nowadays, more people are living longer, yet facing chronic degenerative diseases, experiencing years of multiple health issues (Brown, 2015).

For this reason, Eurostat (2020a) accentuates that the limited progress in healthy life expectancy among older adults necessitates innovative approaches to address the associated health and social burdens. Achieving an extended period of healthy and productive life, commonly referred to as healthy life expectancy, is crucial for individuals, communities, and societies as a whole.

3.3.1 Health state of older people

Ageing Europe report by Eurostat (2020a) signifies the role of state of health in gauging an individual's overall well-being, and it is closely linked to aspects of personal autonomy. While many older individuals do not expect perfect health during their later years, they wish for a certain level of physical condition that allows them to continue working, socializing, maintaining independence, and self-care.

Eurostat (2020a) reports that as people age, there is an increasing proportion of the adult population facing challenges in their daily lives, such as basic activities like eating, bathing, and dressing. This trend can largely be attributed to the relatively higher occurrence of physical, sensory, and cognitive limitations among older individuals, along with high occurrence of non-communicable diseases, affecting their vision, hearing, mobility, communication, or memory capabilities.

Levine et al. (2019) points out that chronic diseases can significantly diminish the quality of life not only for patients but also for their families, impacting their ability to derive pleasure from life, compromising family dynamics, and imposing financial burdens. Individuals fighting chronic diseases often encounter challenges in sustaining employment, leading to elevated rates of absenteeism and diminished earnings compared to their healthier peers. The occurrence of functional constraints can evoke distress, and the prevalence of depression.

Brown (2015) found that the issue with merely increasing life expectancy is that it results in increased morbidity due to the prolonged exposure to age-related diseases, disabilities, cognitive decline, and dysfunctions. Numerous serious conditions, such as cancer, heart disease, stroke, respiratory disease, kidney disease, dementia, arthritis, and osteoporosis,

show increased prevalence with age. For example, in 2022, the prevalence of dementia in the US ranged from 5.0% among those aged 65-74 years to 13.1% among those aged 75-84 and further to 33.2% among people of age 85 and older (Rajan et al., 2021).

Chronic diseases also stand as the primary catalysts behind escalated healthcare expenses in the US. In 2023, cumulative direct expenditures for the medical treatment of chronic illnesses surpassed 4.1 trillion USD, with diabetes, Alzheimer's, and osteoarthritis emerging as the most financially burdensome conditions (Centers for Disease Control and Prevention, 2023a). These financial burdens are anticipated to rise in tandem with the aging population (Levine et al., 2019).

Crimmins (2015) explains that while the prevalence of certain diseases has globally declined among the elderly in recent decades (e.g., bronchitis and emphysema due to reduced smoking rates), others like diabetes have seen a steady increase. The prevalence of chronic diseases like cancer and heart disease has also risen from the 1970s to the 1990s. Although heart disease and stroke prevalence might have decreased slightly after 2000, cancer and diabetes continue to rise. This can partly be attributed to improved diagnosis but is mainly indicative of enhanced survival among those with the conditions. As mortality is being defeated by delaying death amongst those with diseases, the prevalence of diseases itself increases in the population.

It is evident that the proportion of people perceiving their health as good or very good decreases as they age (Eurostat, 2023g). Self-assessed health status is a valuable measure that reflects an individual's perception of their own health, categorized as very good, good, fair, bad, or very bad. In 2022, approximately 67.8% of the EU adult population (aged 16 years or older) rated their health as good or very good. However, this percentage decreased to 47.1% among older people aged 65-74 years, further declining to 32.6% among those aged 75-84 years, and around 21.0% for individuals aged 85 years or older. The rate at which the older population perceived their health to be deteriorating varied significantly among the EU Member States. Ireland (56.1%), the Netherlands (45.8%) and Belgium (41.0%) ranked at the top according to the share of people aged 85 and above reporting to be in very good or good health. On the contrary, Lithuania (2.0%) and Slovakia (2.5%) had the lowest shares of people aged 85 and above to be in very good or good health.

Nonetheless, the pattern of declining health with age was consistent across all EU Member States in 2022, however varied between the genders. In the same year, the proportion of older men (aged 65 years or older) in the EU who perceived their health as good or very good was 42.0%, which was 5.2 percentage points higher than the corresponding share for older women (36.8%).

According to Eurostat statistics, in 2022, almost three-quarters (74.5%) of oldest-old people (aged 85 years and older) in the EU reported having a longstanding illness or health problem. This share decreased within population aged 75-84 years, with approximately

two-thirds (66.5%) affected, and even further decreased (56.2%) for people aged 65-74 years. In the same year, the share of old women (aged 65 years or older) in the EU suffering from a long-standing illness or health problem was 62.4%, 2.1 percentage points higher than the corresponding share for older men (60.3%) (Eurostat, 2023h).

Despite efforts through regular checkups and screenings, chronic illnesses cannot always be prevented for some older individuals, as the prevalence of chronic diseases typically increases with age. Eurostat statistics (2023i) reveal that in 2019, more than half (54.6%) of all people aged 75 years or older in the EU suffered from high blood pressure during the 12 months preceding the survey, while relatively high shares of this age group experienced arthrosis (46.0%) and back problems (39.0%). Notably, a higher proportion of women, rather than men, aged 75 years or older in the EU suffered from chronic diseases such as arthrosis, back and neck problems, high blood pressure, and chronic depression in 2019, which can be partially explained by longer life expectancy among women. There were some chronic diseases that affected a higher proportion of older men, although the differences between the sexes were relatively small. These diseases included heart attacks, chronic lower respiratory diseases, and diabetes, among others.

In 2022, 19.1% of people aged 50.64 years reported being in poor health in the US, while the share rose to 23.5% among people aged 65 years and over. Moreover, 53.9% people aged 75 years and over were diagnosed with arthritis, 64.4% of them were diagnosed with hypertension and 19.7% experienced coronary heart disease, indicating double or even triple the share of prevalence of these diseases among the population aged younger than 65 years (Centers for Disease Control and Prevention, 2023b).

Health state follows the same trend within the UK population as well. Office for National Statistics (2023) reveal that in 2021, 57.7% of the older population aged 65 or over reported to be in good or very good health. A study by Kingston et al. (2018) showed that by 2035 there will be 67.8% of older people within the UK that will be affected by multiple diseases and impairments such as cancer, arthritis, diabetes, chronic heart disease, depression, and cognitive impairment. Already in 2015, over half (54%) of the studied population (people aged 65 and over) had two or more diseases. Based on the study, arthritis was the most commonly reported disease (48.6%), while diabetes was the least (14.7%). Same as within the US, the share of population affected by two or more diseases increased with age.

In 2021, only 10.9% of people aged 21 to 64 reported having disability in the US. The percentage grew significantly among individuals aged 65 to 74 to 23.9% and even further to 47.1% for persons ages 75 and more (Cornell University, 2021). Comparable trend is seen also within the UK population. Disability increased significantly with age, with over 80% of individuals aged 85 years or more reporting a disability. Moreover, disabilities in late life were often multiple and severe, with 50% of people aged 85 years or more requiring care and/or assistance with daily activities (Office for National Statistics, 2014).

Eurostat (2022a) shows that in 2019, the share of people aged 65-74 years in the EU experiencing severe difficulty in seeing was only slightly higher at 2.6%, compared to the average for the entire adult population (defined here as people aged 15 years or older) at 1.2%. However, a much higher proportion (7.6%) of people aged 75 years or older in the EU faced severe difficulty in seeing. Similarly, the share of the EU adult population with severe difficulties in hearing was 2.1% in 2019, with higher shares among people aged 65-74 years (6.3%) and those aged 75 years or older (16.0%). Despite the potential benefits of regular exercise in preventing elderly mobility issues as Langhammer et al. (2018) explains, almost one-third (31.1%) of people aged 75 years or older in the EU reported severe difficulties in walking, while close to one-tenth (10.7%) of people aged 65-74 years faced this limitation.

Similarly, older individuals also exhibited a higher utilization of prescribed medicines. In 2019, just under half (37.7%) of the EU adult population (defined here as people aged 15 years or older) reported using prescribed medicines in the two weeks prior to the survey interview. This proportion increased with age and reached its peak among people aged 75 years or older, reaching 86.1%.

3.3.2 Causes of death

According to Eurostat's definition (Eurostat, 2016), cause of death is the disease or injury that initiated the series of morbid events leading directly to death, or the circumstances of the accident or violence that resulted in the fatal injury. This information is crucial for health authorities to determine the focal points of their public initiatives, such as launching health information programs to prevent illnesses or diseases or adjusting health expenditure (Lowrance, 2003).

According to WHO (2023a), the four major non-communicable diseases (cardiovascular disease, cancer, chronic respiratory disease, and diabetes) cause annually over 41 million deaths worldwide. WHO defines non-communicable diseases (NCDs), also known as chronic diseases, as generally of long-time duration, slow progression diseases, which are not passed from person to person. In 2000, non-communicable diseases accounted for 61% of global deaths and by 2019, the percentage had risen to 74%, while the communicable group's share had decreased to 18%. Deaths due to injuries remained relatively stable at around 8%. This overall trend was evident across all regions around the world.

The projected population growth and ageing will lead to a significant rise in the total number of annual deaths in the coming decades. According to United Nation (UN) projections, the global annual death toll is expected to reach nearly 90 million in 2048. Among these, the World Health Organization (2023a) estimates that 77 million deaths will be attributed to non-communicable diseases, signifying a 90% increase compared to 2019.

In 2021, the primary causes of death among individuals aged 65 years or older in the EU were diseases of the circulatory system, cancer, and diseases of the respiratory system, as reported by Eurostat (2023j). Cancer was the leading cause of death for both men and women between the ages of 55 and 74 years. However, from the age of 75 years onwards, diseases of the circulatory system are the most prevalent cause of death. In the same year, more men than women in the EU succumbed to the six principal causes of death, including diseases in the circulatory system, cancer, diseases of the respiratory system, diseases of the nervous system and sense organs, diseases of the digestive system, as well as mental and behavioural disorders.

3.3.3 Habits

Considered from a broader perspective, health extends beyond the mere absence of disease (WHO, 1946). Especially non-communicable diseases arise from a complex interplay of genetic, physiological, environmental, and behavioural factors. Among the behavioural risk factors, are listed excessive alcohol consumption, smoking, physical inactivity, and an unhealthy diet as the ones that can be modified. Additionally, metabolic risk factors like elevated blood pressure, overweight and obesity, high blood glucose levels, and high blood fat levels also contribute to the development of non-communicable diseases (WHO, 2023a).

In a significant epidemiological study conducted by Jagger et al. (2007) in the UK, with a 10-year follow-up of individuals, it was revealed that targeting specific conditions like stroke, coronary heart disease, diabetes, and cognitive impairment could lead to substantial reductions in years of disability among older individuals. Several relevant studies by Nusselder et al. (2000), Fries (2002) and Hubert et al. (2002) have emphasized the importance of improving lifestyle and health behaviours. These studies have concluded that adopting better nutrition, quitting smoking, reducing obesity, and engaging in more physical activity can have a greater impact on reducing morbidity compared to mortality. These factors play a crucial role in preventing conditions such as stroke, chronic heart disease, and diabetes, which have significant effects on disability later in life.

WHO (2023a) addresses how effective regular physical activity is in both preventing and managing non-communicable diseases, including heart disease, stroke, diabetes, and various cancers. It was proven to decrease the risk of developing non-communicable diseases by 20-30%. Moreover, it plays a significant role in preventing hypertension, maintaining a healthy body weight, and enhancing mental health, overall quality of life, and well-being. The term "physical activity" encompasses all forms of movement and can be enjoyed by people of all skill levels, whether through walking, cycling, sports, active recreation, play, or other means.

Despite the numerous benefits of physical activity, current global estimates indicate that a concerning proportion of the population remains inactive. WHO (2022) advises adults 18-

64 years old to do at least 150-300 minutes of moderate-intensity aerobic physical activity or at least 75-150 minutes of vigorous-intensity aerobic physical activity throughout the week. Older adults aged 65 and above are advised to do the same as younger adults and should add also physical activity that emphasizes functional balance and strength training three or more days a week. Global status report on physical activity 2022 published by WHO (2022) reveals that approximately one in four adults and a staggering 81% of adolescents do not engage in sufficient physical activity. In EU alone, there were more than 43% of population aged 70 or more that were insufficiently physically active in 2016. In the UK the share was even a little higher at 51.8% and the highest in the US at 56%.

The consumption of fresh fruits and vegetables is often cited as a contributing factor to increased longevity and protection against a range of illnesses and diseases, such as cancer or osteoporosis. In 2019, older people (aged 65 years or more) in the EU were more likely to incorporate fresh fruits and vegetables into their daily diet compared to the overall adult population (defined as people aged 16 years or more). About 61.6% of older people consumed 1 to 4 portions of fresh fruit and vegetables daily, while only 52.1% of younger generations (aged 64 and less) consumed the same amount of fruit and vegetables daily (Eurostat 2022b).

Furthermore, relatively high and persistent levels of alcohol consumption can lead to chronic physical or mental illnesses. In 2019, approximately 21.5% of older people in the EU consumed alcohol once a week, and 15.8% of the same population reported daily alcohol consumption. These figures were quite similar to the overall proportion among the working-age population, where 32.2% of individuals aged 18-64 years consumed alcohol at least once a week, and only 6.4% reported daily consumption, which was significantly lower than that observed among older individuals (Eurostat, 2022c).

While smoking rates have been generally declining, smoking remains the most significant health risk, imposing a major burden on healthcare systems. Interestingly, Ageing Europe report by Eurostat (2022d) discloses that although a higher percentage of older people compared to the working-age population consumed alcohol at least once a week, older individuals were less likely to be daily smokers. In 2019, 9.2% of older people in the EU reported daily smoking, while the corresponding figure for the working-age population was more than two times higher, at 22.5%. Similarly, in the US, 8.5% of older population were daily smoking daily, and the share within the working-age population was approximately twice as high (15.9%) (Centers for Disease Control and Prevention, 2023c).

