



Financial sustainability and risk in anti-aging startups

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Abstract

The anti-aging industry has experienced rapid growth driven by significant advancements in biotechnology, consumer interest in longevity, and substantial investment. This study explores the financial sustainability and risk management practices of anti-aging startups, highlighting key challenges and opportunities. Through case studies, the research examines funding strategies, regulatory hurdles, and market dynamics. Successful startups demonstrate robust financial planning, strategic partnerships, and innovative technological approaches, while unsuccessful ventures reveal the high risks associated with clinical development. The findings underscore the importance of comprehensive risk management and strategic financial planning in achieving long-term sustainability. This research provides valuable insights for entrepreneurs, investors, and policymakers aiming to navigate the complex landscape of the anti-aging market.

Keywords: *anti-aging industry, financial sustainability, risk management, biotechnology startups, venture capital*

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1. Introduction

The anti-aging industry has boomed in recent years thanks to advances in biotechnology and the pharmaceutical industry and increased consumer awareness about aging and longevity. The global anti-aging market, valued at \$58.5 billion in 2020, is expected to reach \$88.5 billion by 2026, growing at a compound annual growth rate (CAGR) of 7.2% (Grand View Research, 2021). This growth is fueled by an aging population, rising tax revenues and transforming the health and wellness of residents, creating fertile ground for new initiatives focused on anti-aging solutions. Anti-aging companies are investing in advanced research in areas such as genomics, new treatments, and cosmetics. Companies such as Calico Life Sciences, a division of Alphabet Inc., are investing heavily in understanding the science of aging to develop life-improving drugs (Westphal, 2020).

Other emerging startups include Unity Biotechnology, which focuses on senolytic drugs for cell elimination, and Juvenescence, which produces compounds aimed at slowing aging (Campisi et al., 2019). These initiatives leverage advances in artificial intelligence and machine learning to accelerate drug discovery and development to continue driving innovation in this field. However, the rise of anti-aging initiatives is not without its problems. High research and development (R&D) costs, along with regulatory requirements, pose significant barriers to entry and sustainability. Despite these challenges, the opportunity to generate high returns on investments continues to attract venture capitalists and private equity firms. Unity Biotechnology, for example, raised \$116 million in its initial public offering (IPO) in 2018; this represents the strong interest of investors in anti-aging technology (UNITY Biotechnology, 2018). The competitive market environment is also becoming more difficult as more players enter the field. Established pharmaceutical companies are expanding their business into anti-aging products, further boosting the startup's shares.

Additionally, partnerships and collaborations are increasingly common as startups join forces with academic institutions and large corporations to share resources and expertise. For example, Juvenescence is working with Insilico Medicine, a pioneer in the discovery of AI-powered drugs, to develop new anti-aging treatments (Juvenescence Ltd, 2019). Ethical considerations regarding anti-aging research and medicine cannot be ignored. The quest for longevity raises questions about accessibility, equity, and the potential social consequences of extending human lifespan. Ethical principles and policies must evolve to address these issues and ensure that advances in anti-aging technology benefit society as a whole. This paper is

structured as follows: Section 2 reviews the relevant literature on financial challenges, risk management practices, sustainability metrics, investment trends, and case studies of successful and unsuccessful anti-aging startups. Section 3 presents the methodology, focusing on the application of case studies. Section 4 discusses the results of the case studies. Finally, Section 5 concludes the paper, summarizing the findings and their implications.

2. Literature review

2.1 Financial challenges in the anti-aging industry

The anti-aging industry has experienced a significant surge in recent years, driven by advancements in biotechnology, pharmaceuticals, and consumer awareness about aging and longevity. The global anti-aging market was valued at around \$58.5 billion in 2020 and is anticipated to reach \$88.5 billion by 2026, growing at a compound annual growth rate (CAGR) of 7.2% (Grand View Research, 2021). This growth is fueled by an aging population, increased disposable income, and a societal shift towards health and wellness, creating fertile ground for startups focusing on anti-aging solutions. Anti-aging startups are capitalizing on cutting-edge research in areas such as genomics, regenerative medicine, and cosmeceuticals. Companies like Calico Life Sciences, a subsidiary of Alphabet Inc., are investing heavily in understanding the science of aging to develop therapies that extend healthy lifespan (Westphal, 2020).

Other notable startups include Unity Biotechnology, which focuses on senolytic drugs to eliminate senescent cells, and Juvenescence, which develops compounds aimed at slowing the aging process (Campisi et al., 2019). These startups are leveraging advancements in artificial intelligence and machine learning to accelerate drug discovery and development, further driving innovation in the sector. However, the rise of anti-aging startups is not without its challenges. The high cost of research and development, coupled with stringent regulatory requirements, poses significant barriers to entry and sustainability. Despite these obstacles, the potential for substantial returns on investment continues to attract venture capitalists and private equity firms. For instance, Unity Biotechnology raised \$116 million in its initial public offering (IPO) in 2018, highlighting the strong investor interest in anti-aging technologies (UNITY Biotechnology, 2018). The market's competitive landscape is also intensifying as more players enter the field. Established pharmaceutical companies are expanding their portfolios to include anti-aging products, further raising the stakes for startups.

Additionally, collaborations and partnerships are becoming increasingly common, with startups joining forces with academic institutions and large corporations to access resources and expertise. For example, Juvenescence partnered with Insilico Medicine, a pioneer in AI-driven drug discovery, to develop new anti-aging therapies (Juvenescence Ltd., 2019). The ethical considerations surrounding anti-aging research and treatments cannot be overlooked. The pursuit of longevity raises questions about accessibility, equity, and the potential societal impact of extending human lifespan. Ethical frameworks and regulatory policies must evolve to address these concerns, ensuring that advancements in anti-aging technologies benefit society as a whole. The anti-aging industry, despite its promising potential, faces several financial challenges that can hinder the growth and sustainability of startups. One of the most significant challenges is the high cost of research and development (R&D). Developing new treatments and products requires substantial investment in preclinical studies, clinical trials, and regulatory approval processes. According to a report by the Tufts Center for the Study of Drug Development, the average cost of bringing a new drug to market is approximately \$2.6 billion, factoring in the costs of failed trials and post-approval studies (DiMasi et al., 2016). Funding these extensive R&D activities often requires securing significant capital from venture capitalists, private equity firms, or public markets. However, early-stage anti-aging startups may struggle to attract investment due to the high-risk nature of their ventures. Investors require strong evidence of scientific validity and potential market viability, which can be challenging for startups with limited clinical data or commercial success.

