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Which Direction to Take Further Research on the Impacts of Telomere Attrition on Aging, Age-Related Diseases, and Overall Healthcare Expenditures

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Abstract: Given the increasing prevalence of telomere research in the healthcare field, this paper first analyzes how newfound discoveries in the domain link to aging, and then explores how research has found a correlation between telomere shortening and health complications in particular age-related diseases. Afterwards, the complications faced by elderly populations due to age-related diseases and chronic conditions are discussed, including the association between increased chronic conditions and increased out-of-pocket expenditures. Then, a general overview about how aging has impacted the US healthcare system is addressed, including aspects such as healthcare expenditures, Medicare, access to resources, and overcrowding. A brief overview of how the COVID-19 pandemic has impacted access to healthcare and brought about discussion of reform is also mentioned.

Keywords: aging; chronic conditions; healthcare spending; telomere science

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1. Introduction

Telomeres are protective caps located on the ends of chromosomes, and telomerase is an enzyme that both maintains and rebuilds telomeric DNA (Warner and Hodes 2000; Demanelis et al. 2020). Telomeres are a necessary biological structure because of the way in which linear DNA replication occurs in cells. DNA replication occurs in such a way that each time a cell divides, some of the cell's DNA is lost from each end of the chromosome; this means that with each division, the cell loses DNA, and, as such, approaches the end of its life (Warner and Hodes 2000; Demanelis et al. 2020). Whenever a cell divides, the non-coding nucleotides of the telomeres are destroyed, causing them to shorten with each division until they are so short that the cell can no longer divide. At this point, the cell is referred to as senescent; once a cell is senescent, cell death results shortly afterward (Warner and Hodes 2000; Demanelis et al. 2020). Without these protective caps, human DNA would be destroyed upon replication, and cell division would be unable to occur. This would mean that living organisms, including humans, would be unable to grow and cease to exist. In addition, it is logical to infer from telomere science that having longer telomeres, or even a way to regenerate telomeres, could lead to a prolonged lifespan. This hope is shared by multiple scientists—if delaying telomere loss through reactivating telomerase or slowing telomere loss is a possibility, then perhaps the cell lifespan could be extended (Warner and Hodes 2000). Telomeres are an ongoing area of study for many researchers due to the mystery that still surrounds them even after years of research. Research has been conducted for decades as of the early 2020s, which is documented by an article in Generations: Journal of the American Society on Aging, published in 2000. Despite all of the years and resources put into research, the results still remain somewhat inconclusive on how targeting telomeres might help with aging. Such unresolved questions, along with the potential benefits of telomere research, are the primary driving factors behind continued research.

Telomere research has advanced throughout the years, branching multiple ways; one area of interest to researchers has been to search for ways to extend telomere length. A recent update on this area of research has led to promising results, such as the newly discovered process of translocating telomeres from antigen-presenting cells to T-cells, which increases the proliferation rate nearly three-fold while maintaining the T-cells' ability to generate immune memory (Zhang and Tong 2023). This new discovery holds promise for the future due to the possibilities that it could open up. For example, the process could provide insights for long-term immunotherapeutic strategies and potentially extend telomeres in selected T-cells that are prone to telomerase depletion (Zhang and Tong 2023). The potential that this research holds is extremely significant, especially when considering how it could change the lives of people with lowered immune systems or immunocompromised systems, such as the elderly. However, like many other areas of telomere research, there are still several uncertainties and questions surrounding the discovery of this new process of telomere extension. Further investigation and research are required to explore the mechanisms that underlie the differential ability of T-cells to undergo the process of telomere extension through translocation and its relationship with telomerase activity (Zhang and Tong 2023). Due to the slow nature of biological research, telomere research is a domain that is constantly involving, and as such, requires time, patience, and continued research to corroborate past findings and fill in the gaps that exist in the current science. The goal of this paper is to explore the current state of telomere science, along with the existing gaps in the research, and how it relates to aging and the age-related diseases that emerge as health complications. Afterwards, these complications and the healthcare costs that result from these health issues are analyzed.