Moreover, older people were found to be more susceptible to obesity than the average population, posing a serious public health concern due to the increased risk of chronic conditions such as cardiovascular disease, type-2 diabetes, coronary heart disease, and certain cancers. In 2019, over one-fifth (22.2%) of individuals aged 65-74 years in the EU were classified as obese, compared to an average of 16.1% among the adult population (aged 16 years or more). For people aged 75 years or more, around 17.3% of this age group

were obese. The prevalence of obesity tended to decline more rapidly among oldest-old individuals (Eurostat, 2022e). Similar trend can be observed in the US from the National Health and Nutrition Examination Survey, revealing that 44.8% of individuals aged 60 to 69 years were classified as obese, while the share of population aged 70 and over was slightly lower at 40.4% in 2018 (Centers for Disease Control and prevention, 2021).

Within the EU, there was little discrepancy in obesity between genders in 2019. For men and women aged 65 to 74 years, there were basically no differences in the shares of individuals classified as obese. Conversely, the share of older women aged 75 years who were obese (19.0%) was approximately 4.1 percentage points higher than that of older men in the same age group (14.9%). (Eurostat, 2022e).

4 INCREASING HEALTHY LIFE EXPECTANCY

A study from (Ahlawat et al., 2021) projects that by implementing interventions more promptly and consistently over the next two decades, the burden of disease could potentially decrease by approximately 30%, which would result in remarkable enhancements in health. The burden of disease refers to the overall effects of a specific illness or a variety of detrimental conditions on the well-being of a population. These effects encompass various dimensions such as health, social implications, and the economic impact on society (Hessel, 2008). An individual of around 65 years old in Europe by 2040 could experience the same level of health as a 55-year-old today, and an additional 11 million lives could be saved by 2040.

The majority (85%) of this prospective enhancement in health would stem from addressing preventable health issues linked to noncommunicable diseases, while the remaining (15%) would result from decreasing injuries due to road traffic accidents, falls, and self-harm, and mitigating the risk posed by infectious diseases, addressing nutritional deficiencies, and enhancing childbirth safety (Ahlawat et al., 2021).

The same analysis (Ahlawat et al., 2021) suggests that approximately two-thirds of the potential for improvement lies within realms of health promotion, prevention, health literacy, and creating healthier environments. This would involve a more consistent, comprehensive, and early utilization of widely available and highly cost-effective strategies.

Authors of the McKinsey report (2020) on economic costs of preventive healthcare reveal that investing in fostering conditions for better health could mitigate disparities in health outcomes across different groups, alleviate pressure on acute healthcare services, and enhance resilience in the face of forthcoming health-related challenges and disruptions.

The study found that achieving better health outcomes would lead to a reduction in the prevalence of health conditions, resulting in fewer instances of sick leave, work absences,

and long-term disabilities. This aspect alone accounts for 29% of the overall economic impact that stems from health enhancement (Ahlawat et al., 2021). The potential for expanded labour force participation therefore emerges as a significant driver of economic impact. OECD reports (2009) that with more health-conscious individuals experiencing prolonged periods of good health and fewer limitations due to caregiving responsibilities, a larger portion of the population might opt to work and extend their working years for personal satisfaction and increased retirement income and be less inclined to exit the job prematurely due to existing age-related pension or disability arrangements. If the effective retirement age were to extend by an average of five years and greater economic participation were achieved among individuals with disabilities and informal caregivers, this shift could result in a remarkable 1.3 trillion USD increase in regional GDP, accounting for 53% of the total economic impact. This transformation in health could effectively counter projected labour shortages in Europe over the next two decades, leading to a 10% expansion in the workforce size by 2040 (Ahlawat et al., 2021).

4.1 Preventive health care

Multiple researchers (Lunenfeld, B., Katz, D. L., Ali, A., Jagger, C.) are of the opinion that promoting healthy aging, which involves maintaining the elderly population's well-being and preserving their autonomy and self-sufficiency throughout a more extended phase of their remaining years, is widely acknowledged to directly influence both healthcare and long-term care expenses. Furthermore, OECD (2009) emphasizes that promoting healthy ageing inherently enhances the overall well-being of the elderly.

Preventive medicine encompasses the care of individual patients as well as public health practice, with its primary focus on disease prevention rather than direct treatment. Both preventive medicine and public health share common goals of promoting overall health, preventing specific illnesses, and utilizing epidemiological concepts and methods to achieve these aims (Katz & Ali, 2009).

While preventive medicine aims to enhance individuals' lives by assisting them in improving their health, public health strives to promote well-being among populations through organized community endeavours. Despite discussions often treating preventive medicine and public health as separate entities, there is a seamless continuity among various aspects: the implementation of preventive medicine by healthcare professionals (clinical preventive services), individual and familial efforts to improve health and the well-being of loved ones, and the endeavours of governments and voluntary organizations to attain similar health objectives for entire populations. The distinction between preventive medicine and public health practice, like the boundary between prevention and treatment, is not sharply defined (Katz & Ali, 2009).

The emergence of enhanced pan-European and global cooperation, the exchange of knowledge and data, collaborative partnerships, and dynamic ecosystems is contributing to

the advancement of health promotion and prevention. Notably, the EU Commission's EU4Health initiative represents an initial stride in this direction, while WHO-Europe is also prominently engaged in facilitating such endeavours (Ahlawat et al., 2021). Namely, the United Nations General Assembly officially designated the period from 2021 to 2030 as the UN Decade of Healthy Ageing and entrusted the World Health Organization with leading its implementation. This global initiative serves as a collaborative endeavour uniting governments, civil society, international organizations, professionals, academia, the media, and the private sector to promote extended and healthier lifespans (WHO, 2020).

Spanning from 2021 to 2030, the UN Decade of Healthy Ageing is dedicated to enhancing the well-being of older individuals, their families, and communities while also addressing health disparities. This collective endeavour revolves around four core domains: fostering a shift in societal attitudes towards age and ageism; cultivating communities that empower the capabilities of older individuals; providing person-cantered integrated healthcare and primary services tailored to the needs of seniors; and ensuring that older people requiring it have access to high-quality long-term care (WHO, 2020).

The foundation of the Decade is established on the WHO Global Strategy and Action Plan, as well as the United Nations Madrid International Plan of Action on Ageing. The first Strategy focuses on main five strategic objectives such as: commitment to action on Healthy Ageing in every country; developing age-friendly environments; aligning health systems to the needs of older populations; developing sustainable and equitable systems for providing long-term care (home, communities, institutions); and improving measurement, monitoring, and research on Healthy Ageing (WHO, 2020).

In April 2002, representatives from governments worldwide gathered in Madrid, Spain, for the Second World Assembly on Ageing. This assembly collectively decided to adopt a comprehensive global Plan of Action encompassing a wide range of commitments applicable to United Nations Member States across the globe. It focuses on three core priority directions: the integration of older individuals into development, the enhancement of health and well-being throughout the ageing process, and the establishment of supportive and enabling environments (UNECE, n.d.).

The UN Decade of Healthy Ageing operates in alignment with the United Nations Agenda 2030 on Sustainable Development and its corresponding Sustainable Development Goals (WHO, 2020). The 2030 Agenda lays out a comprehensive blueprint for achieving sustainable development on a global scale while upholding the human rights of all individuals. This agenda emphasizes inclusivity and equality, aiming to ensure the attainment of Sustainable Development Goals (SDGs) for all segments of society, including the most vulnerable groups such as older persons (UNDP, 2018).

As an example, SDG 3, "Ensure Healthy Lives and Promote Well-Being for All at All Ages," directly addresses the implications of population aging. The aging population

places escalating pressure on public healthcare systems to adapt and cater to the increasing demand for age-appropriate care, encompassing long-term care, preventive measures, disease detection, and treatment services and technologies. The confluence of population aging shifts in epidemiological patterns, and changing lifestyles contributes to the heightened prevalence of non-communicable diseases. The goals outlined in SDG 3, which prioritize good health and well-being, encompass a range of targets that bear relevance to issues linked with aging. In this manner, the EU's commitment to the 2030 Agenda and its alignment with SDG 3 reflect its recognition of the multifaceted nature of aging-related challenges and its active pursuit of measures aimed at fostering a healthier and more resilient aging population (UNDP, 2018).

The European Union shows further engagement with the issue is reflected in its introduction of the European Innovation Partnership in Active and Healthy Ageing (EIP on AHA). This partnership seeks to stimulate innovation in the utilization of digital technologies to promote active and healthy aging and involves forming collaborative networks that bring together stakeholders at EU, national, and regional levels across various domains to address specific societal challenges and facilitate innovation. The EIP on AHA, established in 2011, was the pioneering EIP, concentrating on the changing demographics and the promotion of active and healthy aging within Europe. Its objectives encompass a Triple Win for Europe: Enhancing the health and quality of life of older Europeans; Supporting the sustainability and efficiency of healthcare systems and boosting the competitiveness of EU industries by expanding into new markets (European Commission, 2022).

Starting in 2021, the EIP on AHA has closely aligned its goals with the life-course approach outlined in the Green Paper on Ageing. It has directed its efforts towards scaling up and implementing digital tools for lifelong health promotion and prevention, lifelong learning, empowerment through digital tools, the advancement of age-friendly environments, and the growth of the European Silver economy and digital health ecosystem. This initiative has embraced a more collaborative approach, facilitated by the establishment of the community platform "Active and Healthy Living in the Digital World” (European Commission, 2022).

Furthermore, the Joint Action CHRODIS PLUS, spanning three years from 2017 to 2020, is a venture funded by the European Commission and collaborative organizations. It encompasses forty-five beneficiaries from 21 European countries. The overarching objective of JA CHRODIS PLUS is to provide support to Member States by means of cross-national endeavours, building upon the initiatives identified in JA CHRODIS, with the aim of alleviating the burden of chronic illnesses, enhancing the sustainability of healthcare systems, and cultivating human capital. The primary focus lies on concrete trans-national initiatives that hold the potential to stimulate health and chronic disease policies within Member States, leading to improved health outcomes. More specifically, JA CHRODIS PLUS aims to facilitate the adoption of innovative policies and practices

related to patient empowerment, health promotion, prevention, quality management of chronic diseases and multiple health conditions, and fostering the adaptation of the employment sector to cater to individuals with chronic health conditions (Barnfield & Savolainen, 2019).

Envisioning a society where individuals can realize their maximum potential for health and well-being throughout their lives, the US initiative Healthy People 2030 is driven by a mission to advance, reinforce, and evaluate the nation's endeavours to enhance the health and well-being of all citizens. Healthy People 2030 stands as the fifth evolution of this initiative, building upon accumulated knowledge to address current public health imperatives (US Department of Health and Human Services, n.d.).

Central to Healthy People 2030's objectives are its overarching goals, each of which strives to attain healthier, flourishing lives free from preventable diseases, diminish health disparities, and create environments that foster optimal health potential. By promoting healthy development and behaviours across all life stages and involving leadership and stakeholders from various sectors, the initiative aims to encourage actionable policies that amplify health and well-being for everyone (U.S. Department of Health and Human Services, n.d.).

Further efforts in the US antiaging field is promoting also The American Academy of Anti-Aging Medicine (A4M). It is a nonprofit organization active in the field, training, and certifying physicians in this specialty. According to A4M, a transformative shift in the approach to aging can be achieved through a comprehensive array of interventions encompassing hormones, antioxidants, adjustments to lifestyle, and physical activity. These measures encompass maintaining a healthy body weight, discontinuing smoking habits, engaging in regular exercise, nurturing active social and sexual lives, embracing mental stimulation, avoiding stress, adopting a wholesome diet, and practicing moderation. The A4M contends that these interventions not only contribute to anti-aging effects but can also potentially extend human life expectancy (Ok, 2022).

OECD (2009) emphasizes how extensive the potential range of global policies geared towards promoting "healthy ageing" is. However, all endeavours focused on enhancing healthy ageing can be categorized into four overarching domains: Enhanced incorporation into the economy and society, fostering healthier lifestyles, tailoring health systems to cater to the elderly's requirements, and addressing fundamental social and environmental aspects that influence healthy ageing.

Katz and Ali (2009) explain that the scope of preventive medicine as a discipline has historically encompassed primary, secondary, and tertiary prevention. However, only the first of these levels is nominally considered exclusively within the domain of "preventive" medicine compared to other medical disciplines. Primary prevention stops the progression of the disease by eliminating its causes or enhancing the body's resistance to it. Secondary

prevention intervenes before the disease shows symptoms, while tertiary prevention reduces the physical and social impacts of symptomatic disease.

Report prepared by McKinsey (2020) highlights a significant potential for enhancing global health, although the effectiveness of established interventions varies significantly in relation to specific diseases. A substantial portion, more than 70%, of the potential health improvements can be realized through primary preventive measures such as improving environmental conditions, promoting healthier lifestyles, tackling underlying social determinants, and expanding the reach of vaccinations and preventive medical practices. Conversely, the remaining 30% of potential improvements would result from the actual treatment of diseases and acute conditions using proven therapeutic approaches, encompassing medications and surgical interventions.

4.1.1 Primary prevention

Primary prevention encompasses health promotion, fostering general well-being, thereby reducing the chances of disease, disability, and early death in a nonspecific manner. For instance, advocating physical activity, healthy dietary habits, quitting smoking, and managing stress are the most common policies of primary preventive care (Katz & Ali, 2009). Many studies already over 20 years ago (Nusselder et al., 2000; Fries, 2002; Hubert et al., 2002) have primarily centered around enhancing lifestyle and health habits that will have a greater impact on reducing morbidity as opposed to mortality (Jagger, 2007).

OECD (2009) stresses the positive impact of physical activity on both the duration and quality of elderly individuals' lives, while fostering independence. Nevertheless, as individuals age, their activity levels often decline. Some indications suggest that policies designed to encourage physical activity can counteract this decline.

Same report (OECD, 2009) points out that even though energy demands decrease as people age, the need for essential nutrients remains constant. Consequently, focused efforts are necessary to promote healthy dietary habits among older individuals. Managing substance use/misuse is one of most important focuses of policy makers. While initial smoking frequently occurs during adolescence, the adverse long-term consequences predominantly affect the elderly. Therefore, promoting smoking cessation and lowering excessive alcohol consumption constitute critical policy goals.