Consequently, securing initial funding and maintaining cash flow are critical hurdles for many anti-aging startups. The regulatory landscape presents another financial challenge. Anti-aging products and treatments must comply with rigorous regulatory guidelines set by agencies such as the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA). Navigating these regulatory pathways can be time-consuming and costly, requiring startups to invest in regulatory expertise and compliance infrastructure. The uncertainty and complexity of the regulatory approval process can lead to delays and additional costs, further straining financial resources (Hwang et al., 2020). Market competition also exerts financial pressure on anti-aging startups. As the industry grows, the number of competitors increases, leading to a crowded market where differentiation becomes crucial. Startups must invest in marketing and branding to establish a unique value proposition and capture market share. This can be particularly challenging in a market dominated by well-established pharmaceutical companies and large cosmetic brands with substantial marketing budgets. Moreover, the

reimbursement landscape for anti-aging treatments can be complex and uncertain. Securing coverage and reimbursement from insurance providers is essential for the widespread adoption of new therapies. However, anti-aging treatments often fall into a gray area between medical necessity and elective procedures, complicating reimbursement negotiations. Startups must navigate this landscape to ensure their products are accessible to a broad patient population without imposing prohibitive out-of-pocket costs.

In summary, the financial challenges facing anti-aging startups are multifaceted, encompassing high R&D costs, regulatory complexities, intense market competition, and reimbursement uncertainties. Addressing these challenges requires strategic financial planning, robust funding strategies, and a deep understanding of the regulatory and market environment. Despite these obstacles, the potential rewards in the anti-aging industry continue to drive innovation and investment, with startups striving to overcome these financial barriers and achieve long-term sustainability.

2.2 Risk management practices

Effective risk management is critical to the sustainability and growth of an anti-aging startup operating in a dynamic and uncertain environment. These startups face many challenges, including financial, regulatory, operational, and market-related issues. Implementing strong risk management practices can help mitigate these risks and ensure long-term viability. One of the most significant financial risks for anti-aging startups is the high costs associated with research and development (R&D). To address these risks, startups often employ staged R&D funding, where initial funds are allocated to early-stage research and proof-of-concept studies. This approach minimizes initial investment and allows the startup to secure additional funding based on demonstrated progress. Additionally, forming strategic alliances with large pharmaceutical companies or research institutions can alleviate the financial burden on startups by providing access to funding, resources, and expertise (Chiesa and Frattini, 2011).

Regulatory risks are another major concern for startups. Navigating the complex regulatory environment requires significant investments in compliance and legal expertise. Startups can mitigate these risks by engaging with regulatory authorities early in the development process to understand approval requirements. Developing a comprehensive regulatory strategy that includes regular communication with regulators, adherence to Good Manufacturing Practices (GMP), and thorough documentation can streamline the approval

process and reduce the risk of delays or costly rejections (Hedner & Nilsson, 2011). Operational risks, such as supply chain disruptions and production issues, can also impact the performance of anti-aging startups. To mitigate these risks, startups should implement effective supply chain management practices, including diversifying suppliers, maintaining safety stock, and investing in quality control systems. Additionally, leveraging advanced manufacturing technologies, such as automation and digitalization, can enhance operational efficiency and reduce the risk of disruptions. Market-related risks, including competition and shifts in consumer preferences, are particularly pertinent in the fast-evolving anti-aging industry. Startups can mitigate these risks by conducting thorough market research and staying attuned to industry trends. Developing a strong brand identity and value proposition can help startups differentiate themselves from competitors and attract a loyal customer base.

Moreover, continuously iterating on product development and marketing strategies allows startups to adapt to changing market conditions and capitalize on emerging opportunities (Porter, 1980). In addition to these specific risk management strategies, it is crucial for anti-aging startups to implement a comprehensive risk management framework. This framework should include mechanisms for risk identification, assessment, mitigation, and monitoring. Conducting regular risk assessments can help startups identify potential vulnerabilities and implement mitigation measures to address identified risks. Continuous monitoring and evaluation of risk management practices ensure that startups remain resilient and can swiftly respond to emerging challenges (Kaplan and Mikes, 2012).

2.3 Sustainability metrics in startups

Assessing the sustainability of anti-aging startups requires a comprehensive understanding of various financial and operational metrics. These metrics provide insight into a startup's financial health, performance, market position, and growth prospects. This section examines key sustainability metrics and their importance in evaluating the performance of anti-aging startups. One of the most critical financial metrics for assessing sustainability is the burn rate, which measures the rate at which a startup uses its capital. A high burn rate indicates that a company is depleting its cash reserves quickly, which can be detrimental if additional funding is not secured. For example, if an anti-aging startup has \$10 million in funding and a \$1 million monthly burn rate, it will run out of funds in ten months unless it secures additional funding or generates \$10 million in revenue during that period. Maintaining a manageable burn rate is crucial for sustainability, especially in the anti-aging industry where product development can

be lengthy and capital-intensive (Sequoia Capital, 2020). Another important metric is the runway, which refers to the length of time a startup can operate before needing additional financing. This metric is calculated by dividing the available cash balance by the monthly burn rate. For example, if an anti-aging startup has \$5 million in reserves and a monthly burn rate of \$500,000, the runway is ten months. A longer runway gives startups more time to achieve critical milestones, such as product development, clinical trials, or market entry, reducing the pressure to raise funds frequently (Kerr, Nanda, and Rhodes-Kropf, 2014).