Methodology

This paper serves as an examination of a cross-section of the available literature on telomeres, aging, resulting complications, and the impact on health expenditures. Due to the gradual nature of changes in biological research, this paper recognizes that the results may evolve and change in the future. As such, this paper strives to include both older and more recent sources to provide a true cross section of the literature at the present time. The articles referenced in this paper were selected based on a keyword search in an online database. The keywords used to find the chosen articles include the following: telomeres, telomeres and aging, telomeres and age-related diseases, telomeres and inconsistencies, aging population, and health expenditures and the elderly. The most impactful papers in various fields were then identified based on content as well as citation count; well-known authors and contributors were especially used in discussing the biology of telomeres and their influence on aging, such as Elizabeth Blackburn. Older articles were used as a foundation, and then a filter was used to find newer research that has built upon these foundational papers. The literature review also serves to identify the gaps present in the available research while building on existing theories and results from prior investigations. The existing gaps will then be explored for the purpose of determining which direction telomere research should be taken in the future to answer the unsolved questions posed as a result of the literature review. This paper fits in well both with the general literature (Carraher et al. 2004, 2005; Chapter 5 of Evaluating Challenges and Opportunities for Healthcare Reform, Haas et al. 2020; Carraher et al. 2008; Vojinović et al. 2022; Yu et al. 2022; Kamath et al. 2023; Sullivan 1999; Sullivan et al. 2009) and the journal literature (Courbage and Nicolas 2021; Nobanee et al. 2021; Stype 2022; Sibindi 2022; Al Rahahleh 2022; Hamin et al. 2022; Kyriakopoulos et al. 2022; Leightner 2022; Narita 2023). This paper fits into the Special Issue of the *Journal of Risk and Financial Management*, as it discusses the influence of age on healthcare expenditures as well as the demand and utilization of healthcare services.

2. Influence of Telomeres on Aging

A finding that has become more prevalent in recent studies is that telomere attrition plays a rather significant role in the aging process. When humans age, there are

obvious changes that occur in the body, both internally and externally. Of course, external physical traits such as graying hair, wrinkled skin, and diminished muscle mass are some of the things that first come to mind when we think of aging. However, there are significant changes that occur internally that are less obvious to non-medical professionals. It is commonly understood that as humans grow older, they become more susceptible to age-related diseases, ranging from cardiovascular disease to decreased immune function (Blackburn et al. 2015). What is not exceedingly known is that telomeres can contribute to these age-related diseases. As humans age, the length of the telomeres on the ends of the chromosomes shortens as cells continue to divide during the cell cycle. This makes them more susceptible to telomere dysfunctions, which are closely associated with age-related diseases.

Telomere maintenance deficiency in humans can cause disease processes during normal aging. Mutations that compromise telomere functions can result in naturally short telomeres in vivo, in turn leading to extreme telomere shortening; this results in the rapid loss of telomere capping and the protection that it provides to chromosomes. The signaling from the damaged telomeres has been connected to the emergence of phenotypes that lead to a variety of age-related diseases (Blackburn et al. 2015). These diverse inherited diseases all relate back to the shortened and unprotected telomere, and as such, are referred to by some researchers as "inherited telomere syndromes" (Blackburn et al. 2015). Although these diseases express themselves in different ways, they all accompany at least one of the following medical issues: loss of immune function, pulmonary fibrosis, gastrointestinal disorders, liver cirrhosis, and neuropsychiatric conditions; affected persons could also have additional phenotypes of accelerated aging, such as diabetes, myocardial infarction, hair graying, and skin pigmentation (Blackburn et al. 2015).

These diseases are also impacted by telomeres based upon the context of an organism's health as well as potential agonists due to lifestyle. For example, telomere syndrome symptoms can be exaggerated by health risks; this is seen most readily in smokers whose telomere mutations can eventually develop into emphysema and chronic obstructive pulmonary disease (Blackburn et al. 2015). Due to genetic components surrounding the biology of telomere mutations, telomere dysfunctions can interact with other disease etiologies and contribute to more severe forms of disease. This is one of the many ways that telomeres can contribute to disease, as telomere attrition from lack of telomerase-mediated replenishment is not the only way in which these diseases emerge.

In addition, evidence suggests that telomere attrition is not only associated with a variety of age-related diseases, as previously stated, but also the increased morbidity and mortality of these age-related diseases (Wang et al. 2018). For example, leukocyte telomere shortening is suggested to be associated with an increased risk of all-cause mortality in the general population (Wang et al. 2018).

Telomere attrition is not only influenced by aging, but other factors as well (Srinivas et al. 2020). For example, genetic factors such as the inheritability of telomere length can impact the regulation of telomere length in the aging process. Long-term environmental exposure to air pollution is also associated with age-related diseases and biological aging measures (Kaszubowska 2008; Ward-Caviness et al. 2016). This paper focuses on the aspect of telomere attrition in relation to age-related diseases and does not take into account different rates of attrition and telomere length from other genetic and environmental factors.

These findings have been supported by further experimentation and research on other organisms, such as mice. Researchers have demonstrated that telomere dysfunction caused by progressive shortening of the telomeres coincides with medical issues such as tissue stem cell depletion, delayed wound healing, diminished cardiac function, increased cancer incidence, frailty, and much more (Chakravarti et al. 2021).