Improved well-being is likely pivotal for advancing the long-term well-being of the elderly, however, given that it necessitates alterations in individuals’ habits, improvements in this aspect of policy might prove challenging to implement. While the potential to modify lifestyles is viable at any age, it's evident that changing behaviours earlier significantly raises the probability of an extended period of better health (OECD, 2009).

Structural improvements entail changes within society that simplify the adoption of health-conscious choices. For instance, Katz and Ali (2009) studied how accessibility of variety of nutritious and appealing foods in stores at reasonable prices challenges changing one's diet. Similarly, engaging in exercise might be hindered if activities like cycling or jogging pose risks due to traffic or safety concerns.

At a more fundamental level, health promotion is closely tied to ensuring basic life necessities, which includes safeguarding against poverty, environmental pollution, discrimination, social and economic inclusion (Katz & Ali, 2009). Preventive efforts also encompass promoting secure living to reduce accident incidents and supports initiatives to combat violence and depression. Such mental health issues, spanning from depression to dementia and psychiatric disorders, are prevalent among the elderly in OECD nations and contribute to increased institutional care requirements. Also extending one's working life holds significance due to the role work plays as a vital social network. For those who are no longer employed, enhancing "healthy aging" can involve fostering enhanced social integration by engaging in collective endeavours within the community such as involvement in charitable or community organizations, among others (OECD, 2009).

Substandard housing conditions, often endured by low-income households, can according to OECD (2009) detrimentally impact health as these areas are usually lacking essential services and public transportation. Fostering a secure and pleasant environment has the potential to motivate individuals to engage in more activities and can contribute to diminishing feelings of social isolation and loneliness.

For this reason, OECD (2009) places great emphasis on amplifying health literacy to foster improved self-care. Facilitating access to technology like information and communication technology and the Internet can empower individuals to better comprehend their conditions and make adjustments in their lives for optimal management.

These connections underline the interplay between preventive medicine and public health. The principles of health promotion are applicable to both infectious and non-infectious diseases. Many non-infectious diseases have an initial stage where causal factors begin to induce physiological abnormalities. The objective of activities that optimize one’s lifestyle is to mitigate risk factors in a favourable direction (Katz & Ali, 2009).

4.1.2 Secondary prevention

Secondary prevention pertains to identifying and managing pre-symptomatic illnesses, along with slowing their progression into symptomatic diseases (Katz & Ali, 2009). The health assessment associated with anti-aging therefore serves as a fundamental approach for detecting indicators and manifestations of aging. This involves the evaluation of factors such as blood vessel health, hormone levels, sensory functions, as well as screenings such as cancer screening (e.g., mammography, colonoscopy) and cardiac risk assessment These

assessments are integrated into the broader context of comprehensive general health checkups and serves to identify and address early signs of both physical and mental aging (Ok, 2022).

As outlined in the OECD report (2009), the escalating prominence of chronic disease within the elderly demographic necessitates more fitting approaches, achieved through improved collaboration and patient-centric care. Priority encompasses enhanced and more frequent monitoring of individuals with chronic conditions and the facilitation of more coherent care delivery. A mounting proportion of the elderly suffer from one or more chronic health conditions, while healthcare structures have, over time, evolved into more specialized and fragmented entities. Emphasizing direct public strategies aimed at upholding the health of the elderly by enhancing healthcare systems that align more effectively with their needs is therefore of significant importance.

The line between primary and secondary prevention may blur on occasion, contingent on how diseases, their risks, and their antecedents are defined. If hypertension is regarded as a disease, its management becomes secondary prevention; however, if it's viewed as a risk factor for coronary disease that hasn't yet manifested, it falls under primary prevention. The term "secondary prevention" pertains to pre-symptomatic diagnosis and treatment via screening initiatives. While it doesn't prevent the root cause from triggering the disease process, it may delay or prevent progression to symptomatic stages (Katz & Ali, 2009).

4.1.3 Tertiary prevention

According to Katz and Ali, (2009), tertiary prevention involves addressing symptomatic disease with the aim of slowing down its progression toward disability or early mortality. The inherent overlap with treatment suggests that preventive medicine encompasses broad ambitions. Nonetheless, there's a valid emphasis on prevention even after the disease has manifested, such as preventing the metastasis of early-stage cancer or averting a myocardial infarction or heart failure induced by coronary disease.

This domain also covers rehabilitation, which aims to maintain or restore functional capacity, thus avoiding its decline. As a tertiary preventive measure, disability mitigation entails medical and surgical interventions designed to minimize anatomical and physiological aspects of symptomatic diseases in patients. Most medical care falls under this description. It can be regarded as a form of prevention due to its objective of averting the disease process, thus avoiding potential impairment or disability. An example is surgically removing a tumour to prevent its local spread or metastasis to other sites (Katz & Ali, 2009).

4.1.4 Best practices

The country assessments stemming from the JA CHRODIS PLUS initiative reveal that all partner nations have established National Health Plans and other health-specific legislations and policies. Notably, certain countries such as Denmark, Finland, Germany, the UK, and the Netherlands highlighted their adoption of the social model of health, with the social determinants of health approach serving as the foundation for most of their health policies. As an example of such specifically targeted health promotion policies, the Prevention Act in Germany mandates insurance providers to allocate €7 per insured individual into a designated prevention fund. Conversely, in countries like Bulgaria, Greece, Hungary, Poland, Lithuania, and Serbia, there seemed to be a greater inclination toward the epidemiological, disease, or medical model (Barnfield & Savolainen, 2019).

Numerous country reports explicitly referenced evidence-based policy development, with Denmark, Finland, Italy, the UK, the Netherlands, and Ireland being among them. Implicit references to ethical considerations, particularly regarding equity, were discernible in most countries' reports. The principle of Health in All Policies (HiAP) found resonance in various European nations, including Croatia, Denmark, and Finland. Notably, Finland displayed a robust emphasis on HiAP, with legal mandates requiring all government sectors to incorporate health and well-being considerations. Moreover, specific tasks and obligations pertaining to HiAP implementation were designated to municipalities in Finland (Barnfield & Savolainen, 2019).

This extensive preventive approach has yielded favourable outcomes for Finland. As a testament to the effectiveness of their comprehensive preventive healthcare measures, Finland boasts one of the lowest rates of cardiovascular disease in Europe. This achievement has been largely attributed to the country's proactive initiatives. In parallel, the prevalence of tobacco use among Finnish adults has experienced a significant decline over the past few decades, largely attributed to the enactment of government policies discouraging smoking. Notably, through the enactment of the Tobacco Act in 2010, Finland has set an ambitious target to become tobacco and nicotine-free by 2030, establishing an unprecedented national commitment. Remarkably, Singapore, much like Finland, has witnessed success in reducing smoking rates within its population. Moreover, Singapore's remarkable achievement in having one of the lowest mortality rates from cardiovascular diseases worldwide underscores the efficacy of their preventive efforts (Lecci, 2023).

Both Ireland and the UK have implemented a Sugar-Sweetened Drink Tax with the dual purpose of combatting obesity and generating revenue through taxing sugar content in soft drinks. The UK's Sugar Tax is structured to impose a levy on the sugar percentage exceeding a certain threshold in soft drinks, and the funds generated are directed towards physical activity programs targeting school children (Barnfield & Savolainen, 2019). According to research conducted by the team at the University of Oxford in collaboration

with the Mexican Ministry of Health and the National Autonomous University of Mexico (Alegre-Díaz et al., 2016), the sugar tax's introduction resulted in an 8% relative decline in obesity rates among sixth grade girls. This reduction equates to preventing approximately 5,234 cases of obesity annually in this specific demographic. The term "relative reduction" signifies the difference between the expected obesity incidence in the absence of the sugar tax and the actual observed incidence.

Concurrently, the Netherlands has initiated a comprehensive two-year lifestyle-based program for individuals dealing with obesity, which is fully reimbursed. An exemplary initiative in the Netherlands involves remote monitoring and coaching for cardiac patients at home, yielding a remarkable 52% reduction in hospital admissions, a 26% reduction in costs, and garnering high levels of satisfaction among both patients and clinicians (Barnfield & Savolainen, 2019).

Another example of effective preventive strategies can be observed in Japan, a country renowned for its impressive life expectancy and minimal rates of metabolic syndrome, a cluster of risk factors linked to diabetes and heart disease. Japan's success can be attributed to its focus on healthy lifestyles. A report on public health in Japan prepared by the OECD (2019) discusses the Health Japan 21 strategy, which offers a nationwide framework for enhancing population health through interventions spanning workplaces, schools, and local communities. This approach targets aspects such as dietary habits, physical activity, smoking cessation, and the reduction of alcohol consumption.

Not solely confined to new policy formulations, there exists a prospect to amplify the impact of ongoing endeavours that support health promotion and preventive measures, reports (Ahlawat et al., 2021). Take, for instance, exercise programs, which have been conclusively shown to reduce the risk of falls and mitigate the severity of fall-associated injuries among elderly individuals. Although certain such initiatives are presently operational within medical facilities and residential care setups, these beneficial programs are yet to attain broad-scale availability for those who stand to gain from them. Similarly, the adoption of comprehensive diabetes prevention programs is a rarity across European countries, with Finland and the United Kingdom representing exceptions to this trend.

Recent research evidence by Saaristo et al. (2017) emanating from Finland underscores the potential for effectively averting type 2 diabetes in high-risk individuals through lifestyle modifications encompassing heightened physical activity and weight reduction. The FIN-D2D initiative is dedicated to implementing these lifestyle intervention strategies within the primary healthcare context.

Further, a comprehensive study by Stokes et al. (2019) analysing diabetes prevention programs (DPPs) reveals their overarching aim to execute behaviour change interventions focused on prevention to reduce incidence. These programs diverge from conventional primary care setups concerning their delivery mechanisms, location, and responsible

personnel, while providing proven strategies that support their objectives. Five fundamental areas of insight emerge from the endeavour to implement such a large-scale program including: management of new providers; fostering awareness about services; patient recruitment; incentive disbursements; and mechanisms for knowledge dissemination. In general, tensions arise predominantly due to an ambiguity in roles and responsibilities among hierarchical stakeholders, as well as communication gaps, for which the author provides practical policy recommendations based on real-life learnings.

4.2 Longevity industry

The longevity biotechnology sector focuses on extending the duration of the life that an individual enjoys in good health, known as their healthy life expectancy. The companies within the industry are dedicated to creating and evaluating treatments that examine the geroscience hypothesis (Boekstein et al., 2023). Longevity is a fundamental consideration within the field of gerontology, which encompasses the comprehensive study of aging processes and associated challenges across various domains, including biology, clinical aspects, psychology, sociology, legal matters, economics, and politics (Freeman, 1975). In recent decades, a key strategy in gerontology has been the pursuit of morbidity compression, a strategic approach designed to restrict the prevalence of diseases and disabilities to a brief period near the end of life. This approach seeks to delay the onset of common age-related pathological conditions, thereby alleviating the burden of such conditions (Seals et al., 2016). Notably, a relatively recent development in geriatric medicine is the emergence of geroscience, referred to as interdisciplinary research field aimed at elucidating the mechanistic connections between aging and aging-related diseases (Sierra & Kohanski, 2017; Sonntag & Ungvari, 2016). Geroscience places a primary emphasis on extending the period of good health (Kennedy et al., 2014).

According to the "geroscience hypothesis," it is conceivable to manipulate the aging process in a manner that concurrently delays the onset of all age-associated chronic disorders, given that these pathologies share age as their primary common risk factor (Austad, 2016). The extension of health span is a central element in the pursuit of 'optimal longevity,' a state characterized by a long life accompanied by good health and a high quality of life. This includes improvements in productivity, functioning, and independence (Seals et al., 2016).

Current research efforts aimed at enhancing health span primarily focus on slowing down the biological processes that underlie aging. These processes encompass dysfunctions in mitochondria, impaired proteostasis and stem cell function and maintenance, disrupted cellular energy status sensing and growth pathways, cellular senescence, age-related declines in stress resistance, as well as increased oxidative and inflammatory stress (Fontana et al., 2014; Kirkland, 2016).

The exploration of strategies to extend human lifespan is an integral facet of the emerging research field known as "anti-aging medicine," which has garnered increasing attention in recent years (Anton et al., 2005; de Cabo et al., 2014). Traditionally, concerns have arisen regarding research endeavours aimed at extending human life, as they could potentially lead to a substantial increase in the elderly population and, consequently, a higher prevalence of age-related chronic diseases. Nevertheless, experimental studies have consistently demonstrated that life extension generally corresponds to delayed and/or reduced morbidity (Fontana et al., 2010). In alignment with these findings from animal studies, investigations into centenarians have shown that a majority of them not only achieve remarkable longevity but also tend to remain free from chronic disorders and disability until an advanced age (Vaiserman et al., 2016).

Anti-aging medicine is directed at offering therapeutic solutions to combat age-related functional declines and chronic disorders. Having emerged since the early 1990s, it has become a highly debated topic in the past two decades. The primary objective of antiaging medicine is to promote both health span and lifespan through specific dietary and exercise regimens, as well as biomedical interventions intended to delay or decelerate the aging process (Vaiserman & Lushchak, 2017).

However, the precise delineation of the term "anti-aging" is a complex matter (Zhao & Stambler, 2020). In the scientific community, anti-aging is primarily concerned with technical aspects capable of retarding, preventing, or even reversing the aging process. Conversely, within the medical domain, anti-aging refers to the early identification, prevention, and treatment of age-related ailments. This medical perspective contrasts with the scientific community's focus on the aging process itself, encompassing a range of strategies and treatment modalities (Ok, 2022).

Notwithstanding these nuanced interpretations from distinct vantage points, they share a common objective: the preservation of physical and mental well-being (Ok, 2022). Particularly, anti-aging diagnostics and medicine, a subset of medical and healthcare practices, leverage advanced scientific and medical technologies for the early detection, prevention, treatment, and reversal of age-related dysfunctions, disorders, and diseases (Klatz, 2005).