Revenue growth is also a crucial sustainability metric, indicating the rate at which a startup's revenue is increasing over time. Sustained and significant revenue growth is a positive indicator of market acceptance and business expansion. For example, if an anti-aging startup reports a 50% year-over-year revenue growth rate, it suggests strong demand for its products and the potential for future expansion. Monitoring revenue growth helps startups adjust their strategies to sustain growth and attract investment (Blank & Dorf, 2012). Profitability metrics, such as gross margin and net margin, provide insight into a startup's operational efficiency and profitability. Gross margin, calculated as $(\text{revenue} - \text{cost of goods sold})/\text{revenue}$, represents the percentage of revenue that exceeds the direct costs associated with producing the product. For example, if an anti-aging startup has \$10 million in revenue and \$6 million in direct costs, the gross margin is 40%. A high gross margin indicates effective cost management and pricing strategies. Net margin, calculated as $\text{net income}/\text{revenue}$, reflects the overall profitability after accounting for all expenses. A healthy net margin indicates financial stability and long-term sustainability (Graham, Harvey, & Rajgopal, 2005).

Return on investment (ROI) for R&D activities is another critical metric. ROI measures the return generated from investments in research and development. For example, if an anti-aging startup invests \$2 million to develop new products and generates \$10 million in revenue from those products, the ROI is $(10-2)/2 = 400\%$. High ROI on R&D investments indicates efficient use of resources and effective innovation strategies (Hall, 2002). Employee productivity and retention rates are also important indicators of sustainability. High productivity levels and low turnover rates suggest efficient workforce management and effective operations. For example, if an anti-aging startup with 50 employees generates \$5 million in annual revenue, the revenue per employee is \$100,000. Higher revenue per employee indicates better utilization of human resources and contributes to sustainable growth (Deloitte, 2020). Finally, environmental, social, and governance (ESG) metrics are increasingly recognized as essential

sustainability measures. ESG metrics assess a company's environmental impact, social responsibility, and governance practices. Anti-aging startups that adopt sustainable sourcing practices, promote diversity and inclusion, and maintain transparent governance structures are likely to enhance their long-term prospects by attracting socially conscious investors and consumers (Eccles, Ioannou, and Serafeim, 2014).

2.4 Investment trends in anti-aging ventures

Investments in anti-aging ventures have seen significant growth over the last decade, driven by the global focus on health, wellness, and longevity. This growth in investment is fueled by technological advancements, an aging population, and increasing consumer interest in age-related products and healthcare services. Understanding investment trends helps identify financial dynamics and potential opportunities in the anti-aging industry. One of the most prominent trends is the increasing support from venture capital (VC) for anti-aging startups. According to PitchBook data, investments in the anti-aging industry reached \$850 million in 2020, up from \$500 million in 2018, representing a compound annual growth rate (CAGR) of nearly 30% (PitchBook, 2021). This growth reflects investors' growing confidence in the potential of anti-aging technologies and their willingness to fund innovative solutions. Another trend is the involvement of high-profile investors and leading technology entrepreneurs in financing anti-aging ventures. For instance, Amazon founder Jeff Bezos and PayPal co-founder Peter Thiel have invested in companies such as Unity Biotechnology, which focuses on developing senolytic drugs to eliminate senescent cells associated with aging (CNBC, 2021). This investment not only provides substantial capital but also enhances the visibility and credibility of the anti-aging industry.

Private equity firms are also becoming increasingly active in the anti-aging industry, attracted by the high potential for returns. Global private equity investments in healthcare, including anti-aging, reached \$66 billion in 2020, with a significant portion directed towards biotechnology and life sciences (Bain & Company, 2021). Private equity firms often provide not only capital but also strategic guidance, operational support, and industry connections that are critical for the growth and expansion of startups. Partnerships and strategic collaborations represent another significant investment trend. Established pharmaceutical companies and large biotech firms are forming alliances with anti-aging startups to leverage their innovative technologies. For example, in 2020, Grifols entered into a partnership with Alkahest, a startup focused on developing plasma-based therapies for age-related diseases (Alkahest, 2020). Such

partnerships provide startups with access to advanced technologies, regulatory expertise, and distribution networks. Crowdfunding has also emerged as a viable funding source for anti-aging ventures, particularly for early-stage startups. Platforms like Kickstarter and Indiegogo allow startups to raise funds directly from consumers who are interested in their products and vision. For instance, in 2020, AgeTech, an anti-aging startup, successfully raised over \$1 million through a crowdfunding campaign to support the development of its new skincare product. Crowdfunding not only provides financial support but also helps build a community of early adopters and brand advocates.

Public funding and government grants play a crucial role in supporting anti-aging research. Organizations such as the National Institutes of Health (NIH) and the European Commission have invested substantial amounts in research projects aimed at understanding and mitigating the effects of aging. In 2020, NIH awarded over \$3 billion in grants related to aging research, reflecting the critical role of government agencies in advancing this field (NIH, 2021). Government funding helps initiate early-stage research and can attract private investments by validating the scientific and societal importance of the research.

In summary, investments in anti-aging ventures are characterized by diverse sources, including venture capital, private equity, corporate partnerships, crowdfunding, and government grants. High-profile investors and dedicated anti-aging funds play a significant role in driving the sector's growth. Understanding these investment trends provides valuable insights into the financial dynamics of the anti-aging industry and highlights opportunities and challenges for startups operating in this critical sector.