It is important to note that the prior conclusions have been made on a variety of the available research available on telomeres and aging and age-related diseases. However, there are still many instances in which said relationships are still highly debated or inconclusive. For example, the extent to which environmental stressors have an effect on

telomere length, such as in the case of space radiation on the telomere length of astronauts, has not been thoroughly researched; similarly, the suggestion that longer telomeres are directly associated with less metabolic aging and longer lifespans is not always true, as there are potential negative effects due to elongation (Bevelacqua et al. 2021). Additionally, in the case of how involved telomeres are in causing age-related diseases, there are several inconsistencies in the available literature. One such case is that of atherosclerotic cardiovascular disease (aCVD). Some studies suggest that telomere length is a causal aCVD risk factor, while other research has suggested that telomere shortening is a consequence of the disease rather than a cause of aCVD (De Meyer et al. 2018).

3. Consequences of Aging on Healthcare Costs

It is important to discuss the effects of age-related diseases on the elderly population. Given that age-related diseases are significantly impacted by telomere shortening and dysfunction, it is important to question the overall role of age-related diseases in the elderly as well their need for healthcare.

As previously stated, age is often associated with multiple medical issues due to deteriorating health. The elderly are more predisposed than younger groups to age-related diseases and complications, ranging from cardiovascular disease and hypertension to osteoporosis and dementia (Jaul and Barron 2017). Some of these complications are more severe than others, but they all have their own costs. Even seemingly simple health issues can have staggering consequences, such as how frailty correlates to the progression of many age-related diseases and often puts the elderly at a higher risk for physical and cognitive decline as well as death (Fulop et al. 2010). As such, it is important to analyze how the current proportional population of elderly people in the United States utilizes healthcare, and whether or not this group is more at risk of increased healthcare expenditures due to complications from age-related diseases.

First, the proportion of elderly people in the United States is increasing, and it is projected to do so for the years to come. In 2010, the proportion of elderly people above the age of 65 was approximately 13% (Ortman et al. 2014). By 2030, it is expected that more than 20% of United States residents will be above the age of 65 (Ortman et al. 2014).

Given these statistics on the elderly population of the United States, there exists a reasonable concern regarding healthcare utilization and costs. In 2016, elderly patients represented 45.2% of the top decile of healthcare users, despite making up only 13.5% of the overall population (Zayas et al. 2016). This trend is consistent with data, which, when analyzed, proved that the age group of 65 to 85 years of age required a high utilization of healthcare (Zayas et al. 2016).

In addition, many instances of healthcare utilization by elderly patients seem to occur due to chronic diseases. For example, a study performed in 2019 on the number of adults who partook in healthcare utilization in Italy revealed that medical issues such as hypertension and diabetes strongly increased in prevalence as age increased (Atella et al. 2019). Chronic diseases, including vascular disease and arthritis, more than doubled for the population sample from 2005 to 2015 (Atella et al. 2019). Although the population sample does not come from the United States, it demonstrates this shift in the overall demand for healthcare services, especially for those involving chronic diseases, which have increased over the years.

Although chronic diseases are not synonymous with age-related diseases, there are many cases in which they correlate with each other, especially in the case of older adults and elderly patients. Age-related diseases are illnesses that occur more frequently in people as they increase in age, whereas chronic diseases are diseases that are long in duration, gradually change over time, and have no definite cure (Martin 2007). However, there is a significant amount of overlap in certain diseases, as they may be chronic and tend to appear as a person ages. In fact, conditions such as hypertension, diabetes, and myocardial infarction are all simultaneously categorized as both chronic diseases and age-related diseases, as chronic conditions tend to increase with age (Panaszek et al. 2009; Hwang

et al. 2001). A study in 2009 revealed that elderly patients typically suffer from multiple chronic diseases, with those over the age of 65 having at least three chronic diseases, while a substantial proportion of these patients suffer from at least five chronic diseases (Panaszek et al. 2009). These chronic diseases typically affect the cardiovascular, respiratory, and nervous systems and oftentimes occur simultaneously with other diseases, aggravating the symptoms that patients may face. Examples of chronic diseases in this categorization are chronic obstructive pulmonary disease (COPD) and chronic heart failure (CHF) (Panaszek et al. 2009).

When the frequency of age-related and chronic diseases is combined with the current proportion of the elderly population and their tendency for high healthcare utilization, it is likely to result in very high expenditures and costs for older American citizens. A study conducted in 2000 found that 5% of the elderly population over the age of 65 spent USD 500 or more out-of-pocket for prescription drugs. Additionally, of the group that spent USD 1000 or more on prescription drugs, 80% suffered from nonarrhythmic cardiovascular disease, 20% were diagnosed with diabetes, and approximately 33% had arthritis (Steinberg et al. 2000). This means that of the elderly people who had to pay larger out-of-pocket sums for prescription drugs, many of them suffered from chronic and age-related diseases. It is also fair to assume that both the percentage of elderly paying out-of-pocket costs for drug prescriptions as well as the price that they must pay has increased due to multiple economic factors that have occurred since the data were collected in 1998.