As already discussed in chapter 4.1 about preventive health care, conventional healthcare policies often emphasize treatment following the onset of illnesses under universal medical systems, albeit with the drawback of escalating medical costs. In contrast, anti-aging medicine, with its preventive orientation toward aging, adopts multifaceted approaches (Ok, 2022).

Given the considerable economic and financial prospects it offers, anti-aging science presents significant commercial opportunities. Although the reputation of the anti-aging industry has faced challenges in the past (De Magalhães et al., 2011), the field of longevity

pharmacology is currently witnessing exponential growth, exemplified by the discovery of numerous longevity drugs in pre-clinical animal models. This dynamism and enthusiasm underscore the burgeoning domain of longevity pharmacology, with a nascent longevity industry beginning to take shape, accompanied by increased investments in this field. Notably, the translation of insights from the fundamental biology of aging into clinical practice is increasingly prioritized, with pharmacological approaches serving as the primary conduit for achieving this translation (De Magalhães, 2021).

Furthermore, recent marketing research has revealed a widespread desire among individuals to acquire supplements and medications aimed at delaying or preventing age-related declines in both mental and physical functions (Couteur et al., 2011). According to the latest sociological surveys, there exists a strong global yearning for an extension of human health span and lifespan. Previously, inquiries often presupposed that life extension entailed prolonging the period of functional impairment, frailty, and disability in later life. Consequently, cautious attitudes toward life extension emerged in these surveys. However, when the concept of an extended health span was introduced in questionnaire design, responses overwhelmingly favoured a longer life. For instance, in a recent survey by Donner et al., approximately 20% of respondents expressed a desire to live to the age of 85, while 42% aspired to have no limitations imposed on their life expectancy (Vaiserman & Lushchak, 2017).

Indeed, while the definition of an "anti-aging company" may carry a subjective aspect, it is evident that there has been a notable surge in the number of companies focusing on longevity in recent years. This growth trajectory is underscored by data indicating an increase from 20 companies between 2002 and 2014 to over 50 such companies presently (De Magalhães 2022). The size of the anti-aging market worldwide was recorded at 62.6 billion USD in 2021 and is projected to grow to over 106 billion USD by 2030 (Vantage Market Research, 2022). This burgeoning interest has attracted substantial investment and funding, with notable entities like Calico, a biotech firm backed by Google, playing a prominent role in catalysing the recent enthusiasm within the field. The realm of aging research has attained mainstream recognition, firmly establishing itself as a prominent field of scientific inquiry (De Magalhães, 2021).

Nonetheless, there persist uncertainties regarding the translatability of longevity drugs from animal studies to humans, particularly in terms of their therapeutic efficacy and potential adverse effects (Partridge et al., 2020). An escalating number of clinical trials are presently underway to evaluate various pharmaceutical agents targeting the mechanisms of aging as prospective treatments for age-related diseases. These trials are poised to illuminate our understanding in the forthcoming years concerning the efficacy of drugs in extending healthy lifespans. Notably, a pivotal endeavour in this regard is the Targeting Aging with Metformin (TAME) clinical trial, which is anticipated to serve as a proof of concept and potentially pave the way for a US Food and Drug Administration (FDA) clinical trial dedicated to aging-related interventions (Barzilai et al., 2016).

The very fact that the FDA has allowed the TAME study represents a significant turning point in the development of a regulatory framework for evaluating drugs designed to address aging. Furthermore, given that aging itself does not presently serve as a suitable primary endpoint in clinical trials, TAME aims to establish a set of measurable parameters that can be subsequently employed in clinical trials centered on aging (De Magalhães, 2021). Namely, just recently, substances demonstrating potent anti-aging properties were typically excluded from consideration as candidate drugs for clinical trials by regulatory agencies like the US FDA. This exclusion stemmed from the absence of recognition of aging as a clinical condition. However, it has become increasingly evident that this stance is inconsistent with the observable reality as aging is invariably accompanied by a range of health issues that are from a clinical standpoint, acknowledged as diseases necessitating specific therapeutic interventions. Consequently, a vigorous debate has arisen within academic and policy-making circles regarding the classification of aging as a disease (Vaiserman & Lushchak, 2017).

4.2.1 Anti-aging interventions

The majority of anti-aging approaches available from longevity companies in the market are primarily rooted in diet, lifestyle, pharmacology, or data-driven solutions. However, akin to many medical conditions, conventional pharmacological methods are considered the most direct and extensively researched for addressing aging (De Magalhães et al., 2017).

Significant advancements have been made in recent years within the realm of pharmacological interventions targeting aging. Researchers have identified numerous natural and synthetically derived compounds and nutraceuticals with the potential for anti-aging interventions, exhibiting the capacity to extend lifespan by as much as 25–30% across various animal models. These most promising anti-aging agents can be divided into agents with no observed demographic effects until now; agents suggesting promoting longevity mainly by inhibiting particular disease(s); and agents with both anti-aging and pro-longevity effects (Vaiserman et al., 2016).

4.2.1.1 Anti-aging compounds

In recent times, there has been a notable surge in investments directed towards non-conventional therapies and direct-to-consumer (DTC) products and services designed to enhance individual consumers' healthy lifespan (De Magalhães et al., 2017). For instance, research findings from clinical trials (The Age-Related Eye Disease Study, 1999; Chew et al., 2012) have demonstrated the safety and efficacy of minerals, lutein, vitamins, zeaxanthin, and beta-carotene supplementation in slowing the progression of age-related cataracts and molecular degeneration.

Recent clinical studies have garnered significant interest in the therapeutic potential of vitamin supplementation, particularly in vitamin D, in promoting human longevity and reducing risk of age-related diseases. Laboratory investigations suggest that vitamin D exhibits a range of beneficial effects, including the postponement of age-related diseases by inhibiting oxidative stress, supporting innate immune responses, DNA damage repair, regulation of metabolic processes, suppression of cellular senescence, and enhancement of telomerase activity (Garay, 2021).

Beyond vitamin D, other vitamins such as B and K vitamins have also been studied as supplements promoting healthy aging and improved quality of life. Additionally, ensuring adequate intake of vitamins D, B and K, along with minerals like calcium and zinc, and essential fatty acids, not only shows promising effects during the aging process but also suggests a paradigm shift towards the potential complementarity of these supplements with modern medical interventions (Chen et al., 2022).

Longevity companies are increasingly formulating supplements based on a variety of active ingredients and compounds that have demonstrated their potential in supporting a healthy lifespan. One such ingredient is nicotinamide riboside, an NAD+ precursor whose levels tend to decline with age (De Magalhães et al., 2017). Currently, the intravenous infusion of NAD+ stands as the sole clinically acknowledged method for enhancing systemic NAD+ levels. Nevertheless, there is anticipation that alternative NAD+ precursors like NA, NAM, NMN, NR and NAR might offer potential benefits in this regard (Liu, 2022). A prominent player in the field of longevity has already completed a pre-registered, two-month trial involving 120 healthy individuals aged 60–80. While the results are pending publication, a press release from the company asserts that participants experienced a 40% increase in their blood NAD+ levels during the second month (De Magalhães et al., 2017).

Noteworthy examples of endeavours in anti-aging drug discovery also encompass efforts to manipulate sirtuins, which are targeted by resveratrol, and TOR, a target of rapamycin (De Magalhães et al., 2011). Resveratrol, a polyphenol found in grapes and red wine, initially garnered attention for its potential to extend lifespan in yeast and became famous due to its association with the "French paradox," wherein French individuals maintained cardiovascular health despite a high-fat diet. The compound has demonstrated protective effects in models of stress- and age-associated diseases, including chronic overfeeding, insulin resistance, type 2 diabetes, and cardiovascular dysfunction (de Cabo et al., 2014).

Rapamycin, on the other hand, is a natural substance produced by a soil bacterium initially discovered on Easter Island, also known as Rapa Nui, from which it derives its name. Prior to its adoption in the field of anti-aging, rapamycin was recognized for its immunosuppressive properties. Recent studies have demonstrated its lifespan-extending effects across various organisms, including yeast, flies, worms, and mice (de Cabo et al., 2014). In a groundbreaking clinical trial conducted by a prominent pharmaceutical

company, rapamycin was shown to enhance immune function in elderly volunteers (Mannick et al., 2014).

Spermidine is yet another compound naturally occurring and associated with lifespan extension when added to the dietary intake of yeast, flies, and worms. Notably, spermidine concentrations tend to decrease with the aging process, including in humans, except for centenarians (de Cabo et al., 2014).

Historically, antioxidants have received significant attention in the field due to the prevailing belief that free radicals play a primary role in causing age-related damage. Accordingly, antioxidants were thought to mitigate this damage, potentially slowing down the aging process and enhancing overall health. However, it is becoming increasingly evident that a single causative factor cannot comprehensively explain the health and longevity benefits conferred by various pharmacological classes (De Magalhães et al., 2017).

Finally, it's worth noting that metformin has demonstrated the ability to extend both mean and maximum lifespan. Recent studies conducted by numerous laboratories have explored pharmacological interventions as potential caloric restriction mimetics capable of retarding aging and reducing the prevalence of age-related diseases. Notably, some of the metabolic effects of metformin closely resemble those associated with caloric restriction. Additionally, metformin supplementation has been linked to the inhibition of chronic inflammation and oxidative stress, two well-established factors that can compromise overall health and longevity (de Cabo et al., 2014). Importantly, metformin, among a select few medications, has already received approval from the US Food and Drug Administration (FDA) and other regulatory authorities for the treatment of various age-related conditions (Vaiserman & Lushchak, 2017).

4.2.1.2 Genetic manipulation

With substantial investments pouring into research endeavours, numerous companies have committed significant financial resources to the development of senolytic treatments, which are agents designed to target and eliminate aging cells. There is accumulating evidence indicating that senescent cells accumulate with age, at least in certain tissues. In a groundbreaking study, genetic manipulation was shown to extend the median lifespan of mice by 24–27% without a concurrent increase in cancer incidence (De Magalhães et al., 2017).

4.2.1.3 Data-driven interventions

Originating as one of Google's ambitious moonshot projects in 2013, Calico is dedicated to harnessing big data to enhance our understanding of the fundamental biology governing

lifespan. Simultaneously, Calico is actively involved in developing drugs aimed at addressing age-related diseases. Several other companies are leveraging big data techniques to discover novel applications for already approved drugs. This approach holds considerable appeal as pharmaceutical companies typically invest around US$1.8 billion in capitalized costs to develop and secure approvals for new drugs, whereas the safety profiles of approved drugs are well-established. One notable example involves the utilization of deep learning techniques on various 'omics' data types to uncover new associations between existing drugs and gene regulatory pathways relevant to aging-related diseases (De Magalhães et al., 2017).

Companies focused on data are primarily trying to create large databases of integrated data on patients to fully inform health care in general. An article by McKinsey Global Institute (2020) based on a systematic survey reveals the current pipelines in clinical research and development to understand future innovations. The authors identified ten categories of technologies: omics and molecular technology (e.g. CRISPR to curb malaria), next-generation pharmaceuticals (e.g. regulation of cellular aging), cellular therapy and regenerative medicine (e.g. CAR T-cell therapy), innovative vaccines (e.g. vaccines for noncommunicable diseases), advanced surgical procedures (e.g. robotic surgery), connected and cognitive devices (e.g. portables, wearables, ingestible or implantable devices), electroceuticals (e.g. implantable devices), robotics and prosthetics, digital therapeutics (e.g. AI and Big Data powered apps), and tech-enabled care delivery (e.g. online platforms).

In each of these domains of advancement, there already exist small-scale pilot programs and practical applications. For example, surgical robots are currently employed with notable success in a range of surgical procedures, particularly in the treatment of prostate cancer. Presently, in the United States, approximately 20 advanced therapies rooted in omics and molecular technologies, as well as cell therapy, are accessible. These therapies encompass gene-based interventions targeting conditions like muscular atrophy and genetic vision disorders, as well as cell therapies designed to combat leukemia (McKinsey, 2020).

4.2.1.4 Caloric restriction

Caloric restriction (CR) stands as the most extensively researched and consistently effective intervention for enhancing both health span and lifespan. CR entails reducing calorie intake without incurring malnutrition. Ideally, this reduction corresponds to a decrease of around 30% of daily calorie consumption, at least in mice. In humans, there is some evidence suggesting that a CR regimen reducing calorie intake by approximately 15% may be particularly beneficial in mitigating mortality during the aging process (Willcox and Willcox, 2014).

Nearly a century ago, the connection between reduced caloric intake and extended lifespan was already documented. Since that time, CR has demonstrated its capacity to prolong both mean and maximum lifespans across the majority of animal models, while concurrently reducing the risk of conditions such as diabetes, cardiovascular disease, and cancer (Fontana et al., 2010).

One of the most compelling correlations between CR, improved health span, and extended lifespan in humans is observed in the long-lived population of Okinawa, Japan (Mizushima et al., 1997). In contrast to the broader Japanese population, Okinawans typically maintain an above-average level of daily physical activity while adhering to a below-average dietary intake (Willcox and Willcox, 2014). However, when Okinawan families migrated to Brazil and adopted a Western lifestyle, their diet and physical activity patterns shifted, resulting in increased weight gain and a reduction in life expectancy by 17 years (Mizushima et al., 1997).

While a strict CR diet may be impractical for most individuals, intermittent fasting (IF) has emerged as a less restrictive alternative. Building upon this premise, numerous companies have developed fasting-mimetic meals aimed at delivering the beneficial effects of IF (Longo et al., 2021). Multiple lines of evidence suggest that fasting regimens yield anti-aging benefits. Notably, Spanish home nursing residents who practiced alternate day fasting, involving fasting every other day while having unrestricted access to food on non-fasting days, exhibited reduced age-related morbidity and extended lifespans. A registered, randomized clinical trial involving 38 participants demonstrated reduced weight and abdominal fat, as well as the maintenance of healthy levels of blood glucose (De Magalhães et al., 2017).

4.3 Empirical study

In addition to secondary data gathered from reputable sources such as existing research studies, health databases and organization reports, this study relies also on primary research through in-depth interviews with professional from longevity companies. While secondary data analysis provided an overview of the current health status of older populations, labour participation by older populations and global healthcare initiatives, the interviews provide in-depth first-hand insights from the experts in the field, focusing on understanding the role of longevity companies and identifying best practices for expanding human health spans. Through the interviews, I aimed to answer the following research questions:

Research question 1: What is the current status of health and lifestyle choices among populations in different countries?