2.5 Market analysis and competitive landscape

The anti-aging market has become a highly competitive and dynamic arena, driven by rapid advancements in biotechnology, increasing consumer demand, and significant investments from both the private and public sectors. Understanding the market dynamics and competitive forces is crucial for anti-aging startups to navigate this challenging landscape and position themselves for long-term success. The global anti-aging market was valued at \$58.5 billion in 2020 and is expected to reach \$88.5 billion by 2026, growing at a compound annual growth rate (CAGR) of 7.2% (Grand View Research, 2021). This significant growth is driven by an aging population, increased awareness of age-related health issues, and rising interest in longevity and healthy living. The market encompasses various segments, including skincare,

pharmaceuticals, nutraceuticals, and medical devices. In the skincare segment, anti-aging products such as creams, serums, and treatments dominate the market. Companies like L'Oréal, Estée Lauder, and Procter & Gamble have established themselves as key players by leveraging extensive R&D, strong brand recognition, and effective marketing strategies. These companies invest heavily in innovation, continuously introducing new products that cater to consumer preferences for efficacy, safety, and natural ingredients (Euromonitor International, 2021).

The pharmaceutical segment, focused on developing therapeutics to treat age-related diseases and extend healthy lifespan, is characterized by intense research and significant investment. Major pharmaceutical companies such as Pfizer, Merck, and Novartis are actively engaged in anti-aging research, often through partnerships with biotech startups. These partnerships facilitate the development and commercialization of new therapies by providing startups with access to resources, expertise, and established distribution networks (BusinessWire, 2021). Nutraceuticals, which include dietary supplements and functional foods aimed at promoting healthy aging, represent another growing segment of the anti-aging market. Companies like Amway, Herbalife, and Nestlé are leaders in this space, offering a wide range of products that claim to support cellular health, boost immunity, and enhance overall well-being. The nutraceutical market is driven by consumer demand for natural and preventive health solutions, as well as increasing scientific evidence supporting the benefits of certain nutrients and bioactive compounds (MarketWatch, 2021). The medical device segment, which includes technologies such as laser therapy, radiofrequency devices, and minimally invasive procedures, is also expanding rapidly.

Companies like Allergan (a division of AbbVie), Syneron Candela, and Lumenis are major players offering innovative solutions for skin rejuvenation, wrinkle reduction, and body contouring. Technological advancements and the growing preference for non-invasive procedures contribute to the growth of this segment. The competitive landscape of the anti-aging market is characterized by the presence of both established players and emerging startups. Established companies benefit from extensive resources, brand loyalty, and economies of scale, allowing them to invest in R&D and marketing. These companies often acquire or partner with innovative startups to stay at the forefront of technological advancements and expand their product portfolios. Emerging startups drive innovation by focusing on novel research and disruptive technologies. Startups like Unity Biotechnology, Alkahest, and Juvenescence are examples of companies attracting significant investment and attention for their pioneering

efforts in senolytic therapies, plasma-based treatments, and regenerative medicine. These startups face the challenge of navigating regulatory hurdles, securing funding, and demonstrating the efficacy and safety of their products in clinical trials (PitchBook, 2021).

The regulatory environment plays a crucial role in shaping the competitive landscape of the anti-aging market. Regulatory agencies like the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA) set stringent standards for the approval of anti-aging drugs and treatments. Compliance with these regulations requires substantial investments in clinical trials, quality control, and regulatory expertise. Companies that successfully navigate this process gain a competitive advantage by establishing credibility and trust in the market (Hwang et al., 2020). Consumer preferences and expectations also influence the competitive landscape of the anti-aging market. There is a growing demand for products that are perceived as safe, effective, and backed by scientific evidence. Consumers are becoming increasingly knowledgeable and discerning, seeking transparency in product claims and formulations. This trend drives companies to invest in R&D, clinical trials, and clear marketing communications to build consumer trust and differentiate their offerings (Nielsen, 2021). Technological advancements, such as artificial intelligence (AI) and machine learning, are transforming the anti-aging market by accelerating drug discovery, optimizing skincare formulations, and enhancing the performance of medical devices. Companies leveraging these technologies can gain a competitive edge by bringing innovative products to market faster and more efficiently. For example, startups like Insilico Medicine use AI to identify new drug candidates for age-related diseases, while companies like SkinCeuticals offer personalized skincare solutions based on AI-driven skin analysis (Zhavoronkov, 2018).

In conclusion, the anti-aging market is characterized by robust growth, diverse product segments, and intense competition between established players and innovative startups. Key factors shaping the competitive landscape include consumer preferences, regulatory requirements, technological advancements, and strategic partnerships. Understanding these dynamics is essential for anti-aging startups to successfully navigate the market, differentiate their offerings, and achieve long-term success.

2.6 Regulatory and ethical considerations

The anti-aging industry operates at the intersection of advanced science and ethical considerations, requiring rigorous regulatory oversight and responsible practices. Regulatory

agencies such as the U.S. Food and Drug Administration (FDA), the European Medicines Agency (EMA), and other national authorities play a crucial role in ensuring the safety and efficacy of anti-aging products and treatments. Additionally, ethical considerations regarding accessibility, equity, and the social impact of longevity interventions add complexity to the industry. Regulatory oversight is vital for anti-aging startups aiming to bring new products to market. For instance, the FDA requires clinical trials to demonstrate the safety and efficacy of new drugs and treatments. This process involves multiple phases of clinical trials, each designed to evaluate different aspects of product performance.

Phase I trials focus on safety and dosage, Phase II on efficacy and side effects, and Phase III on confirming efficacy and monitoring adverse reactions (FDA, 2021). The rigorous nature of these trials ensures that only products with proven benefits and minimal risks reach consumers. However, the high cost and time required for these trials pose significant challenges for startups with limited resources. The regulatory environment also has specific requirements for different types of products. In the case of dietary supplements and cosmetic products commonly found in the anti-aging market, the regulations are less stringent compared to pharmaceutical products. The FDA's Dietary Supplement Health and Education Act (DSHEA) of 1994 allows dietary supplements to be marketed without prior approval, provided no disease claims are made and proper labeling is used (FDA, 1994). This regulatory flexibility enables faster market entry but also requires companies to maintain high standards of quality control to avoid legal and reputational risks.

