Commentary

# Is there a limit to human life expectancy?

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## Abstract

The analysis and prediction of life expectancy trends hold an important role in many aspects of our society. On a macro level, governments rely on life expectancy data to make decisions about public welfare programs, health care, retirement age, and pension programs. On an individual level, many people take life expectancy data into account when planning their retirements and making decisions about their future. Currently, two main schools of thought dominate the debate on the trajectory of life expectancy trends. The Olshansky School argues that global human life expectancy is reaching its absolute limit and predicts that a worldwide plateau in life expectancy will soon be reached. The Vaupel School, however, believes that such a plateau is nowhere in sight, and that humans possess no biological barrier that will prevent life expectancy from increasing indefinitely. In this commentary, I build upon the evidence generated by the Vaupel School by introducing socioeconomic factors into the debate and I argue that with consistent improvements to medical technology and general prosperity we will not encounter a biological limit to human life expectancy in our lifetimes.

Keywords: life expectancy; life span; longevity; mortality

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## Introduction

Life expectancy trends have a critical impact on government decisions about public welfare programs, health care, retirement age, and pension programs.[1,2] Many individuals also rely on life expectancy data when planning their retirements and making decisions about their future.[1] Therefore, it is no surprise that so many people are interested in the question, "Is there a natural limit to human life expectancy?" The goal of this commentary is to present evidence addressing this question and to argue that a limit to human life expectancy is nowhere in sight. Two opposing ideologies dominate the discussion on life expectancy limits: the "Olshansky School" and the "Vaupel School".[3] In the first section I will present the ideas of the Olshansky School, which adamantly insists that global human life expectancy is approaching its absolute limit, in order to establish the arguments I hope to refute in this paper. In the next two sections I will present the demographic and biologic arguments of Vaupel and his supporters, who use life expectancy trends to demonstrate an optimistic outlook for human mortality. In the final section, I extend the position of the Vaupel School by introducing a socioeconomic side to the argument, which I believe addresses one of the main criticisms of the Vaupel School. In sum, my arguments will demonstrate there is little reason to assume we will hit a life expectancy limit in our lifetimes.

## The Olshansky School

The central argument of the Olshansky School is that as expectations of life expectancy at birth increase, life expectancy becomes less sensitive to changes in death rates, meaning it will inevitably plateau.[3] This argument is rooted in two interrelated principles. The first is Fries Theory, also called the limited life-span theory, which predicts that human life expectancy is capped at around 85 years of age due to internal, physiological processes—namely the reduction in organ capacity and compensation that inevitably occurs with age.[3,4] The second important concept to the Olshansky School is the theory of entropy. As applied to life tables, the entropy phenomenon causes the magnitude of the reductions in age specific mortality rates (ASMR) necessary to improve life expectancy to grow substantially as life expectancy increases.[2] This means that gains in life expectancy should naturally slow down over time as the reduction in mortality rates needed to sustain these gains increases exponentially, requiring an almost endless stream of medical innovation.[2] It is these two theories that shape the majority of the Olshansky School's work.

In 2001, Olshansky, Carnes, and Désesquelles published a paper intended to support and correct predictions made in the Olshansky School's original 1990 paper.[2] In their revised paper, which focuses on life expectancy trends in France, Japan, and the United States (US), the authors concluded that a life expectancy of 100 is extremely unlikely, while the idea of a life expectancy ever surpassing 100 is impossible.[2] As evidence, they demonstrated that reaching a life expectancy of 100 in Japan or France requires an 85% reduction in ASMR at all ages.[2] In addition, due to the entropy phenomenon, if the same magnitude of mortality reductions that occurred between 1900 and 1995 in the U.S., which increased life expectancy by thirty years, occurred in 1995 it would only result in a 10.1 year increase in life expectancy.[2] Finally, the authors pointed out that the ASMR decreases seen in the 20th century were due to dramatic reductions in infant mortality and deaths from infectious diseases, reductions that are unlikely to be repeated.[2]

From this paper, and similar evidence presented in more recent papers, the Olshansky School concludes that the limited life-span theory is essentially correct, although the limit may be higher than 85 years.[5,6] The reductions in ASMR needed for further increases in life expectancy are significantly greater now, while developing the necessary medical interventions will be objectively harder than preventing infectious diseases or infant mortality.[2,5] The Olshansky School also draws attention to new life expectancy threats; namely obesity, antibiotic resistance, and global pandemics.[3] There is also evidence that, unlike life expectancy, the maximum age that any human has lived to (a number that is much less influenced by environment and lifestyle) is not increasing substantially.[7] This suggests an ultimate life expectancy cap that sits at around 115 years, barring a radical change in the aging process of humans.[7] Overall, the Olshansky School emphasizes underlying biological mechanisms and empirical evidence that it believes demonstrates life expectancy is reaching its limit.

## A demographic rebuttal

The Vaupel School's major rebuttal to the arguments of the Olshansky School hinges on Vaupel's analysis of trends for the record-holding female life expectancy over time. Through analyzing these trends, the Vaupel School discovered that the record-holding female life expectancy has increased linearly ($r^2$ of 0.992) by three months every year for the past 160 years.[1] In other words, while gains in individual countries' female life expectancy may appear to be slowing, the record for the highest female life expectancy consistently grows every year with shocking linearity. Oeppen and Vaupel point out that if life expectancy was reaching a limit then this trend should be decelerating, but more recent evidence suggests that it is not.[1,3] The Vaupel School believes their finding illustrates that life expectancy increases are due to continuous innovation, refuting the Olshansky School's claim that the gains experienced from reducing infectious disease and infant mortality are unrepeatable today.[3] The Vaupel School also launches valid criticisms against proponents of the limited life-span theory, pointing out that they are consistently wrong in their predictions. For example, the limits set by the Olshansky School in 1990 were surpassed in only five years, and several of their 2001 predictions were also surpassed soon after they were made.[3]