Research question 2: How do longevity companies try to contribute to expanding the health spans of the population?

Research question 3: What best practices can be identified from the approaches that longevity companies employ?

4.3.1 Methodology and data

To explore and identify best practices and innovative solutions in addressing the challenge of limited healthy life expectancy, qualitative research in the form of in-depth interviews with company representatives from the longevity industry was performed. In total, I have conducted 9 interviews. Four of the interviewed companies were EU based, three were USA based and two from the UK.

The interviews were conducted in a semi-structured format to fully engage and explore potential solutions to expanding healthy life expectancy. For the same reason, the questions were prepared in advance and sub-questions were asked when there was an opportunity for deeper understanding of the main topic or where classification was needed. The interview questions were organized into three main themes: 1) objectives and health state overview, 2) interventions and 3) future developments.

In the first part, I investigated the primary objectives and initiatives of the longevity companies, shedding light on their overarching missions in the context of healthy life expectancy. I explored specific interventions, such as supplements, devices, tools, employed by the companies to contribute to healthy aging and enhancing healthy life expectancy. In this part I also examined the interviewees' perspectives on the current state of healthy life expectancy, providing insights into trends and movements in parallel with life expectancy.

In the second part, I investigated whether longevity companies target specific demographic groups when designing interventions and explored the role of scientific research and collaboration with other stakeholders in the development process. In addition, I explored how companies measure the effectiveness and impact of their interventions on improving healthy life expectancy, along with the challenges faced by longevity companies. In the second part I collected also examples of success stories to highlight the positive impact of interventions on individuals' healthy life expectancy.

In the third part, I explored the interviewees' perspectives on insights and best practices gained from their experience, potentially offering valuable lessons for other organizations and policymakers. I examined also potential future developments and strategies longevity companies are exploring to further follow their objectives and asked about the evolving role of longevity companies in the coming years within the context of an aging population. A complete list of interview questions is available in Appendix 2.

Table 2: Interview sample characteristics

Company	Company size	Interviewee's position	Interviewee's gender	Country of Origin
Company 1	Micro	Co-Founder, COO	Male	Switzerland
Company 2	Micro	Business Development Manager	Male	Switzerland
Company 3	Micro	Head of Research	Male	Austria
Company 4	Micro	Director and CSO	Male	UK
Company 5	Micro	Head of Machine Learning	Male	UK
Company 6	Micro	President & CEO	Male	USA
Company 7	Micro	Marketing Associate	Male	USA
Company 8	Micro	Chief Genius	Male	Croatia
Company 9	Micro	Co-Founder, CEO	Male	USA

Source: Own work.

The interview participants were selected based on their active and diverse involvement within the industry, ensuring they had significant experience and insights into the field. The in-depth interviews were conducted in English and were carried out between 24th of October and 20th of November 2023, using online videoconferencing tools, such as Zoom, Google Meet and MS Teams. On average, an interview lasted 36 minutes. Each interview was recorded and transcribed. The interview transcripts are archived and available upon request but considering confidentiality restrictions. More information on interviews is available in Table 2.

4.3.2 Results

4.3.2.1 Current state of healthy life expectancy and life expectancy

When investigating a comprehensive understanding of the interviewees' perspectives on the existing status of healthy life expectancy in connection with overall life expectancy I found out that the perspectives on the current state of healthy life expectancy among the population vary among the interviewed companies. Company 1 had noted that healthy life expectancy is approximately 20% shorter than overall life expectancy, which is in line with the EU statistics from 2021: »What we see is that average life expectancy is around 80 depending on which countries you take…. So, your years in good health is around 20% shorter, which means about 65, which means you spend about 15 years in poor health or with age-related diseases.« Company 5 has expressed potential future concerns regarding healthy life expectancy lagging behind life expectancy, due to increased frailty with time and its impact on the quality of life of older people: »Even though you might be curing specific diseases so heart disease, diabetes, cancer, et cetera, your body becomes so frail to the point that even if you fix something, something else is going to go wrong quite

quickly… So, a lot of people live longer but it's not great lives if you cannot move, you're just in bed all the time.« Company 4 added on the note of deteriorating quality of life: »So, I mean, you go into an old people's care, you see these poor old people shuffling down the corridor, holding onto a rail. And it's usually not because of arthritis or something, but because their muscles are so weak... So, if you could do something about that, you would substantially improve their quality of life.«

Company 4 challenged the conventional notion of health span, arguing that while our ability to manage illnesses has improved, true health span progress remains limited: »What we've done is improved our ability to manage illness. In theory, all those years for example taking insulin as a diabetic are unhealthy, but in practice, the drug's managing and what we're doing is we're extending something that isn't quite health span but is not sick either… I think there's a middle line which is sort of active span or happy span or something…«

4.3.2.2 Objectives, initiatives, and interventions

To fully understand how these companies strive to contribute to extending healthy and active years of life, various strategies and multidimensional approaches were investigated. I found that the primary objectives and initiatives of the interviewed companies reflect a diverse range of approaches toward extending healthy life expectancy, however they all share a common mission to keeping people as healthy as long as possible, noting that it is never too late to start: »We try to engage with people when they turn 35, which is when you start to realize your performance decline and so that's where we try to get people on board of longevity to make sure you start at where you are, just right after your prime time. Having said that, also, if you're 55 or 65 and you have not looked into longevity yet, it's not too late…It can still be very protective to what's going to happen next.« Company 7 further emphasized the importance of starting with preventive measures and regular biological age testing at an earlier age, increasing possibility to be more successful in preventing diseases: »The earlier you get started the more successful you can be…it is never too late to get started, so it's not like, oh, I am 60 years old, I'm pretty much already done.«

Company 1 emphasizes keeping individuals healthy for as long as possible through longevity supplements routine, such as NMN and other active compounds, along with insights focusing on lifestyle, as the interviewee explained: »Today we know 70-80% of you staying healthy is about lifestyle. And then there is a part where your lifestyle is not enough or not at all influenced, and then supplements play an important role.« Also companies 3 and 4 develop and provide proven life-extending supplements and therapeutics on the market, targeting age-related diseases such as sarcopenia, cardiovascular disease, neurodegeneration etc. Notable compound that has been discovered to be effective is spermidine, a wheat germ extract, provided by Company 3: »This is really work from Professor Frank Madeo, who tried to identify certain compounds that can

trigger this autophagy process, but he found out that especially spermidine worked the best…«

Company 2 and Company 7 seek to revolutionize the traditional medical paradigm by preventing and predicting, rather than treating, using epigenetic tests that quantify one's lifestyle. Company 2 described: »Sometimes they (patients) thought they were doing this and that and then with our technology in the lab, we identified that at the epigenetic level, the person is not eating enough vegetables for example… sometimes it can be surprising, the results and this acts as a, let's say a wakeup call for some patients. They say: Oh, OK I thought I was doing well, but actually I'm not.« Company 7 enables consumers to read what their current ageing within their lifespan is: »We have this biological age testing service that we offer to not only consumers but also clinics to test their patients as well and our biological age clock can provide people an accurate reading of what their current aging within their lifespan is.«

On the other hand, Company 5 delves into regenerative medicine and rejuvenation through gene discovery, utilizing machine learning models to find the genes that can rejuvenate without cells losing their function, while Company 6 explores the biology of aging through gene therapy, especially telomere lengthening but is also active in pharmaceutical development: »When I was listening to the guy talking about telomeres, I realized those are perfect ride tickets that every time a cell divides, a telomere gets a little shorter and shorter and shorter and then when it gets to a certain length, the cell can no longer divide… And that it might be the only thing we ever have to do to cure aging is figure out a way to lengthen telomeres.«

Company 8 explores the bidirectional communication between the gut and the brain using machine learning-driven tools, while also having a production of specific bio active compounds in house: »We are focused on gut-brain axis and we believe that the subjective mind emerges from that bidirectional communication and interaction.« Finally, Company 9, a health and longevity app, leverages AI and longitudinal data to monitor aging, emphasizing fundamental as key contributors to longevity, as described by Company 9**:** »In fact, most of the longitudinal evidence shows that the things that help you the most are the things that are maybe less tech interesting, are generally free but are much more fundamental to the organism, and that is things like movement, getting your heart rate up, calorie restriction or increasing fasting duration, sleeping well, mental health, emotional health, health being, having high quality social connections and quantity of them and so on.«

4.3.2.3 Demographic targeting

Just like objectives and interventions to supporting extension of healthy life expectancy differ, also demographic targeting varies amongst companies. During the research and development process most of them want to be as broad as possible as aging relates to every

person alive and the goals is to have interventions that would work on everyone, like the interviewee from Company 5 explained: »If you do something about aging, then literally everyone would need something like this. So, when it comes to the research that we've been doing, we have to get cells from people so that we can test things on them and we've been trying to get different ages, different ethnicities, different sexes, so that we can cover as much of the population as we can. Fundamentally, we wouldn't want to have a drug that would only work for one specific demographic.« Company 6 further emphasized the importance of focusing on different demographic groups, noting that everyone ages already from the moment we are conceived: »You start aging from the moment you're conceived… The first time that cell divides, you start aging.« Company 9 added scalability and accessibility of the interventions as important factors why targeting a broader population is important: »The goal is to make them (interventions) as scalable and mainstream as possible, which means they need to be both accessible and beneficial to as many people as possible, which means it doesn't matter if you're in your 80s or in your 20s, if you're tech literate or tech novice, you should be able to benefit from these interventions.«

However, marketing demographic groups narrow down, especially to specific sex and age groups. Company 1 observes primarily individuals aged 45 to 55, with a notable gender difference in triggers, where males are motivated by performance, and females by outer appearance: »We see our biggest customer group being around 45 to 55. I think it's a bit more female than male, but we see definitely differences in triggers why would people think of aging or start to become active. We know from our male customers it's a lot around performance…On the female side, it has more to do or often it has more to do with also the outer appearance…« On the other hand, Company 4 explicitly focuses on all older individuals, as they are developing therapeutic that targets various age-related conditions: »We've got a number of diseases where we think our mechanism can target, and they're all highly age associated.«, however are still far away of the market.

In contrast, Company 8 opts for a psychographic approach, targeting early adopters who resonate with the company's vision and mission, emphasizing support for scientific progress in the field: »Not so demographic, more psychographic because it's about persona that is early adopter and people that can relate to vision of applied science.« Company 7 similarly caters to health-conscious individuals, typically in their 30s or 40s with a significant interest in the latest biohacking trends: »What we've seen within our target audience for our epigenetic test is very health-conscious people.«

4.3.2.4 Role of scientific research

To further illustrate the foundational principles guiding the companies' approaches to healthy aging, understanding the role of scientific research was vital for later evaluating the effectiveness of the proposed strategies. It is evident that scientific research and evidence-

based practices are foundational to the approaches of the interviewed companies in enhancing healthy aging.

Company 5 claims that the substantial development and progress observed in the field are attributed to scientific research in the first place: »I think when it comes to research, that's fundamentally why we're talking so much about aging at the moment. If you go back 20, 25 years, pretty much nothing was known about the biology of aging… So, we are fundamentally a research company.« Moreover, several companies, such as Company 3, trace their origins to scientific backgrounds or university research, illustrating a dedication to understanding the impact of compounds on the organism as a whole: »Since we started from scientific finding, the research was one of the most important parts for our product development and for our ongoing company development.« University origins and the commitment to science is highlighted by Company 1, emphasizing that everything, including formulations, is science-based, some developed in collaboration with laboratories of certain universities: »We have to develop products in the 1st place, so we have to be connected to the ones doing research.« Similarly, Company 6 expresses an unwavering commitment to research, asserting that they will always remain in the realm of research: »We will always be in the research space; we would never get out of the research space. I just want to cure aging and then I want to cure other diseases. Period.« The importance of scientific research is further emphasized by Company 8, where it plays a key role in their development: »It's a key role, so it's our fundamental principle in deep science, deep technology that we are developing. It's really to understand through building blocks because every study is bringing us new insights because we are researching things that are not “googleable”.«

Company 2 further underscores the significance of credibility, distinguishing itself from marketing-oriented competitors by maintaining a focus on scientifically validated practices: »Credibility first. Today you don’t really know what you buy and companies, they are extremely marketing oriented…Everything that we do has been scientifically validated and has strong studies published about it.«

4.3.2.5 Measurement of effectiveness and success stories

To measure the effectiveness and impact of interventions on improving healthy life expectancy, companies revealed different approaches from subjective assessments like customer reports, anecdotal evidence and questionnaires as explained by the interviewee from Company 1: »One is the subjective track, which means what does it do for you, and if once you have 10,000 customers, you will see patterns, you will see if 80% report something.« Company 9 explained the positive customers’ response about their personalized lifestyle plans are: »We're constantly hearing, how it's (the platform) changed people's lives for the better and it ranges all the way from athletes to people that are not

healthy at all, but they recognize they need to do something and that's really the thing we're most proud of…«

Company 8 further added that it adopts three pillars to measure the effectiveness of their intervention including clinical and preclinical trials as well as anecdotal evidence: »There are hundreds of anecdotal evidences, especially regarding skin and then bloating, heartburn, more energy, mental capacity, et cetera.« It further explained the need for three pillar measurement, as it was needed to eliminate the possibility of placebo effect: »We are not happy with the possibility of having placebo. But basically with preclinical research, we already disputed placebo because there is no placebo in cells.« Clinical trials seem to be the gold standard for measuring the effectiveness of interventions, as interviewee from Company 4 summarized the process of a trial: »So going after therapeutics there would be a very well defined therapeutic endpoint. So, for example, for sarcopenia, you take a clinical trial, and you take a group of people who you characterise as well as you can. You split them into two groups, one you treat with the drug, other treat with the placebo.«