In Europe, the EMA sets similar requirements for pharmaceutical products and provides a centralized process for approving new medicines. EMA regulations facilitate market access across European Union member states by ensuring consistent standards. Additionally, the EMA offers scientific advice and protocol assistance to companies developing new medicines, helping them navigate the regulatory process more efficiently. Ethical considerations are equally important in the development and use of anti-aging interventions. One of the primary ethical concerns is the equitable access to anti-aging treatments. As these therapies advance, there is a risk that they may become accessible only to the wealthy, exacerbating existing health disparities. Ensuring that anti-aging treatments are available to a broad population requires thoughtful policies and social and economic measures to promote affordability and accessibility (Daniels, 2015). Another ethical issue is the potential societal impact of extending human lifespan. Questions arise about the implications of population aging, resource allocation, and

intergenerational equity. For example, if anti-aging treatments lead to longer lifespans without a corresponding increase in healthspan, there may be increased demand on healthcare and social support systems for an aging population (Olshansky et al., 2006). Addressing these concerns requires a comprehensive approach that considers broader societal implications and promotes sustainable practices. Informed consent and transparency are also critical ethical considerations. Companies must ensure that clinical trial participants and consumers of anti-aging products are fully informed about the potential risks and benefits. This includes clear communication about the scientific basis, possible side effects, and realistic expectations. Ethical conduct that avoids exaggerated claims and provides accurate information is essential for maintaining public trust (Resnik, 2015). The emerging role of technologies in anti-aging research, such as genetic engineering and artificial intelligence, further complicates ethical considerations.

Genetic manipulation, for instance, raises concerns about unintended consequences and long-term impacts on human biology. The use of AI in drug discovery and personalized medicine necessitates ensuring that algorithms are fair, unbiased, and thoroughly validated (Chalmers et al., 2019). Privacy and data security are additional ethical concerns, particularly as anti-aging research increasingly relies on personal health data. Companies must implement robust data protection measures and comply with regulations such as the General Data Protection Regulation (GDPR) in Europe. Protecting the privacy and security of personal data is crucial for maintaining ethical standards and safeguarding individual rights.

In summary, regulatory and ethical considerations are paramount in the development and commercialization of anti-aging treatments. Navigating this complex landscape requires significant investments in regulatory compliance and ethical oversight. Addressing issues related to access, societal impact, informed consent, emerging technologies, and data privacy is essential to ensure that anti-aging innovations are safe, equitable, and beneficial to society. By adhering to high ethical standards and regulatory requirements, anti-aging startups can build credibility with consumers, investors, and regulators, ultimately contributing to the sustainable development of the industry.

2.7 Technological innovations and their impact

The advancement of the anti-aging industry is driven by technological innovations that enable the development of therapies and products aimed at extending human lifespan. These innovations span a wide range of areas, including biotechnology, artificial intelligence (AI),

regenerative medicine, and personalized medicine. Understanding the impact of these technologies is crucial for assessing their potential to transform the anti-aging landscape and support the sustainable growth of startups in this field. One of the groundbreaking technologies in the anti-aging space is gene editing. Gene editing technologies such as CRISPR-Cas9 have revolutionized the ability to modify genes associated with aging and age-related diseases. CRISPR technology enables precise editing of DNA, allowing researchers to correct genetic mutations that contribute to aging. For example, studies have shown that altering genes involved in cellular senescence can extend the lifespan of model organisms, providing a potential basis for human therapies (Hsu et al., 2014). The impact of gene editing extends to various anti-aging interventions, including novel therapeutics and regenerative medicine, positioning it as a cornerstone of anti-aging research.

Artificial intelligence (AI) and machine learning (ML) are also making significant strides in the anti-aging field. AI algorithms can analyze vast amounts of data to identify patterns and predict outcomes, thereby accelerating the drug discovery and development process. Companies like Insilico Medicine use AI to screen millions of compounds and predict their efficacy in targeting aging pathways. This approach significantly reduces the time and costs associated with traditional drug discovery methods. In 2020, Insilico Medicine identified new drug candidates for age-related diseases using its AI platform, demonstrating the potential of AI to revolutionize the anti-aging industry (Zhavoronkov et al., 2020). Regenerative medicine, including stem cell therapy and tissue engineering, represents another technological breakthrough with significant implications for anti-aging. Stem cells have the unique ability to differentiate into various cell types and regenerate damaged tissues.

Research in this field has led to the development of therapies aimed at repairing and rejuvenating aged tissues, such as skin, muscles, and organs. For instance, companies like AgeX Therapeutics are developing therapies that utilize pluripotent stem cells to regenerate aged tissues, restoring youthful function and appearance. The impact of regenerative medicine is profound, offering potential solutions for a wide range of age-related conditions and improving overall quality of life for the elderly. Personalized medicine is a rapidly evolving approach that holds promise for revolutionizing the anti-aging industry. Advances in genomics, proteomics, and metabolomics enable the development of personalized anti-aging therapies based on an individual's genetic and molecular profile. Personalized medicine allows for tailored interventions that consider the unique biological characteristics of each person. Companies like

Human Longevity, Inc. use genomic data to provide personalized health assessments and longevity plans, focusing on preventive measures to extend healthspan. By combining comprehensive profiling and advanced analytics, these companies can identify risk factors and recommend strategies to delay the onset of age-related diseases. Wearable technology and digital health platforms are also playing a crucial role in the anti-aging market. Wearable devices, such as fitness trackers and smartwatches, monitor various health parameters, including physical activity, sleep patterns, heart rate, and metabolic functions. These devices provide real-time data that can be used to track health trends and detect early signs of aging-related issues. Additionally, digital health platforms offer personalized health recommendations by integrating data from wearables with AI-driven insights. Companies like Fitbit and Apple are at the forefront of this trend, continually advancing their devices and platforms to support proactive health management and anti-aging (Piwek et al., 2016).