Age has also had a significant impact on out-of-pocket expenditures. A study conducted in 2001 revealed that amongst the population that was analyzed, the sample population of elderly patients aged 65 years and above who faced prevailing chronic conditions that were covered by Medicaid was lower than those covered by Medicare and private insurance or both Medicare and Medicaid (Hwang et al. 2001). There was a strong relationship between out-of-pocket expenditures and the number of chronic conditions, and further analysis suggested that the number of chronic conditions is a significant predictor of out-of-pocket healthcare expenditures (Hwang et al. 2001). However, there was variance between the groups based upon insurance coverage, as the average out-of-pocket expenditures for the elderly were the lowest for those insured by both Medicare and Medicaid (Hwang et al. 2001). This study demonstrates that there is a strong correlation between the number of chronic conditions the elderly population face and out-of-pocket expenditures that must be paid towards medical services. Many people above the age of 65 suffer from multiple chronic diseases and must receive treatment; from this, it is fair to infer that they are the target of more expensive medical services and must pay more out-of-pocket expenses than other age groups unless they have Medicaid and Medicare coverage. Once again, it is fair to assume that the price of the out-of-pocket expenditures has increased since this study was performed in 2001 due to different economic and medical circumstances.

Similarly, another study in 2000 confirmed that the long-term care of United States citizens tends to fall outside of Medicare's scope, and that the current long-term care system has many problems that need to be resolved due to an aging population; this includes the balance between institutional and noninstitutional care, financing mechanisms, the guarantee of high-quality care, and the integration of acute and long-term care (Feder et al. 2000).

Now let us explore the impact of an aging population on providers. Most providers did not concern themselves with providing care for chronic illnesses until the 1950s; for a long time, members of the healthcare community refused to acknowledge the prevalence of chronic diseases, and their limited recognition resulted in inappropriate responses to the wave of chronic diseases that emerged during the time period (Holman 2020). In fact, many providers instead focused on acute diseases, and medical education did not change to accommodate the rise of chronic illnesses, resulting in a healthcare crisis (Holman 2020). In the 1980s, healthcare began to acknowledge the seriousness of chronic diseases and took steps to ensure that proper research was being conducted. This was noted by the establishment of the National Center for Chronic Disease Prevention and Health Promotion as part of the CDC in 1988 (Holman 2020).

Since healthcare providers began to acknowledge the relevance of chronic illnesses and their impacts on the elderly population, geriatric doctors who are familiar with the chronic and age-related diseases the elderly encounter have become more and more common. Because the population of elderly patients has continued to increase throughout the decades and is expected to increase even more, geriatric and general medicine doctors are expected to be in high demand in the near future (Evans 1997). A 2012 study made a projection through to 2025, claiming that the total number of office visits to primary care physicians is expected to increase from 462 million in 2008 to 565 million in 2025 due to population growth and aging (Petterson et al. 2012). In addition, the study projected that at least 10,000 additional physicians will be required to deal with issues emerging from population aging alone (Petterson et al. 2012). A more recent study from 2018 supports this claim, as the study predicts that if a change to undergraduate medical education does not occur, there will be a deficit of 52,000 primary care physicians by 2025 (Phillips et al. 2019). This means that by 2030, 25% of US graduates must choose family medicine in order to avoid this deficit. Although there has been an increase in the proportion of medical students beginning family residency programs in the past ten years, only 12.6% of allopathic and osteopathic medical school graduates are entering these ACGME-accredited programs, meaning that a significant change is still needed (Phillips et al. 2019).

4. Ramifications of the Aging Crisis on the US Healthcare System

Considering the impacts that age has on the consumer population regarding age-related diseases as well as how it has influenced providers, it is important to account for how an aging population also impacts the United States' healthcare system. Similarly, it is important to address whether and how the healthcare system must change to best serve patients given the ongoing demographic change.

First, we must establish that the projected gradual increase in the elderly population over the decades to come can have detrimental impacts on the current US healthcare system. The concern of how aging might impact the healthcare system has been brought up several times in the past decade. There are questions about whether or not the current systems and safety nets put into place to provide the elderly with financial security are enough to accommodate the increasing proportion of old to young people (World Bank 1994). This concern was aggravated during the global crisis of the COVID-19 pandemic, as the pandemic revealed that while programs such as Social Security are a foundation for economic security for older adults, it alone is insufficient—especially during times of crisis (Li and Mutchler 2020).