Another way of measuring the effectiveness is by using different tools, such as tests and other devices such as NAD level test, epigenetic clocks, CGMs, depending on the product and compounds that it contains: »Objective track really depends on the product and the ingredients. If there are so-called endpoints, you can easily identify, and test and I make an example: if you use an NAD precursor like NMN and you can measure intracellular NAD levels before and after.« Company 5 suggested epigenetic clocks as a mean of measurement biological age: »The way that we assess biological age is using something called epigenetic clocks, which are measures of biological age, so, when it comes to the trial for humans, you would measure everyone's biological age before the trial and then give placebo and give the intervention, and then at the end of the trial you measure again everyone's biological age and see if there was any difference.«

On the other hand, Company 6 discussed various means of measuring, suggesting long term clinical trials as an ideal method, but revealing its inconveniences: »The gold standard of measuring how well longevity intervention works is if you would give it to people, follow them over several decades and see if one group survived for longer than the other one. But when it comes to time and money, that's not very feasible.« Therefore, the company opted for epigenetic clocks as well: »The way that we assess biological age is using something called epigenetic clocks. So overtime you have your DNA and you have modifications that you can track.«

However, Company 4 questioned the mechanism of epigenetic clocks as an accurate and reliable measuring method, as the interviewee explained: »There's this huge controversy about how you actually measure biological age. The epigenetic markers are interesting. If you develop something that reverses epigenetic aging, are you actually developing something that just reverses that marker or is it genuinely anti aging?«

4.3.2.6 Collaboration

To address healthy aging, interviewed companies emphasised various collaborative strategies, showcasing efforts to align with research, healthcare, and policy domains, ultimately influencing the broader landscape of healthy aging. Most of them listed especially collaborations with research institutions, academic partners and healthcare providers, like the interviewee from the Company 2 explained: »We are partnering with a lot of research institutions to improve our product and to also test in different categories how our service can be of help to other people and patients.« Company 5 stressed the importance of academic partnerships stating that academic individuals are even members of the advisory board of the company: »Some of our advisors are professors at Cambridge.«

Company 3 highlighted the expertise of their scientific board, which includes renowned researches, while also engaging with physicians working in clinics to perform their clinical trials with: »I think from a research point of view we are very proud of our scientific Board, so all of the experts on autophagy, but also a lot of physicians working in clinics as we do a lot of clinical trials with partners, very famous clinics.« Company 2 extends even further by partnering with various B2B entities such as clinics, hospitals, medical centers, wellness resorts and even individual doctors specializing in longevity, healthy ageing, rejuvenation and anti-aging practices: » We then also partner with B2B clinics, hospitals, medical centers, wellness and well-being resorts and also some individual doctors that practice longevity and healthy aging rejuvenation and even anti-aging.«

Notably, the engagement with policymakers varies, with some expressing difficulties in establishing collaborations due to highly regulated nature of the industry, especially the ones focusing on nutritional supplements and pharmaceuticals as Company 3 explained: »The issue with nutritional supplements, it's very, very difficult to get involved with the state concerning healthcare… So normally you get prescription for certain illness, but for nutritional supplements it's very difficult to get into this field.« Company 4 also expressed challenges when engaging policymakers, due to lack of time and resources: »We've sort of engaged informally a little bit with policymakers and policy groups in the UK, without any formal engagement. Largely due to lack of time and resource…«

4.3.2.7 Challenges

Regulation seems to pose quite a significant challenge for many of the interviewed companies in a few ways. The first issue lays in different jurisdictions within different countries, as explained by the interviewee from Company 1: »Some of those molecules or some of those products may not yet be registered or legally accepted in some jurisdictions, like the Novel Food Register in the EU, then FDA works differently in the US, so regulatory part is a challenge.« Another regulatory challenge confronted by companies pertains to the non-classification of aging as disease, an elucidation articulated by the

representative from Company 5: »At the moment aging is not classified as a disease per say, at least in the eyes of FDA and some other medicine regulators so it (delivering a drug to the market) would have to be through another type of avenue…« Company 4 similarly addressed the same concern: »It would sort of be nice to be able to get a drug for aging itself approved… you can't have a therapeutic product proved for aging. It's not an indication, so you have to go after the disease. The regulation on drug discovery is very tight. And getting a drug approved is very tight.«

On another note, Company 4 raised concerns about testing drugs for aging, questioning how to accurately measure the effects and conduct lengthy clinical trials without patents expiring: »The issue is how do you test it? How do you test a drug for genuinely aging and how you measure it and if you can't do a drug for aging and say we're going to have a 30 year long clinical trial because your patent will run out before the clinical trial finish. So right now, I can't tell you a lot about technology because this was all just sort of stuff I invented in the back of a lecture room one day and we haven't got any IP around it.« Company 1 added about the issue of protectability: »These are natural molecules which you usually cannot protect and for a health company that's a bit difficult. In biotech you develop a drug, and you own it. So, you probably spend a billion to get it to market but this is not something that works in supplements.«

Furthermore, Company 8 described the challenging environment of a startup, including the lack of funding, science and other resources: »You always lack funds. You lack money. You lack customers. You lack people in your team. You lack scientific evidence and you're trying to achieve something that sounds completely crazy with 1,000,000 times less money than big players out there that are doing it already for a couple of decades…« Company 4 explained a distinct perspective on the funding challenge, underscoring the difficulty in securing investor support as a primary obstacle, resulting in a deficiency of financial resources: »Well, the big problem is always money. For investors this is investment, how am I going to get my money back. For us it's risky, it's research and a high chance that things will not work.« Interviewee from Company 6 emphasised the challenge of the research process itself being costly: »The problem is that it is super expensive. To actually test gene therapies in humans is going to cost approximately about 1,000,000 USD per patient…Finding funding is number one obstacle.« Along with high financial burden, Company 4 highlighted the extensive regulatory requirements and lengthy processes leading up to clinical trials: »Because before you even got into clinical trials, you've blown one and a half million on all the regulatory stuff that's not even to mention all the paperwork, which is massive.« Interviewee from Company 8 added on the time-consuming phase of scientific research, cautioning that if the development process takes too long, it might become obsolete by the time it is finished: »Scientific research is something that is not so easy because it takes a lot of time. Machine learning models are something that we do in house as well, so it's completely new area that is fast developing. So that means if you are developing a model for too long it will be obsolete.«

The final but consequential challenge confronted pertained to the niche nature of this industry, associated with misinformation online, stressing credibility concerns, as emphasized by Company 1: »It's still a niche. It's not a drug, it's a natural compound, it's a molecule, it's new. So, you also have a lot of rubbish on the Internet, people can sell what they want. So, it has a lot to do with credibility and making sure that people understand it's not us as a company coming forward with a product, it's a huge scientific community that exists now maybe 10-15 years only.« Company 5 suggested a slightly different perspective on the lack of knowledge about the field within the population, resulting in customers' reluctance as lifestyle interventions such as sleeping and exercise are time-consuming and effort-intensive: »Whenever doing any sort of lifestyle invention like exercise and sleeping that takes a lot of time and effort that sometimes people don't want to put in so, ideally, we would have a pill that would solve all these problems…« Furthermore, Company 7 highlighted the same difficulty of prompting change in people's beliefs and habits: »Whenever you're trying to bring new technologies such as this... Once there's a status quo or systems that people are used to doing, it's hard to get them to change.« In fact, Company 7 emphasized that many people mistakenly believe that supplements alone can reverse aging, yet stressed that achieving youthfulness requires a comprehensive approach involving multiple factors working together: »A lot of them think that there may be supplements or pills that are going to be the single answer to their ability to get younger but it's an entire network of things that need to happen in order to do that.«

Company 2 added on the topic of people's inadequate education about epigenetics. The interviewee noted that many individuals they interact with either lack knowledge about epigenetics or misunderstand it, often confusing if with genetics. This confusion requires considerable effort to clarify, and the level of awareness varies by country, indicating that it's still an emerging field in some regions: »The first challenge I encounter is education. A lot of people that I contact, don't know much about epigenetics or they think they know, but they don't. They confuse genetics with epigenetics quite a lot. So, this is something that takes a while to get the right message across. This is still a bit early, depending on the country.«

On the other hand, Company 6 criticized that many scientists with noble intentions have been overshadowed by investors who prioritize financial gains over humanitarian goals: »I have a lot of friends in the field that are very good scientists that really wanted to make a difference and they got investors and then investors just completely took over. And now they're doing things that they never wanted to do.« The interviewee further emphasized that this shift in focus hindered progress in curing diseases like cancer, heart disease and aging. The interviewee believes that the lack of control of the science in the field has distorted the attention form addressing pressing health issues: »That's why cancer is not cured. That's why heart disease isn't cured. That's why aging isn't cured.«

4.3.2.8 Key strengths

Even though the challenges that the interviewed companies are facing are significant, they strengthened the companies and enriched them with experiences. Many of the interviewed companies emphasized translating longevity science into practical applications for everyday life, basing products on rigorous scientific research focused specifically on the aging process, as Company 1 explained: »We want to be at the point where we translate what longevity science has just discovered and how can that be translated into every day's life.« Interviewee from Company 9 similarly added on accessibility of the intervention as an important factor: »It doesn't matter if you're in your 80s or in your 20s. If you're tech literate or tech novice, you should be able to benefit from these interventions.«

Furthermore, tight regulations and the niche nature of the industry pushed companies to place significant emphasis on the research process, showcasing a sense of pride in their distinctive methodologies, exemplified by in-house approach of Company 3, providing them comprehensive control: »One of our strengths is that we have our lab in house, and we control the whole process from A-Z.« Company 3 emphasized that unlike other marketing-oriented companies, it produces its own extract instead of outsourcing it: »They (other companies) mostly buy compounds from overseas and produce products, and then push a lot of marketing effort in it…But our approach was different, we really wanted to stay focused on one compound, produce our own extract, so we're also the manufacturers of it.«

Company 6 embarked upon a distinctive research methodology of its own, conducting critical meta-analysis of peer reviewed studies, scrutinizing experimental designs, data and analyses. They sift through papers to separate reliable ones from those with flawed methodologies or questionable data: »So, what I do, what's called critical meta-analysis of peer review studies, which means: I read the paper. I look at their experimental design, I look at their data, I look at their data analysis and if all is legit then I put it into the legit pile.« The interviewee emphasized that many papers promoting products lack quality, often due to biases introduced by companies: »I can tell you that 90% of the papers that I read, fail.«

The commitment of Company 3 to research is underscored by its exclusive status, having the Novel Food allowance from the European Food Service Administration, making it a preferred choice for scientists conducting spermidine studies, which ensured the viability and recognition of their unique approach in a competitive market also by entering into pharmacies: »I think if you Google or if you type in spermidine into the clinic trials database you will find that I think 90% of these studies focused on spermidine are with our extract, since we are the only ones that have the Novel Food allowance from the European Food service administration.«

In addition, some companies highlighted the endorsement of their products by medical professionals, as Company 7 illustrated: »There are groups of longevity medical clinics that that we work with that they specialize in that. We're providing this tool (epigenetic aging clock) for them to accurately depict the success of their patients.« Besides, Company 3 pointed out significant achievements in penetrating pharmacies, enabling people to purchase their products directly: »One of the major successes was to get into pharmacies in Austria and in Germany…so people are really able to buy products that are used in clinic trials,..«

4.3.2.9 Best practices and future developments

When further investigating the best insights and best practices that interviewees derived from their experiences in the field, themes focused on personalization, preventive and precise approaches to cater to individual needs prevailed. Company 5 illustrated the importance of different tiers for achieving longevity, including lifestyle interventions, supplements or drugs and lastly future innovations: »I think there are different tiers of what you can do for longevity: the basic ones, which is just lifestyle interventions: healthy sleep, diet, exercise, which are effectively the pillars of good health, and they've been shown to help with health span and lifespan... I think a step after this would be some more specialized supplements or drugs, for instance metformin, that is going to be tested in this clinical trial in the US. And I would say that the third tier would be things that we're still searching for that might radically extend lifespan and health span.« Company 9 similarly discussed two distinct approaches within the field: one focused on immediate efforts to enhance health span and lifespan, while the other is dedicated to developing future drugs aiding aging: »So, I think there's like two camps. There's those who are focused on how we can increase health span and lifespan right now and there's those who are trying to create the future of the drugs that may reverse aging or extend health span in in some ways.«

Personalization was referred as a common next step in development for many of the interviewed companies, as for example Company 1 pointed out: »What is clear to us is that we want to work on personalization… We want to be preventive, nothing should actually start to become something, and we want to be precise because we're all different.« Interviewee from Company 9 pointed out the incorporation of additional features into their app, aimed at fostering healthier lifestyles by providing users with personalized support and accountability from peers: »We've recently added social features to the app which actually encourage people to adhere to healthier lifestyles because they have other people celebrating their success and keeping them accountable and so we're going to be adding more richness to those experiences, to make it even more engaging, personalized.«

Continuous improvement, innovation and research are at the forefront as best practices and are key for future developments, as indicated by Company 8: »The success must be rooted in progress and in data. It cannot be just nice marketing.« The interviewee from Company

3 further emphasized the importance of allocating capital towards scientific endeavours to advance their own interventions: »Every player on the market who wants to be part of it and wants to be in a field that is very scientifical, should at least invest some of its capital into the field of science to really improve their own products.«

Moreover, interviewee from Company 3 underscores that building extensive networks with experts, partners, investors and engaging in clinical studies rises the chances of success in the market: »If you want to have high reach in the field of the scientific proven product, try to build a network with physicians. Try to build a network with experts in this field and don't be afraid to get partners on board that ask for money.« Also, Company 6 mentioned that they are actively networking and seeking additional sources of funding to complete the research: »I'm getting the money from the go to market partners, but in the meantime, I'm trying to find sources of funding from people that can provide a few 100 million USD, that's to really get this research done.« In addition, Company 1 expressed the need for greater engagement of policymakers alongside researchers to enhance credibility: »I think that's really super early and really difficult and I think a lot of that needs more involvement of policymakers with researchers to add the credibility…«