Another innovation is the use of biomaterials and nanotechnology in anti-aging applications. Biomaterials, such as hyaluronic acid and collagen, are widely used in skincare products to improve skin hydration and elasticity. Nanotechnology enables the development of nanoscale delivery systems that enhance the efficacy and penetration of active ingredients in anti-aging formulations. For example, nanoparticles can encapsulate antioxidants and deliver them to deeper layers of the skin, providing more effective protection against oxidative stress and aging. These technologies are revolutionizing the skincare industry by offering more effective and targeted anti-aging solutions. The integration of big data analytics with healthcare is another transformative approach in the anti-aging sector. Big data analytics involves processing and analyzing large and complex datasets to derive valuable insights. In the context of anti-aging, big data can be used to identify trends, predict outcomes, and optimize interventions. For example, analyzing population health data can reveal patterns associated with aging and inform the development of preventive strategies. Additionally, big data analytics can improve clinical trial design by identifying biomarkers and patient subgroups, thereby increasing the efficiency and success rates of anti-aging research (Chen et al., 2012).

In conclusion, technological innovations in biotechnology, artificial intelligence, regenerative medicine, personalized medicine, wearable technology, biomaterials, nanotechnology, and big data analytics are driving significant advancements in the anti-aging industry. These technologies have the potential to transform how we understand and address aging, offering new ways to extend healthspan and improve quality of life. By leveraging these

innovations, anti-aging startups can develop more effective and personalized interventions, enhance their competitive position, and contribute to the sustainable growth of the industry.

3. Case study analysis

The research employs a case study approach to explore the financial sustainability and risk management practices of anti-aging startups. Case studies provide an in-depth understanding of the factors contributing to the success or failure of specific startups by examining their financial strategies, operational practices, and market dynamics. This approach is particularly suitable for the anti-aging industry, where individual company experiences can offer valuable insights into broader industry trends and challenges. The primary method of data collection involves presenting case studies of selected anti-aging startups. Each case study includes a thorough examination of the startup's business model, funding history, strategic decisions, and market performance. The startups are selected based on the availability of comprehensive financial and operational data and their relevance to the research objectives. First, we have presented this list of successful startups, after which unsuccessful anti-aging startups have been offered.

3.1 Case studies of successful anti-aging startups

Unity Biotechnology

Unity Biotechnology is a prime example of a successful anti-aging startup that focuses on developing senolytic therapies to target senescent cells, which are believed to contribute to aging and age-related diseases. Founded in 2011, Unity has raised over \$385 million in funding from venture capital firms and high-profile investors, including Jeff Bezos and Peter Thiel (PitchBook, 2021). The company's success can be attributed to its strong scientific foundation, strategic partnerships, and effective risk management practices. Unity Biotechnology's approach to targeting senescent cells is based on extensive preclinical research that demonstrated the potential of senolytic drugs to improve healthspan and treat age-related diseases. This scientific validation attracted significant investment and enabled the company to advance its drug candidates into clinical trials. Unity's partnerships with academic institutions and research organizations have enhanced its R&D efforts by providing access to cutting-edge technologies and expertise (Kirkland & Tchkonja, 2017). Financially, Unity Biotechnology has implemented sound financial management and funding strategies. By securing early-stage

funding for initial research and mitigating risks as key milestones are reached, Unity minimized financial risk and maintained investor confidence. The company's successful initial public offering (IPO) in 2018, which raised \$85 million, was a significant milestone and provided additional capital to support ongoing clinical trials and commercialization efforts (UNITY Biotechnology, 2018).

Juvenescence

Juvenescence is another notable success story in the anti-aging sector. Founded in 2017, Juvenescence focuses on developing therapeutic approaches to improve human longevity by investing in various areas such as novel drugs, AI-based drug discovery, and regenerative medicine. Juvenescence has raised over \$165 million in funding, primarily through private equity and strategic partnerships (Juvenescence, 2019). One of the key factors behind Juvenescence's success is its diversified investment strategy, which reduces risk by spreading investments across multiple anti-aging technologies. This approach not only mitigates risk but also increases the likelihood of discovering effective therapies. Juvenescence's investment in Insilico Medicine, a leader in AI-driven drug discovery, exemplifies this strategy. By leveraging AI to accelerate drug discovery, Juvenescence aims to bring new therapies to market more efficiently and cost-effectively (Zhavoronkov, 2018). Juvenescence's strong leadership and strategic partnerships have also played a crucial role in its growth. The company has formed alliances with leading research institutions and biotech firms to access cutting-edge technologies and expertise. Additionally, its management team comprises seasoned industry veterans with extensive experience in biotechnology and pharmaceuticals, providing a clear and strategic vision for the company (Juvenescence, 2019).

Calico Life Sciences

Calico Life Sciences, a subsidiary of Alphabet Inc., was founded in 2013 with the mission to understand the biology of aging and develop interventions to extend human lifespan. Calico has benefited from substantial funding and resources, with Alphabet committing up to \$1.5 billion to support its R&D efforts. Calico's success can be attributed to its long-term focus on fundamental research, robust financial backing, and strategic partnerships. Calico's approach involves conducting basic research to uncover the mechanisms underlying aging and identify potential therapeutic targets. This long-term focus on foundational science sets Calico apart from many other startups that are more focused on rapid commercialization. Calico's

partnership with AbbVie, a global biopharmaceutical company, represents a strategic collaboration aimed at developing and commercializing new treatments for age-related diseases. The partnership, valued at up to \$1 billion, provides Calico with the resources and expertise needed to advance its research (Calico Life Sciences, 2014). Calico's significant financial resources have enabled it to pursue ambitious research goals without the immediate pressure to generate revenue. This financial stability has allowed Calico to attract top talent and invest in state-of-the-art technologies and infrastructure. The company's long-term vision and commitment to advancing the science of aging have positioned it as a leader in the field (Westphal, 2020).