The competency of the current healthcare system is especially under scrutiny when considering how an aging population can impact healthcare expenditures. Due to physicians' integral role in the US healthcare system, physician expenditures have a direct impact on national healthcare expenditures (Koenig et al. 2003). Therefore, considering the increase in the number of special care physicians, continued research on treatments for chronic diseases, and the steady increase in an elderly population in need of substantial medical care, healthcare expenditures might accelerate and become uncontrollable without proper policies (Koenig et al. 2003). This is supported by the fact that healthcare expenditures, on average, have increased from approximately 5% of GDP in 1970 to 10% in 2009 in Western countries, which correlates with the aging population in these countries (De Meijer et al. 2013). The combination of health economics and epidemiological research suggests that the relationship between age and need detriments explain the pattern of how aging often seems to correlate with health expenditures (De Meijer et al. 2013). In addition, the predicted increase in healthcare expenditures has proven to be an even greater problem, even in recent years. In the United States, national healthcare expenditures are projected to increase, on average, at an annual rate of 5.4% for 2019 to 2028, and to represent 19.7% of GDP by the end of 2028 (Keehan et al. 2020).

Given the rising healthcare costs and expenditures, there is a significant concern as to whether the Medicare program is sufficient to handle the increasing expenses. Medicare

covers approximately 14% of the US population, yet it was the primary payer of 39.4% of hospitalizations in 2015 (El-Nahal 2020). The expansion of the program throughout the years has resulted in many complexities and different aspects of coverage for both beneficiaries and providers (El-Nahal 2020). Nevertheless, although the program has expanded in most states and seems to improve overall access and disparities, the impact of new Medicare enrollment regarding coverage type and the number of chronic illnesses is still relatively unknown (Yeung et al. 2021). Whether or not Medicare can be beneficial to preserving health by increasing preventative care, provider visits, self-reported health, etc., is incredibly relevant to the aging population, especially when considering the impact of chronic diseases on the elderly's use of service. This is because there is a significant overlap between the age at which Medicaid provides coverage and requirement for more intensive treatment; there is a significant increase in the intensity of treatments provided in the hospital once the age of 65 is reached, which is also when the elderly become eligible for Medicare (Card et al. 2009).

Given the need for more intensive treatments for people above the age of 65, it is not a surprise that overall expenditures to continue coverage will greatly increase for the government. Over the next decade, it is projected that the federal government spending for programs such as Medicare and Social Security will increase from 7.9% of GDP in 2019 to approximately 10% of GDP in 2029, which is nearly two-thirds of mandatory federal spending (Super 2020). In addition, chronic and age-related diseases that result in functional limitations are projected to become much more common, as almost 70% of Americans above the age of 65 are expected to have need for long-term services and supports (LTSS); this brings about a greater need for long-term care insurances (Super 2020). Yet another contribution to healthcare expenditures is the population of elderly who are 85 years of age and above, as this age group is considered to be the one with the highest out-of-pocket spending among public and private insurance (Dieleman et al. 2020). This is especially relevant as the population of elderly Americans aged 85 and older is projected to double from 6.7 million in 2020 to 14.4 million in 2040 (Administration for Community Living 2022).

There is also a question of how specific state governments may respond to an increase in elderly population, especially since certain states seem to hold a greater appeal to older citizens. People above the age of 65 seem to prefer locations with warm climates, proximity to coasts, already large elderly populations, etc. (Rajbhandari and Partridge 2018). This has resulted in a concentration of elderly populations in places such as Florida, Arizona, and California (Rajbhandari and Partridge 2018). The migration of the elderly population must be closely monitored due to how increased health expenditures and demand for local services can impact the state economy (Rajbhandari and Partridge 2018).

Yet another concern that has emerged as a result of an aging population is whether or not the current resources provided by the US healthcare system are enough to accommodate the demand for more complex services. Due to the elderly being more prone to chronic and age-related diseases, treatment must be taken under special consideration regarding potential risks and consequences, meaning that the demand for health-related services will increase (Marshall et al. 2002). In general, large tertiary institutions tend to offer more full-scope services than community hospitals and tend to be more involved in geriatric services (Alexander et al. 1984). Elderly patients need access to more complex services provided by hospitals to improve their health and ensure longevity. However, there exists an overcrowding issue in hospitals, especially in emergency departments (EDs), that could have a significant negative impact on geriatric patient outcome (Derlet and Richards 2002). An analysis determined that the risk of death for the adult population was increased by 34% at 10 days for patients exposed to overcrowding during hospitalization (Savioli et al. 2022). A study conducted in 2002 regarding ED overcrowding in Texas, Florida, and New York denoted that increased patient volume was one of several factors that caused overcrowding in emergency departments (Derlet and Richards 2002). Of the patients who require ED services, geriatric patients seem to dominate the spectrum. Elderly patients are brought