The Vaupel School's own predictions for life expectancy are much more optimistic. They expect that current trends should continue relatively undisturbed into the future, meaning global life expectancy should rise nearly linearly and break 85 years by 2050.[3] Vaupel and his collaborators are also not alone in their optimism, as a recent survey of demographic experts suggests most agree with the Vaupel School's optimistic outlook.[3] Kontis et al. (2017) further support this optimistic perspective in their recent paper, which uses 21 models and life table analysis to probabilistically predict future life expectancy increases.[8] They found that there is a greater than 50% chance that life expectancy in South Korea will break the 90-year threshold by 2030.[8] There is also a 65% chance and an 85% chance that women and men, respectively, see a life expectancy increase by 2030 in all 35 industrialized countries studied by Kontis et al.[8] These findings alone question the idea that life expectancy gains are decelerating. However, Kontis et al. also found that a majority of the predicted gains in female life expectancy are due to decreased ASMR above age 65, further refuting the Olshansky School's insistence that reducing ASMR at older ages is too challenging.[8] Altogether, these findings illustrate that Vaupel is not alone in doubting the claims of the Olshansky School.

## A biological rebuttal

The Vaupel School has also provided sufficient evidence to dispute the limited life-span theory and the biological arguments of the Olshansky School. For one, several studies have demonstrated that ASMR actually decelerates with increasing age, starting at around age 80.[9] Furthermore, the risk of dying plateaus at around 50% starting at 103 and 107 years of age for men and women respectively.[10] Therefore, contrary to the theories of the Olshansky School, there appears to be no age in humans where a biological barrier causes rapid acceleration of ASMR. Additionally, while mortality rates may decelerate and plateau at older ages, rates of deterioration are not decelerating.[11] Instead, demographic trends suggest physical deterioration is being postponed to later and later ages while the duration of senescence remains the same, meaning medical interventions are not simply increasing the duration of time one can live past a preset physiological barrier.[11] Finally, a study of Danish identical twins revealed that twins do not share a genetically predetermined maximum life span, as only about 25% of the variation in life expectancy was attributable to genetics, casting further doubt on the limited life span theory.[12,13] Overall, the Vaupel School has demonstrated sufficient evidence from human studies to at least question the validity of the Olshansky School's arguments.

Through their major demographic and biological arguments, the Vaupel School manages to refute most of the arguments of the Olshansky School. However, Vaupel and his collaborators fail to directly address evidence that the maximum age at death continues to sit around 115 years, regardless of plateaus in ASMR. Instead, the Vaupel School proposes that consistent increases in life expectancy occur through consistent innovations in medical technology and improvements to general prosperity.[11] Essentially, as people reach old age in better health and with access to improved health technology, they are able to live longer and delay senescence further.[11] This perspective implies that the current maximum age at death will eventually be surpassed, given time. The Vaupel School also does not directly address the Olshansky School's criticism of optimum lifestyle predictions as ignoring biological influences. In other words, the Olshansky

School posits that by focusing on the best performing countries and individuals, and suggesting individual lifestyles are the most important determinant of survival, the Vaupel School emphasizes outlying over-performers while ignoring the biological processes that are decelerating life expectancy trends in most populations.[3] I would propose, however, that it is growing socioeconomic inequality and not biological processes responsible for the decelerating life expectancy trends observed in many populations, and, by focusing on best-practice life expectancy, the Vaupel School is demonstrating the trajectories that are possible without the influences of socioeconomic inequality.

## A socioeconomic rebuttal

The socioeconomic determinants of life expectancy have an established space in the debate over life expectancy trends, namely in the discussion of so called "best practice" life expectancy, which tries to account for mortality risk factors.[1,2] Throughout the world, growing socioeconomic inequality mirrors stagnation and declines in life expectancy trends.[14,15] Cross-national analysis of Gini coefficients (a measure of inequality) reveals that higher national economic inequality is significantly associated with a lower national life expectancy.[1] Furthermore, changes in inequality over time are significantly associated with changes in life expectancy.[1] Taken together, this international data suggests that growing inequality is masking what would otherwise be significant gains in life expectancy in many countries. In the US, for example, the gap in life expectancy between the richest 1% and the poorest 1% is 14.6 and 10.1 years for men and women respectively, and this gap is growing over time.[11] This means that the top 1% of the US continues to achieve substantial gains in life expectancy over time, even while the life expectancy of the rest of the country plateaus. While the Olshansky School may reject the Vaupel School's optimum lifestyle predictions and risk factor approaches for ignoring biological influences, these approaches can reveal the true gains in life expectancy that may be hidden by socioeconomic inequality.

## Conclusion

The Vaupel School's demographic and biological arguments refute the majority of the claims made by the Olshansky school and demonstrate that the Olshansky School is wrong to conclude that life expectancy gains are decelerating or reaching their limit. The one major criticism that the Vaupel School does not address—the weaknesses of relying on best-practice and risk-factor analyses—is accounted for in my examination of the influence of growing socioeconomic inequality on life expectancy trends. Overall, the overwhelming majority of the evidence presented in this paper rests firmly against the arguments of the Olshansky School. This does not mean that no life expectancy limit exists conclusively, as there are many biological, physical, and chemical processes about which we understand little. Instead the evidence presented here strongly indicates that none of us will encounter a life expectancy limit during our lifetime. Good news for those of us who wish to see humans reach immortality, but perhaps alarming for those who have neglected to plan for their retirements.

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