4.3.2.10 The role of longevity companies

In terms of outlook on the industry, the responses from the interviewees paint a nuanced picture of the industry's evolution in the coming years. Optimism about significant industry growth seems to be a common theme as Company 9 suggested: »I do think that there is a growing awareness and interest in longevity, a growing belief that we can extend health and lifespan using technology, biotech interventions and so on.« Company 1 added on a similar note: »Longevity is an industry that is starting right now, right? So, it will be very probably the biggest industry we've ever seen many say because it impacts everybody.« Company 2 shared its outlook on the optimistic future of the field as well: »It's very ambitious and super interesting«, while Company 3 specifically touched on the field of biohacking and its popularity: »It's (biohacking) always getting bigger from year to year, and this will probably be very interesting in the future.«

Company 1 extends the optimism towards evolving landscape surrounding the longevity industry. The interviewee emphasized the emergence of a multifaceted ecosystem catering to the needs of aging population choosing to remain active: »So, you will have companies still being in the whole research part but then you have a whole ecosystem of what happens if people get older and stay active. There is a lot of companies that cater to those needs of all the people still being active, you don't retire with 65, you repurpose – ohh, to what, right?«

However, while the companies seem to expect significant growth of the industry, some expressed concerns about the entry of numerous new companies, as well as the influence of powerful lobbies. Company 1 explained: »The question is, what kind of companies we

need to run this ecosystem… the more we understand about the process, the more interventions, therapies, products we can actually bring to people.« Company 9 pointed out similar concerns about new companies entering the industry that might be focusing primarily on quick returns: »I do think some (new interventions) are more impactful than others and others just trying to follow the money and find good quick rich… But in the end of the day, if it still trickles down to helping humanity in some way reduce disease risk, then I'm all for it.«

Company 5 expressed optimism about the potential breakthroughs of longevity-oriented companies, yet acknowledges the fear of them clashing with traditional pharmaceutical ones: »I think, more likely, what's going to happen is a few longevity tech companies that are probably going to be quite successful but right after that, I would imagine that a few of the big pharmaceutical companies are probably going to apply them.« Similar fear was addressed by the interviewee from Company 2, expressing conflicting priorities by lobbies, public policies and longevity-oriented companies: »I would say that the threat is lobbies and public policies because we want the population to live longer and be healthier... However, this can pose some problems with insurance companies and some public organizations.«

On the other hand, Company 8 sheds some positivity towards the changing nature of pharmaceutical industry and public policies for the better. The interviewee suggested a shift away from the current pharmaceutical model, which involves lengthy registration processes and high costs, anticipating a more holistic approach to healthcare: »I think we will move from pharma approach of 10 years registration six billion USD overregulated small molecules…It will be much more holistic.« The interviewee further elaborated on the changing healthcare system: »The system we have now will always be sick care but health care will be something that will be rooted in everything from education to buildings to way of living to where we interact with each other.« Company 4 shared a similar outlook about the changing nature of the industry, questioning the need for huge financial resources: » I'm not sure whether suspicion or a hope is that the technologies for doing that (expanding health span) are now so accessible that individuals or groups of individuals will be able to do that for themselves without the backing of venture capitalists.«

Majority of the interviewed companies pointed out the role of future research, technology developments, such as AI, nanotechnology and alike to be shaping the future of the industry. Company 8 emphasized the changing structure of companies' endeavours: »I believe that every serious company will have both diagnostics and intervention.« Company 4 specifically pointed out the continuous emergence of new tools: »New discovery tools. Every year somebody comes up with a better instrument.« Interviewee from Company 5 additionally suggested that technology is enhancing medical devices, making them better, faster and more efficient. Additionally, technology integration allows for greater insights and the potential to detect diseases before symptoms to appear: »You're starting to see how technology is starting to leak into different sectors, right… Most medical devices now are

starting to have technology integrated into them that are making them faster, making them better, or making them more efficient, can provide a lot more insight, can tell you before you even have the disease.« Company 9 also expressed optimism about accelerated breakthroughs and innovations: »I think that with the growing capital investment into this space, growing interest in longevity, I think there's just going to be an acceleration of breakthroughs and innovations that can help humanity.«

5 DISCUSSION

Research of the written work delves into the multifaceted landscape of longevity companies and their pivotal role in shaping the trajectory of healthy life expectancy. The discussion that follows delves into the interpretation of results obtained by conducting nine in-depth interviews with longevity-oriented companies, followed by policy and other stakeholder recommendations, and ending with research limitations.

5.1 Interpretation of the results

The interviews reveal a diverse array of perspectives on the current state and future trajectory of healthy life expectancy, shedding light on both the challenges and opportunities in this domain. Companies contributed insightful perspectives to my first research question about the current status of health and lifestyle choices among populations in different countries. Thereby, the answer to my research question 1 was that healthy life expectancy is in fact shorter than overall life expectancy, aligning with global statistical data. This finding underscores a significant portion of individuals spending their late years grappling with age-related health issues.

Interviewees expressed apprehension regarding future trends, emphasizing the potential exacerbation of frailty among older populations despite advancements in treating specific diseases. Their concern revolves around the notion that prolonged life does not necessarily equate to enhanced quality of life, particularly if individuals face debilitating health conditions. Moreover, a critical perspective was shared by challenging the conventional understanding of health span. An interviewee argued that while medical advancements have prolonged life and improved disease management, the true essence of health span-defined by vitality and overall well-being – remains elusive. Instead, they propose the concept of an "active span" or "happy span," suggesting a nuanced understanding of health beyond mere absence of illness. These varied viewpoints underscore the multidimensional nature of healthy life expectancy, prompting reflection on the complex interplay between longevity, health, and quality of life.

Interviewees added a lot of knowledgeable insights to my second research question. Diverse strategies are undertaken collectively, aimed at keeping individuals healthy for as long as possible. The information gained through the interviews answered my research

question 2, revealing that companies try to contribute to expanding the healthy life expectancy of the population by a spectrum of approaches, including lifestyle-focused interventions, personalized preventive medicine, proven health-extending products, gene therapy and other AI based interventions. Specific interventions are listed in the Table 3.

Table 3: Longevity interventions by company

Company	Intervention
Company 1	Nutritional supplements and longevity insights
Company 2	Epigenetic test
Company 3	Nutritional supplements
Company 4	Therapeutics
Company 5	Predictive platform for cell rejuvenation
Company 6	Therapeutics and gene therapy
Company 7	Epigenetic test
Company 8	Bio active compounds and predictive platform
Company 9	Lifestyle app

Source: Own work

While the emphasis on preventive measures, lifestyle interventions, and supplementation aligns with the growing recognition of the importance of holistic health promotion, questions arise regarding the accessibility and affordability of such interventions for broader populations. Additionally, while regenerative medicine and gene therapy hold promise for addressing underlying biological mechanisms of aging, ethical considerations surrounding safety, equity, and unintended consequences necessitate careful scrutiny.

Furthermore, the reliance on AI-driven technologies and longitudinal data raises concerns about data privacy, algorithmic biases, and the potential medicalization of everyday life. Despite these challenges, the convergence of diverse methodologies underscores the interdisciplinary nature of longevity research and highlights the need for collaboration across scientific, medical, ethical, and societal domains to navigate the complexities of extending healthy lifespan in an equitable and sustainable manner.

While the overarching goal of achieving interventions applicable to a broad population is evident, companies exhibit varying approaches towards demographic segmentation. Majority of the interviewed companies underscore the necessity of inclusivity in research and development, emphasizing the importance of diverse age groups, ethnicities, and sexes to ensure the efficacy of interventions across populations. This stance reflects a commitment to equity and accessibility in addressing aging-related concerns. Conversely,

the marketing strategies of certain companies demonstrate a more focused approach, targeting specific age groups or personas based on gender, age, or psychographic characteristics. These differing approaches reflect the multifaceted nature of addressing aging-related challenges, encompassing scientific, ethical, and commercial considerations.

Scientific research on the other hand, emerges as a fundamental principle through guiding longevity companies. The companies emphasize great importance of translating longevity science into practical applications, basing their products on rigorous scientific research focused on the aging process. With a commitment to evidence-based practices, interviewed companies adopt various approaches to accurate measurement of interventions' efficacy, including subjective assessments such as customer reports as well as objective testing via clinical trials.

The effectiveness and impact of interventions on improving healthy life expectancy are assessed through a variety of approaches, as revealed by the interviews conducted with representatives from various companies. Subjective assessments, such as customer reports and anecdotal evidence, offer valuable insights into the perceived benefits of interventions, however these may lack scientific rigor and objectivity. On the other hand, clinical trials emerge as a gold standard to evaluate therapeutic endpoints.

Yet, ethical considerations and feasibility of conducting long-term clinical trials pose significant hurdles. Simpler methods, including NAD level tests and epigenetic clocks, offer tangible ways to assess biological age and intervention outcomes, yet scepticism arises regarding the reliability of epigenetic clocks, with some questioning whether they truly reflect anti-aging effects or merely alter tested markers. Despite differing methodologies, these insights underscore the complexity of evaluating interventions aimed at enhancing healthy life expectancy, emphasizing the need for a balance and multifaceted approach that integrates both subjective and objective measures while addressing methodological limitations and uncertainties.

The results of the interviews reveal a nuanced landscape of strategies employed by companies to address the imperative of healthy aging. Collaborative efforts emerge as a central theme, with a focus on aligning with research, healthcare, and policy domains to effect substantial change in the field. Companies underscore the significance of partnerships with research institutions, academic entities, and healthcare providers, showcasing a commitment to evidence-based practices and product development.

However, challenges arise particularly in engaging policymakers, with regulatory hurdles posing obstacles for companies, especially those in industries such as nutritional supplements and pharmaceuticals. Moreover, some expressed constraints in engaging policymakers, attributing them to limitations in time and resources. The experiences shared by companies regarding their interactions with policymakers shed light on the complexities and limitations faced in effecting meaningful change at a policy level. While the efforts to

engage policymakers are commendable, the constraints of time and resources underscore the need for more robust strategies to advocate for policy reforms conducive to promoting healthy aging. These findings underscore the intricate interplay between industry stakeholders and regulatory frameworks, underscoring the need for adaptive strategies to navigate the complexities of promoting healthy aging in a regulated environment.

The interviews conducted reveal a multitude of challenges facing companies operating in the longevity and aging-related industries, with regulation emerging as a primary hurdle. The complex landscape of regulatory frameworks across different jurisdictions poses significant obstacles to product development and market entry. Moreover, the non-classification of aging as a disease by regulatory bodies like the FDA complicates the pathway for bringing anti-aging therapies to market. This regulatory ambiguity extends to testing methodologies, with concerns about the practicality of conducting lengthy clinical trials without risking patent expiration.

Financial constraints compound these challenges, with especially startups struggling to secure adequate funding and resources amidst competition from established players. The niche nature of the industry further exacerbates credibility issues, with misinformation online undermining public trust. Additionally, the lack of public understanding and awareness underscores the educational barriers hindering progress in the field.

Besides that, companies highlighted detrimental impact of profit-driven investment priorities on scientific integrity and the pursuit of humanitarian goals, suggesting a systemic issue that hampers innovation and potentially delays breakthroughs in addressing critical health issues like cancer, heart disease, and aging. These insights paint a comprehensive picture of the multifaceted challenges facing companies in the longevity and anti-aging sectors, from regulatory complexities and financial constraints to credibility concerns and educational gaps, underscoring the need for concerted efforts and systemic reforms to foster progress in this vital field of research and development and to align the incentives with humanitarian goals and foster genuine innovation.

However, numerous obstacles contribute to the enrichment and strengthening of the interviewed companies. The emphasis on accessibility regardless of age or tech literacy reflects a commendable commitment to democratizing healthcare solutions. However, while companies pride themselves on their distinctive research methodologies, such as in-house control and critical meta-analysis, questions arise regarding the potential biases and limitations inherent in these approaches.

Moreover, while attaining regulatory approvals like Novel Food allowance and securing endorsements from medical professionals certainly add credibility, they also raise concerns about the influence of regulatory bodies and potential conflicts of interest. Additionally, the success of these companies in penetrating pharmacies may signify market acceptance, yet it also prompts scrutiny regarding the commercialization and commodification of

longevity interventions. Thus, while these insights offer valuable perspectives on the industry's dynamics, they also invite critical examination of the complexities and ethical implications underlying the pursuit of longevity solutions.

When looking into key insights and best practices identified by longevity companies to answer my research question 3, different tiers were observable within the industry. The basic level includes interventions relating lifestyle, followed by the second tier of specialized supplements and drugs, while the third tier revolves around the ongoing search for groundbreaking interventions. Companies are employing different strategies to address all three levels in their future development. Key themes evolve around personalization, prevention, and precision in addressing individual health needs. Personalization especially emerges as a common goal for many companies, emphasizing the importance of tailoring approaches to diverse individuals. Furthermore, integrating social support and accountability features exemplifies a proactive stance towards fostering healthier lifestyles.

However, while these approaches hold promise, challenges such as scalability and accessibility may arise, particularly in implementing personalized interventions on a broader scale. Continuous improvement, innovation and research are highlighted as best practices, with a strong emphasis on the significance of the data-driven progress rather than mere marketing. Yet, questions regarding the ethical implications of longevity interventions and the potential exacerbation of societal inequalities warrant further exploration.

On the other hand, the integration of technology, including AI and nanotechnology is identified as a pivotal factor shaping the industry’s future, leading to changes in health infrastructure and landscape. The role of data-driven diagnostics and interventions, the evolution of pharmaceutical approaches and the transformative impact of technology on medical testing are highlighted as significant trends in the industry’s development. In addition, building extensive networks with various stakeholders is viewed as crucial for success in the longevity market. These findings suggest a dynamic landscape characterized by a blend of current strategies and future aspirations, underlining the complexity and promise inherent in longevity research and development.

The interviews conducted provide a multifaceted perspective on the future trajectory of the longevity industry, highlighting both optimism and concerns. There's a prevalent sense of optimism among the interviewees regarding significant industry growth, driven by advancements in technology and biotech interventions. Moreover, the emergence of a multifaceted ecosystem catering to the needs of an aging population signifies a shift towards more active and purposeful aging. However, alongside this optimism, concerns about the emergence of new companies primarily focused on profit-making and the influence of powerful lobbies are raised by various interviewees, indicating a potential clash of priorities within the industry.