to EDs and hospitals via ambulance much more frequently, they require more frequent hospital admissions, and they are more likely to be triaged as critical than young adults (Yim et al. 2009; Sanders 1992). In addition, patients with risk factors relating to older age, sex, poor health, prior same-year hospital admissions, and diseases such as diabetes and coronary artery disease are more likely to be readmitted and hospitalized repeatedly (Boult et al. 1993). This readmission is likely to have an impact on overcrowding in hospitals and EDs, because the hospitalization of the same patients repeatedly alongside with other patients in need of medical services can cause an overflow of patients.

Unfortunately, the excessive number of patients who contribute to the overcrowding effect in EDs and hospitals has a negative impact on overall patient outcome. The overflow of patients can often result in errors, delayed care in the case of critical cases, increased morbidity, and excess deaths (Richardson and Mountain 2009). Because the nature of overcrowding is an international issue that multiple countries have had to deal with, there have been attempts to find solutions to alleviate the problem of patient overflow. For example, the United Kingdom put into place a rule that over 90% of ED patients should either be admitted to the hospital or discharged within four to six hours of presentation (Di Somma et al. 2015). However, although this rule appears to be effective in decreasing overcrowding in EDs and has led to the further research and development of acute clinical indicators, it also brings about the potential for healthcare employees to override clinical judgements in favor of meeting targets (Di Somma et al. 2015). It is difficult to find a solution to the issue of overcrowding that is effective, yet does not compromise patient outcomes.

Overcrowding in EDs and hospitals has only increased in the last few years, especially due to the COVID-19 pandemic (Savioli et al. 2022). The sudden need for high-intensity care in such an unprecedented manner clashed considerably with the number of available resources in EDs, as there was a lack of beds to deal with the significant inflow of sick patients as well as a prolonged hospitalization period of quarantine to limit the spread of infection (Savioli et al. 2022). As a result of the unexpected overcrowding and complications that occurred during the COVID-19 pandemic, access to EDs and healthcare was especially limited. This limited access was especially detrimental to the elderly population in the US, as the pandemic made facility-based care for chronic illnesses extremely challenging (Núñez et al. 2021). The chronic conditions for which access to care was very limited during the pandemic included diabetes, hypertension, and chronic obstructive pulmonary disease (COPD), which are also considered to be age-related diseases (Núñez et al. 2021). The COVID-19 pandemic also erected barriers to follow-ups and continued treatment. Evidence shows that chronic diseases requiring regular disease management and follow-ups to avoid negative health outcomes significantly decreased during lockdown; as a result, ongoing care and support systems for patients, especially the elderly, greatly diminished (Fekadu et al. 2021).

The issues encountered during the COVID-19 pandemic have resulted in a more in-depth analysis of what changes must be made to the US healthcare system. Suggestions regarding how hospitals should restructure to accommodate demand for both acute and chronic care along with care coordination have been made, along with a movement towards telehealth and digital care (Auener et al. 2020). Given the new ideas for healthcare and policy reform, there is no doubt that further reform to the US healthcare system will follow. The pandemic demonstrated how unprecedented events can put a sudden strain on the system, especially when a significant proportion of the population that simultaneously requires a substantial number of medical services is affected—in this case, the elderly population aged 65 and above.

Elder Financial Abuse

As previously concluded, the elderly are predisposed to increased healthcare expenditures, especially out-of-pocket spending, due to an increased vulnerability to medical issues, including age-related diseases. Unfortunately, the elderly are also more vulnerable financially, not only due to an already high amount of healthcare spending, but also due to

elder financial abuse. Approximately 6.8% of people aged 60 years and above are subject to elder financial abuse, which is defined by the WHO as the illegal misuse of an older person's money, property, or assets (Kiril 2020).

The elderly lose billions of dollars due to financial abuse, with an estimated USD 2.6 billion to USD 36.5 billion dollars being lost annually (Riederer and Golding 2020). Risk factors for elder financial abuse include dependency or frailty, cognitive impairment, and mental illness or distress; this includes diseases such as Alzheimer's Disease (Riederer and Golding 2020). As such, the financial community must be aware that an increasing elderly population could mean an increase in elder financial abuse in the near future, and as such, should pay attention to particularly vulnerable elder groups such as those impacted by age-related diseases that influence cognition.