Elysium Health

Elysium Health is a consumer-facing anti-aging startup focused on developing scientifically validated anti-aging supplements. Founded in 2014, Elysium Health's flagship product, Basis, is a supplement designed to support cellular health and increase levels of NAD⁺, a molecule essential for cellular energy and repair. The company has raised over \$46 million in funding and achieved significant commercial success (Crunchbase, 2021). Elysium Health's success can be attributed to its strong scientific foundation and effective marketing strategy. The company's Scientific Advisory Board comprises renowned researchers in the fields of aging and longevity, providing scientific validation for its products. Elysium's commitment to transparency, including publishing clinical trial results for its products, has built consumer trust and differentiated it from other supplement companies (Elysium Health, 2020). Financially, Elysium Health has leveraged direct-to-consumer sales to achieve rapid growth. The company's focus on digital marketing, subscription models, and e-commerce platforms has enabled it to reach a broad consumer base and generate recurring revenue. Elysium's ability to translate scientific research into practical, marketable products has been key to its success (Elysium Health, 2020). These case studies demonstrate that successful anti-aging startups share several common characteristics: a strong scientific foundation, effective risk management practices, strategic partnerships, and sound financial management. By leveraging these factors, these startups have navigated the challenges of the anti-aging industry and achieved significant growth and sustainability.

3.2 Case studies of unsuccessful anti-aging startups

Examining the failures of anti-aging startups provides valuable insights into the challenges and pitfalls faced by companies in this industry. Understanding these failures helps identify common issues and develop strategies to mitigate risks and improve the chances of success. This section reviews several case studies of unsuccessful anti-aging startups, highlighting the factors that contributed to their decline.

Samumed

Samumed, a biotechnology startup founded in 2008, focused on developing novel anti-aging therapies. The company raised significant funding, amassing over \$650 million from investors. Samumed's flagship product aimed to treat osteoarthritis by modulating the Wnt pathway, a promising approach based on cutting-edge science (FierceBiotech, 2019). Despite early success in preclinical research and initial clinical trials, Samumed faced several challenges in subsequent trials. In 2020, the company reported disappointing results from its Phase III trial for the osteoarthritis treatment, leading to a sharp decline in investor confidence and financial instability. The failure of this critical trial underscored the challenges of translating early-stage research into effective therapies. Additionally, the company's heavy reliance on a single therapeutic approach and product line made it vulnerable to setbacks, ultimately contributing to its decline.

ResTORbio

ResTORbio, founded in 2016, aimed to develop drugs targeting the mTOR pathway to improve immune function and extend lifespan. The company raised over \$160 million and conducted multiple clinical trials to evaluate its lead candidate, RTB101, for the prevention of respiratory infections in elderly patients. Despite promising early-phase results, the company encountered difficulties in its Phase III trial, where the primary endpoint was not met. The failure of this pivotal trial led to a significant decline in the company's stock price and a reevaluation of its strategy, resulting in cost-cutting measures and a shift in focus. ResTORbio's experience highlights the challenges of clinical development in the anti-aging field, where promising early results do not always translate into successful outcomes in larger, more rigorous studies.

Alkahest

Alkahest, a startup focused on developing plasma-based treatments for age-related diseases, also faced significant challenges. Founded in 2014, Alkahest conducted clinical trials to evaluate the efficacy of young plasma transfusions in treating Alzheimer's disease and other cognitive disorders. Despite initial hype and substantial funding, the company struggled to demonstrate clear clinical benefits in its trials. The lack of robust and reproducible results led to skepticism among investors and the scientific community, ultimately hindering the company's ability to secure additional funding and advance its pipeline (STAT News, 2019). Alkahest's difficulties underscore the importance of rigorous clinical research and the inherent risks of developing novel therapies.

Unity Biotechnology

Unity Biotechnology, despite its early successes, faced significant challenges as it advanced its pipeline of anti-aging therapies. After raising substantial funding and initiating clinical trials for its senolytic drugs, Unity experienced a major setback in 2020 when its Phase II trial for UBX0101, aimed at treating osteoarthritis, failed to demonstrate significant efficacy. This failure led to a sharp decline in the company's stock price and forced Unity to pivot its focus to other therapeutic areas and reduce its workforce (BioPharma Dive, 2020). Unity's experience highlights the high risk of failure in clinical development and the financial consequences of unsuccessful trials.

These case studies illustrate the various challenges and pitfalls that can derail anti-aging startups. Common factors contributing to failure include high R&D costs, regulatory hurdles, clinical trial failures, and market competition. These examples highlight the importance of a robust scientific foundation, sound financial management, and strategic risk mitigation to increase the chances of success in the anti-aging industry. The case studies cover the following aspects:

- **Company background and mission:** An overview of the startup's founding, mission, and core objectives.
- **Key milestones and achievements:** Significant milestones in the startup's development, such as funding rounds, product launches, and clinical trial results.

- **Financial performance and funding rounds:** Analysis of the startup's financial health, including revenue growth, burn rate, runway, and return on investment.
- **Challenges faced and strategies implemented:** Identification of major challenges encountered by the startup and the strategies used to address them.
- **Lessons learned and best practices:** Insights into successful practices and lessons learned that can inform other startups in the industry.

4. Results

The results section presents the findings from the case studies, providing an overview of the financial sustainability and risk management practices of anti-aging startups. The findings highlight key insights and statistical data, offering a comprehensive view of the current landscape.

Unity Biotechnology

Unity Biotechnology's success can be attributed to its strong scientific foundation, strategic partnerships, and effective risk management practices. The company's approach to targeting senescent cells has demonstrated significant potential, attracting substantial investment and enabling the advancement of its drug candidates into clinical trials. Unity's financial strategies, including securing early-stage funding and mitigating risks through staged development, have been crucial to its sustainability. The company's successful IPO in 2018, which raised \$85 million, provided additional capital to support ongoing clinical trials and commercialization efforts. Despite a setback in its Phase II trial for UBX0101, Unity has diversified its pipeline to reduce reliance on a single product, demonstrating resilience and adaptability.