Despite these challenges, there's a general consensus among the interviewees regarding the crucial role of research and technological advancements, such as AI and nanotechnology, in shaping the industry's future. This emphasis on innovation, coupled with growing capital investment, suggests the potential for accelerated breakthroughs and innovations that could positively impact humanity. Yet the practical realization of these advancements hinges on addressing regulatory hurdles and ensuring equitable access to emerging therapies. In any case, a shift towards a more holistic approach to healthcare signals a broader transformation in the industry's paradigm, moving away from conventional pharmaceutical models towards more integrated and preventative healthcare strategies. Thus, while the longevity industry presents promising opportunities for advancements in health and lifespan extension, navigating the challenges posed by market dynamics and societal influences will be crucial in realizing its full potential.

Key findings of the empirical study can be found in Table 4. The results are divided into interview topics that were explored during the in-depth interviews.

Table 4: Key insights of the empirical study

Interview topic	Key highlights
Current state of LE and HLE	• Healthy life expectancy shorter than life expectancy • Increased frailty with time • Importance of quality of life
Objectives, Interventions	• Keep individuals healthy as long as possible • Supplements routine, biological age tests, gene therapy, machine learning-driven tools, AI based longevity apps
Demographic targeting	• As broad as possible • Scalability and accessibility
Scientific research	• Research as the main driver • Collaborations with research institutions • Credibility
Measurement of effectiveness	• Subjective assessment: customer reports, anecdotal evidence, questionnaires • Objective testing: preclinical and clinical trials, NAD level testing, biological age testing, etc.
Success stories	• Changing people's lifestyles • Improved skin, reduced bloating, heartburn • More energy and mental capacity
Collaboration	• Research and academic partners • Healthcare providers • Policymaker collaboration limited

Interview topic	Key highlights
Challenges	• Tight and varying regulation • Lengthy and complex testing • Lack of funding • Niche nature of the industry • Credibility concerns • Inadequate education of population
Key strengths	• Translating longevity science into practical applications • Emphasis on research process (in-house approaches) • Governmental support • Endorsed by medical professionals
Best practices and future developments	• Personalization • 3 tiers for achieving longevity • Accountability • Continuous innovation and research • Building extensive networks
The role of longevity companies	• Growing awareness and interest • Catering to the needs of aging population • Concerns about powerful lobbies • Focus on quick returns reducing credibility • Technology developments

Source: Own work.

5.2 Policy recommendations

Based on the findings of the research on expanding human health span and the insights gathered from interviews with longevity companies, proposed policy recommendations aim to alleviate the economic burden associated with an aging population. These recommendations focus on fostering longer, healthier, and more active lives for individuals, while creating an enabling environment for longevity-oriented companies, promoting sustainable interventions for healthy ageing.

The main pillar that is currently missing is partnerships and collaborative relationship between public and private healthcare institutions and stakeholders, which is a foundation to addressing current troubled healthcare landscape. Facilitating collaboration between longevity companies and healthcare providers by creating platforms or incentives for partnerships, involving supporting joint initiatives, providing funding for research collaborations, and easing regulatory processes to encourage more extensive cooperation between private sector innovators and traditional healthcare entities.

Policymakers should recognize the need for public education on healthy aging and longevity interventions, starting with the youngest in schools. Allocating resources for campaigns that raise awareness about the importance of the foundational pillars of lifestyle

choices, such as maintaining a healthy diet, regular exercise, and sufficient sleep, along with preventive measures and the potential benefits of longevity-focused interventions, such as specific nutritional supplements are of significant importance. Public campaigns would help with debunking misconceptions and promote informed decision-making, as educated individuals are more likely to actively engage in preventive measures that support their own health span. Integrating health considerations into education, urban planning, and social interactions would create an environment that promotes overall well-being and reduces the prevalence of age-related diseases.

To successfully raise awareness and get the population on board to practicing preventive measures, policymakers have the power to make longevity interventions accessible and affordable to general public. This might be via measures such as tax incentives for companies developing cost-effective solutions, negotiating partnerships with healthcare systems to integrate interventions, or even exploring public-private partnerships to subsidize costs.

Moreover, in recognition of the challenges posed by frailty and loss of mobility in the elderly, policymakers should further emphasize and promote incentives for programs that encourage active aging. This may involve initiatives supporting physical activity, mental health, and social connections among older populations, contributing to a more robust and active lifestyle.

To enhance the health infrastructure, policies should be directed toward the establishment of clinics and partnerships focused on healthy aging. These should specialize in diagnostics, preventive measures, and interventions designed to enhance overall health span. Such an approach aligns with the shift from reactive to proactive healthcare. Therefore, acknowledging the multidimensional approaches adopted by longevity companies, governments should foster an environment conducive to research and innovation. Collaborations between public institutions and longevity companies should be encouraged to accelerate progress and emphasize to role of credible scientific research to differentiate evidence-based solutions from unsubstantiated claims. Most importantly, acknowledging the financial challenges faced by the longevity companies is crucial for future research on aging, long-term clinical trials and development of regenerative medicine, gene therapy and other health-expanding solutions. Ensuring that the companies in the industry have sufficient funds is fundamental for future development of scientific advancements. In doing so, supporting advanced technologies to leverage epigenetic testing and AI-driven diagnostics that tailor interventions to individual needs might reduce the total need for funding as personalized healthcare plans contribute to more effective and targeted health outcomes.

Aging is a global challenge, and international collaboration is essential. To enhance the success of longevity companies and their impact, policies should promote extensive networks and collaborations. Building connections between longevity companies,

physicians, researchers, and investors can facilitate knowledge exchange and the development of evidence-based products. Policymakers especially should significantly more actively engage in collaborative efforts, sharing best practices, research findings, and innovative solutions to address the common goal of expanding human health span globally. Most importantly, unified regulatory approaches are crucial for a more cohesive global effort in addressing the complexities of an aging population. Starting with classifying aging as a disease, policymakers should explore a streamlined approval process, especially for supplements and therapeutics targeting aging directly, to foster innovation without compromising quality. Policymakers should work in collaboration with industry experts to establish standards, ensuring safety and efficacy of supplements, therapeutics, and other longevity-focused products, preventing the emergence of ineffective or even harmful interventions, and maintaining trust in longevity-related innovations.

5.3 Limitations

Part of the observed period coincided with the global COVID-19 pandemic, introducing a significant external factor that may have influenced health-related statistics. The pandemic could have disrupted healthcare systems, impacted lifestyle choices, and affected the accuracy of data on life expectancies, healthy life expectancies, and working life expectancies. The emergence of COVID-19 may have led to inconsistent reporting, incomplete datasets, and altered health dynamics, making it challenging to draw conclusions that accurately reflect typical aging trends. The unique circumstances during the pandemic might introduce a temporary bias, limiting the generalizability of findings to periods unaffected by extraordinary global health events.

The primary research component involves interviews with nine longevity companies. The limited sample size might not fully represent the diversity within this burgeoning industry, potentially leading to biased conclusions. Moreover, the selection process for these companies may introduce unintentional biases. However, the main purpose of the in-depth interview is to gain insight into the processes, thinking etc. instead of being representative and generalizable.

6 CONCLUSION

This master's thesis delves into the complex interplay between aging, healthy life expectancy, and economic implications, addressing the challenges posed by the disproportionate increase in life expectancy compared to healthy life expectancy. The multifaceted analysis encompasses a thorough examination of statistical data, projections, and insights from longevity companies, shedding light on critical issues and potential solutions.

The data reveals a remarkable rise in the share of older individuals within populations, coupled with an increasing presence of older people in the workforce. However, this positive trend in working life expectancy is not consistently aligned with healthy life expectancy. While advancements in healthcare and lifestyle improvements contribute to extended life spans, the extension of healthy life expectancy lags behind, posing significant challenges for global economies and healthcare systems.

The statistical insights illuminate the impact of age on self-reported health, emphasizing a substantial decline in perceived health status among the elderly. The prevalence of long-standing health conditions and their correlation with limitations in work highlights the intricate relationship between health and workforce participation in later life stages.

To explore preventive health care strategies and their impact on aging populations, a secondary analysis of numerous relating scientific papers, institutional reports and publications was conducted. Analysed data emphasizes primarily the importance of primary prevention, amongst secondary and tertiary prevention, as a means of reducing the risk of diseases and improving overall well-being. The investigated data reveals potential for substantial improvements in health outcomes through timely and consistent interventions, with focus on preventive measures and health promotion, resulting in significant reduction in the health burden.

The inclusion of initiatives like the UN Decade of Healthy Ageing, the European Innovation Partnership in Active and Healthy Ageing, and the Joint Action CHRODIS PLUS reflects the global and regional efforts to address aging-related challenges. The analysis highlights the significance of collaborative partnerships, knowledge exchange, and dynamic ecosystems in advancing health promotion and preventive measures.

Furthermore, the study acknowledges the evolving landscape of longevity medicine and the burgeoning industry it has spawned. The significant growth of longevity-oriented companies and the substantial market size underscore a collective recognition of the potential benefits in extending health span by combating age-related pathologies. Companies in the field focus mostly on pharmacological interventions, genetic manipulation, and data-driven solutions. Promising compounds include nicotinamide riboside, resveratrol, rapamycin, spermidine, antioxidants, and metformin. Uncertainties persist, but the field shows potential for addressing age-related issues and improving overall well-being.

Despite these advancements, the thesis recognizes certain limitations. The impact of the COVID-19 pandemic introduces a temporal factor that may influence the observed statistics, potentially deviating from typical aging trends. Additionally, while longevity companies contribute valuable insights, their perspectives may reflect a specific group of population limiting the generalizability of findings to the broader population.

In light of the findings, it is imperative for policymakers and stakeholders to consider a holistic approach. Policy recommendations, rooted in collaboration between longevity companies and healthcare providers, public education initiatives, reviewing regulatory policies, and the creation of a supporting environment for longevity companies, can contribute to mitigating the economic burden associated with an aging population.

The research underscores the urgency of aligning efforts to enhance health infrastructure, promote active aging, and foster international collaboration. By addressing the intricacies of aging trends and leveraging the potential of anti-aging interventions, a comprehensive and proactive approach can pave the way for a future where individuals not only live longer but also enjoy extended periods of health and productivity. Ultimately, the thesis advocates for a paradigm shift towards holistic and preventative measures, envisioning a society where the aging process is accompanied by a sustained and robust health span.

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APPENDICES

Appendix 1: Povzetek (Summary in Slovene language)

Magistrska naloga preučuje izzive, ki jih povzroča nesorazmerna porast pričakovane življenjske dobe v primerjavi z zdravo pričakovano življenjsko dobo, pri čemer se osredotoča na vplive na gospodarstvo in družbo. Staranje je globalna skrb, ki je zaznamovana z znatnim porastom starejšega prebivalstva, kar vodi v povečano prisotnost starejših na delovnem mestu. Kljub pozitivnemu trendu pričakovane delovne dobe, zdrava življenjska doba zaostaja, kar predstavlja velike izzive za svetovna gospodarstva in zdravstvene sisteme.

Prvi del naloge vključuje teoretično analizo in pregled sekundarnih statističnih podatkov za lažje razumevanje vpliva staranja na zdravje starejših populacij ter ekonomske posledice. Raziskovani so kazalniki, kot so pričakovana življenjska doba pri 65 letih, pričakovana delovna doba in pričakovana zdrava življenjska doba, ki razkrivajo nesorazmernosti povezanega s staranjem. Starejši se pogosto soočajo s poslabšanjem zdravja, kar omejuje produktivnost in tako gospodarstvom povzroča finančno breme.

Naloga v drugem delu raziskuje možne rešitve v podaljševanju zdravih let življenja in s tem preventivnih ukrepov za upočasnitev staranja. Globalni trg proti staranju, leta 2021 vreden 62,6 milijarde dolarjev, naj bi do leta 2030 presegel 106 milijard dolarjev. Znanstvene inovacije so spodbudile obsežno rast biotehnoloških podjetij za dolgoživost, ki razvijajo ukrepe, kot na primer prehranske dodatke, terapevtske posege, genske manipulacije in ostale pristope. Empirična študija, ki vključuje intervjuje z delujočimi v industriji, ponuja vpogled v cilje, ukrepe, izzive, izkušnje in priporočila podjetij za podaljševanje zdravih let življenja.

Ob priznavanju določenih omejitev, vključno z vplivom pandemije COVID-19 in sektorsko specifičnimi perspektivami podjetij za dolgoživost, naloga poudarja nujnost celostnega pristopa. Priporočila poudarjajo sodelovanje med podjetji za dolgoživost in ponudniki zdravstvenih storitev, pobude za javno izobraževanje populacije, pregled regulative ter ustvarjanje okolja, ki podpira delovanje podjetij za dolgoživost. Raziskava naloge poudarja pomen sodelovanja in izmenjave znanja za spodbujanje zdravja in preventivnih ukrepov.

Appendix 2: Interview questions

1. Can you describe your company's primary objectives and initiatives?
- In what specific ways does your company contribute to extending healthy life expectancy for individuals?

2. What is, in your opinion, the current state of healthy life expectancy among the population? How does it move with overall life expectancy?

3. Could you provide examples of interventions (supplements, devices, habits…) or practices that your company has found particularly effective in promoting healthy aging and improving life expectancy?

4. Are there specific demographic groups that your company focuses on when designing interventions to address healthy ageing?

5. What role do scientific research and evidence-based practices play in shaping your company's approach to enhancing healthy ageing?

6. Can you share any case studies or success stories that highlight the positive impact of your interventions on individuals' healthy life expectancy?

7. What do you consider to be the key strengths or unique features of your company's approach to addressing healthy ageing?

8. How does your company measure/planning to measure the effectiveness and impact of its interventions on improving healthy life expectancy?

9. What challenges or obstacles does your company encounter while working to support healthy ageing, and how do you address them?

10. How does your company collaborate with other stakeholders, such as healthcare organizations, researchers, or policy makers, to address healthy ageing?

11. What insights or best practices have you gained from your experience that you believe could be valuable for other organizations or policy makers working in the field of healthy aging?

12. Can you discuss any potential future developments or strategies your company is exploring to further expand healthy life expectancy among the population?

13. How do you envision the role of longevity companies evolving in the coming years in the context of an aging population?