5. Resulting Gaps in Telomere Research

As mentioned at the start of this paper, one of the hopes of researchers is to determine a way to slow telomere attrition and extend the cell lifespan, which could potentially lead to an extended human lifespan (Warner and Hodes 2000). This goal has many possible implications that have yet to be explored in the existing literature and is one of the most prominent gaps in the domain of telomere research. It is especially significant because the lack of concrete literature on the implications of an expanded lifespan means that there is a very vague, if not inexistent, benchmark for what adjustments should be made by society to accommodate the accompanying issues and changes. If the average lifespan were to increase due to telomere regeneration, how might this impact the fundamental aspects of society? For example, what implications might this hold for the workforce? If people have a longer lifespan, perhaps the average retirement age would increase. What would this mean for younger employees? Would this result in a surplus of employees in corporations? How would corporations balance hiring new employees who have new skills and diverse ideas while also retaining their senior workers who are most familiar with company procedures and standards? For example, if a big breakthrough was made in the domain of telomere science that resulted in a ten-year increase in the average American's lifespan, would the retirement age also increase by ten years? Similarly, how would postretirement work engagement be impacted by this increase in lifespan? Current advancements in healthcare have made it so that people may live for over 25 years after they retire, and retirees have shown a willingness to engage in postretirement work programs offered by companies concerned with labor shortages (Sullivan and Al Ariss 2019). Would there be a decrease in the amount of postretirement work programs due to a surplus of workers in the labor force given a later retirement age?

In addition, how would the economy react to such an increase in lifespan? A study analyzing the demographics of France, Germany, and Italy suggested that investing abroad, endogenous human capital formation, and increasing the retirement age should be carried out to avoid the less desirable effects of aging; these modifications would be beneficial to economic aggregates and welfare in an open economy (Vogel et al. 2017). In reference, endogenous human capital formation, in this case, refers to the models of endogenous growth and promotes the idea that improvements in human capital—including knowledge, technology, and skills—contribute greatly to prosperity alongside other internal processes (Dunford 2009).

Having an increased average lifespan would also mean that as time passes, the elderly population would be quite significant in developed countries such as the United States. As such, how would society benefit from an increased elderly population? For example, it is known that the elderly population tends to contribute more to the greater good of society through charitable donations and volunteering than younger adults (Mayr and Freund 2020). Therefore, would there be an increased effort in altruistic tendencies due to an increased elderly population? Perhaps it would be beneficial to consider public policies that encourage the engagement of older adults in society, whether it be via working, caregiving, or volunteering (Gonzales et al. 2015).

Yet another aspect that telomere research could impact is the healthcare business in itself. While it is possible to attempt to predict how the business might change by looking at the changes that occurred in the past due to the emergence of other prominent biotechnologies, this is still a significant gap in the available research that deserves further investigation. The ways in which biotechnology can work to increase lifespan is an area that is highly explored, especially by pharmaceutical companies. For example, Unity Biotechnology has raised USD 116 million from investors, including Jeff Bezos, to develop senolytic treatments that seemed to extend the medium lifespan in mice in a previous study (De Magalhães et al. 2017). If a way to elongate telomeres becomes available for the public and acts as a cure for age-related diseases that are caused by shortened telomeres and telomere dysfunctions, how would this impact healthcare companies? By providing people with a 'cure-all' for some of these diseases, there would no longer be a need for the current medications that are being used for treatment. As such, would this mean that healthcare companies—in particular, pharmaceutical companies—would sell to a shrinking customer base, or would they capitalize from selling drugs that have been tested and can increase the median lifespan? How would they then respond to this new biotechnology? In addition, how would this technology be priced, and how would the intellectual property of the new treatment be handled? How would healthcare businesses navigate the ethical dilemma of how to balance profit generation with a social contract?

The US healthcare system is highly regulated and influenced by government policy; thus, a major discovery in telomere science would likely lead to a change in government regulation. Would the government provide funding for further telomere research if it provides so much relief to a significant portion of the population? Would the government regulate the usage of this new telomere-lengthening technology to be sure that it is not abused? There is also the question of how federal policies would be altered to adapt to this new change. For example, would the qualifying standards for Medicare change? Would states alter their requirements for Medicaid? How would foreign governments respond to this new change, especially considering the different healthcare systems implemented around the world? An increase in the average life expectancy could change the consumption of government support programs and insurance to varying degrees, as there is a strong association between age and consumption of healthcare services, as previously stated. However, there is a question of how much the consumption of healthcare services may change, as there are several factors that influence a consumer's choice to utilize services (Narita 2023).