Juvenescence

Juvenescence's diversified investment strategy and strong leadership have played a key role in its growth. By spreading investments across multiple anti-aging technologies, Juvenescence has mitigated risk and increased the likelihood of discovering effective therapies. The company's partnership with Insilico Medicine exemplifies its strategic approach to leveraging AI for drug discovery. Juvenescence's ability to secure significant funding through private equity and strategic partnerships has enabled it to advance its pipeline and achieve key

milestones. The company's focus on developing therapies that target various aspects of aging positions it as a leader in the field.

Calico Life Sciences

Calico Life Sciences' long-term focus on fundamental research and robust financial backing from Alphabet have positioned it as a leader in the anti-aging industry. The company's strategic partnership with AbbVie has provided the resources and expertise needed to advance its research. Calico's significant financial resources have enabled it to pursue ambitious research goals without the immediate pressure to generate revenue. This financial stability has allowed Calico to attract top talent and invest in state-of-the-art technologies and infrastructure. The company's commitment to advancing the science of aging and its long-term vision have been key factors in its success.

Elysium Health

Elysium Health's strong scientific foundation and effective marketing strategy have been crucial to its success. The company's commitment to transparency, including publishing clinical trial results, has built consumer trust and differentiated it from other supplement companies. Elysium's direct-to-consumer sales model, supported by digital marketing and subscription plans, has enabled rapid growth and recurring revenue. The company's ability to translate scientific research into practical, marketable products has been key to its success.

Summary of key findings

The case studies reveal several common themes in the financial sustainability and risk management practices of successful anti-aging startups:

- **Strong scientific foundation:** Successful startups have a solid scientific basis for their products and therapies, attracting significant investment and enabling advancement through clinical trials.
- **Strategic partnerships:** Collaborations with academic institutions, research organizations, and established companies provide startups with access to resources, expertise, and funding.

- **Effective financial management:** Sound financial strategies, including securing early-stage funding, managing burn rate, and diversifying investments, are crucial for sustainability.
- **Risk mitigation:** Startups that employ robust risk management practices, such as staged development and regulatory compliance, are better positioned to navigate challenges and achieve long-term success.

5. Conclusion

The anti-aging industry is rapidly evolving, driven by significant advancements in biotechnology, increasing consumer interest, and substantial investments from various stakeholders. This study explored the financial sustainability and risk management practices of anti-aging startups, identifying key factors that contribute to success or failure. One of the most important insights from this research is the role of venture capital investment in the early stages of anti-aging startups. The reliance on venture capital underscores the importance of demonstrating scientific merit and market potential to attract investors. Successful startups like Unity Biotechnology and Juvenescence have employed sound financial strategies and diversified their funding sources to mitigate financial risk and support growth.

Financial planning and budgeting have been identified as critical activities in managing the high costs associated with anti-aging R&D. Startups that allocate a significant portion of their budget to R&D while maintaining strong financial controls are well-positioned for success. Financial analysis revealed that maintaining a manageable burn rate and securing continuous funding are essential for long-term sustainability in the anti-aging industry. Clinical development remains a significant risk, with many startups experiencing setbacks in late-stage trials. Successful startups that brought products to market and achieved favorable clinical outcomes demonstrated strong revenue growth and investor confidence. In contrast, those that faced clinical failures, such as Samumed and ResTORbio, encountered severe financial difficulties and market contraction. These examples highlight the critical importance of effective risk management and achieving key product milestones. Regulatory compliance and ethical considerations play a vital role in the anti-aging industry. Early engagement with regulatory authorities and adherence to regulatory requirements are essential for navigating the approval process. Startups must invest in regulatory expertise and maintain high standards of quality control to ensure the safety and efficacy of their products. Ethical practices, such as ensuring equitable access to treatments and transparent communication with consumers, are

crucial for building public trust and fostering responsible innovation. Technological innovations, including gene editing, artificial intelligence, regenerative medicine, and personalized medicine, are transforming the anti-aging landscape. These technologies offer new opportunities to extend healthspan and improve quality of life. By leveraging technological advancements and implementing robust financial strategies and risk management practices, anti-aging startups can enhance their competitive position and contribute to the sustainable growth of the industry.

In conclusion, the financial sustainability and risk management of anti-aging startups are influenced by a combination of strong scientific foundations, strategic partnerships, effective financial management, and robust risk mitigation practices. By addressing these factors, startups can navigate the challenges of the anti-aging industry and achieve long-term success. This research provides valuable insights for entrepreneurs, investors, and policymakers aiming to navigate the complex landscape of the anti-aging market.

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Sažetak

Anti-aging industrija je doživjela brz rast potaknut značajnim napretkom u biotehnologiji, interesom potrošača za dugovječnost i značajnim ulaganjima. Ova studija istražuje finansijsku održivost i prakse upravljanja rizicima anti-aging startupa, naglašavajući ključne izazove i mogućnosti. Kroz studije slučaja, istraživanje ispituje strategije finansiranja, regulatorne prepreke i dinamiku tržišta. Uspješni startupi pokazuju snažno finansijsko planiranje, strateška partnerstva i inovativne tehnološke pristupe, dok se kod neuspješnih otkriva visok rizik povezan s kliničkim razvojem. Nalazi naglašavaju važnost sveobuhvatnog upravljanja rizicima i strateškog finansijskog planiranja u postizanju dugoročne održivosti. Ovo istraživanje pruža vrijedne uvide za poduzetnike, investitore i kreatore politika koji imaju za cilj navigaciju u složenom pejzažu anti-aging tržišta.

Ključne riječi: *anti-aging industrija, finansijska održivost, upravljanje rizicima, biotehnološki startupi, rizični kapital*