It is also worth noting that due to ongoing research regarding innovations in telomere biotechnology, it is uncertain if merely overall life expectancy will increase or if there will also be an increase in the quality-of-life expectancy. Although an increased lifespan due to biotechnology would be a groundbreaking discovery, it may hold little to no appeal if the quality of living decreases during this extended time. As such, further research should be conducted to discover whether quality of life is something that can also be significantly impacted by telomere biotechnology. There are also several unanswered questions regarding telomere shortening and neurological disorders that result from brain aging. A study suggested that additional research is needed in this area, especially regarding the shortening of neuronal and glial telomeres during aging and the relation of telomere degradation to neurological disorders (Eitan et al. 2014). It is also important to note that brain aging can be impacted by multiple factors; for example, late-onset short-term intermittent fasting can potentially be used to reverse age-related cognitive decline and improve the plasticity of an aging brain (Bang et al. 2022). As such, telomere extension may not be the only solution that is worth exploring to solve problems associated with aging.

A very important consideration for future research is the ethical implications of telomere biotechnology. Is it ethical to alter the predisposed length of telomeres, and as such, alter genetic makeup in order to expand life by potentially eradicating certain age-related diseases that may serve as a population control? Even if increasing the average lifespan is a possibility, should it truly be carried out, or is it going against the boundaries

established by nature? There are also ethical implications regarding the distribution of this invention. How would equal access be ensured throughout society? Because this biotechnology would be the first of its kind and provide massive relief, it is fair to assume that the price will not be low. Therefore, how would those of lower socioeconomic status gain access to the treatment? It would be incredibly unethical to provide a 'cure-all' for only the wealthy portion of the population when all socioeconomic classes suffer from age-related complications and diseases. It is worth considering what sort of system should be put in place to attempt to provide a fair and equal distribution of such a biotechnology to all people. Price alone is not likely to be a fair factor, especially for a product that would be in high demand. The distribution of the COVID-19 vaccine is an example of how unfair distribution could occur, as the vaccine was distributed first to wealthier nations (in relation to GDP per capita), especially rich European and North American countries (Basak et al. 2022). As such, what distribution system would minimize this gap to prevent such inequalities from occurring? Is it even possible to equally distribute such a technology that would likely be in high demand? Recent research in the case of the allocation strategies of the COVID-19 booster demonstrates that a constrained optimization (CO) model would reduce the total costs by 60% and reduce medical resource by 81% (Kapoor et al. 2023). Although this distribution strategy is tailored for the COVID-19 booster, it is worth conducting further research to determine whether or not such an allocation strategy could be useful in the case of biotechnology. Similarly, it is important to note that distribution and pricing amongst countries with higher GDP is likely to be different than that of countries with lower GDP. A study completed on the cost-effectiveness of the rotavirus vaccine across different countries with high GDP per capita and low GDP per capita demonstrated that the difference between the neutral price and maximum price is large for countries with low healthcare investment and a high disease burden (Standaert et al. 2014). This suggests that different approaches regarding the pricing of biotechnology might be necessary, and that alternative economic methods should be used to assess the differences in healthcare interventions in different countries to determine said approaches to pricing. Given that in the case of vaccines, it is difficult to perform a total health economic analysis using conventional cost-effectiveness analysis, there is a likelihood for there to be similar, if not more significant, challenges to conduct such an analysis for new biotechnology (Postma and Standaert 2013). It is important that the solution to the distribution of such a technology is not only equitable, but economically favorable and given that in the case of rotavirus vaccination achieving an optimal launch is very important to achieve long-term economic success, more thought and research must be placed into finding an ideal allocation system (Standaert 2023). Additional research on how to achieve an appropriate modicum of equality in distribution while ensuring adequate profit for biotech companies is needed to close this gap in the literature.

6. Further Discussion and Conclusions

Overall, there are several existing gaps in the present literature regarding telomere research, and as such, there are many instances where the necessary accommodations that should be made by society in reaction to potentially life-altering changes are left up to prediction and guesswork. The everchanging nature and continuous development of the research means that it is incredibly difficult to narrow down a concrete direction that telomere research should take in the future. Nevertheless, it is highly recommended that researchers begin to investigate ways in which to modify the current healthcare system in the United States to accommodate the growing elderly population and the multitude of medical problems that accompany them due to age-related diseases.

Telomeres have a significant impact on the aging process, especially the process of telomere attrition. Telomere shortening is directly linked to the emergence of age-related diseases, and, when combined with other health risks, can result in severe symptoms and illnesses. These effects are especially observable in the elderly, who experience deteriorated health and require more treatments as a result. The elderly's high utilization of healthcare

services results in a large number of expenditures, and there is a strong correlation between the number of out-of-pocket expenditures and chronic conditions. This demonstrates how telomeres, particularly telomere shortening, can directly impact both the health and financial status of a significant portion of the existing population.

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