The frailty-mortality paradox: Insights from the Spanish flu pandemic of 1918

Amanda Wissler & Nicolas Gauthier
Arizona State University, School of Human Evolution and Social Change

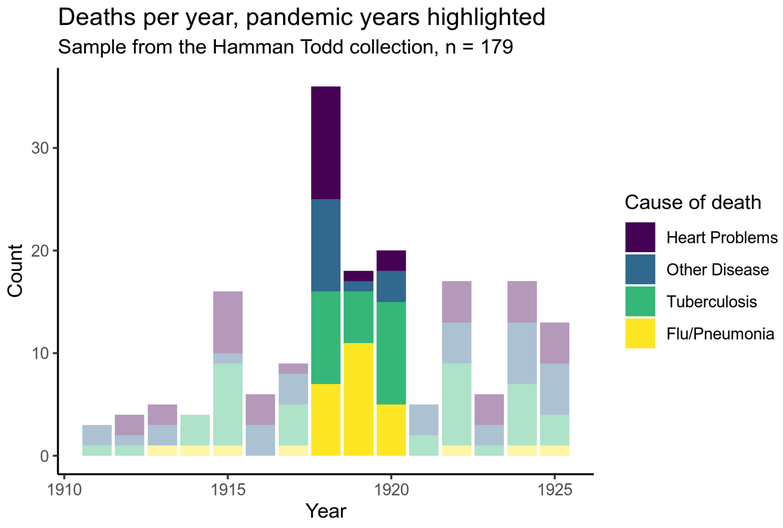
Introduction

Inferring an individual's health from their skeletal remains is an enduring problem in bioarchaeology. The concept of "frailty" has emerged as a convenient tool for relating observed skeletal lesions to human health and mortality, yet the biases inherent in archaeological samples have left the concept under theorized. It remains unclear whether frailty should be considered an unchanging property of individuals – an innate risk of death – or if frailty depends on changes in an individuals external environment, such as a major epidemic event.

Here, we analyze a sample of 193 individuals who died during the Spanish Flu pandemic of 1918, when healthy young adults (traditionally the least frail segment of the population) were most severely affected. We present data on age-at-death, and several nonspecific indicators of skeletal stress, and use a Cox proportional-hazards model to show how the relationship between frailty and risk of death varied over the course of the pandemic.

Data

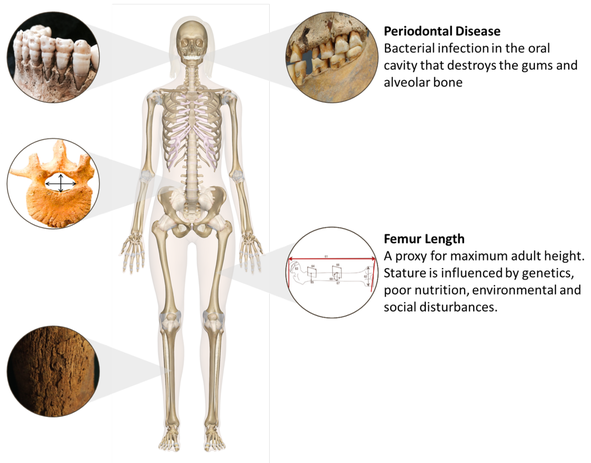
Pathology and age-at-death data were collected from 179 individuals of the **Hamann-Todd documented collection** located at the Cleveland Museum of Natural History. The Hamann-Todd is comprised of over 3,000 individuals who died between 1910-1938 in Cleveland and surrounding areas. Documentation of the individuals name, age-at-death, sex, ancestry, cause of death, and date of death was available for each individual. To eliminate potential confounding factors for this pilot study, data were collected from **white males only**. The individuals of Hamann-Todd collection were separated into two groups based on whether they died during the pandemic (1918-1920) or not.



Methods

We collected paleopathological data from **5 different stress markers** that manifest at various stages in the life cycle from the skeleton and dentition.

Skeletal Markers:



Linear Enamel Hypoplasia
Linear defects in tooth enamel caused by disruption in the process of enamel formation due to systemic stress, malnutrition or disease in childhood.

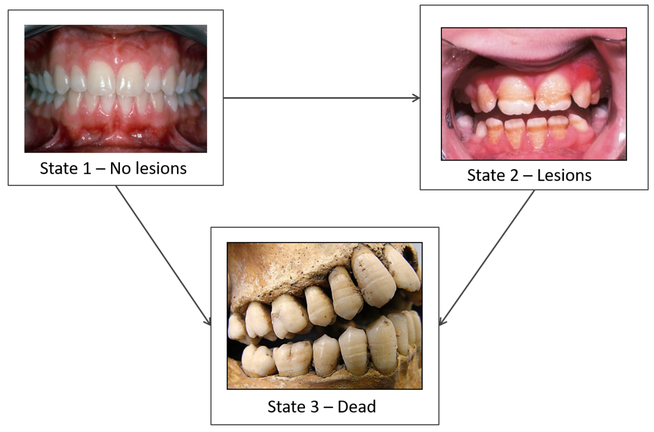
Vertebral Neural Canal Diameter
The size of the canal through which the spinal cord passes in the vertebrae. The diameter can be affected by environmental disturbances, malnutrition or disease.

Periosteal Lesion of Tibia
New bone formation caused by a reaction of the periosteum due to physical trauma, local or systemic infection.

Periodontal Disease
Bacterial infection in the oral cavity that destroys the gums and alveolar bone

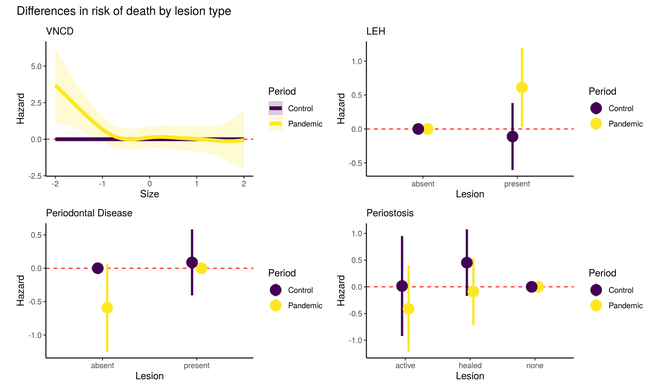
Femur Length
A proxy for maximum adult height. Stature is influenced by genetics, poor nutrition, environmental and social disturbances.

Data Analysis:
We used a **Cox proportional-hazards model** to assess how markers of frailty predicted risks of death or survival. Hazards models describe how the risk of death changes over time in response to specific variables, in this case, the presence of a lesion or the absence of a lesion. The model estimates the rate of transition between these states, predicting if an individual with lesions has an increased risk of dying compared to an individual of the same age without lesions.

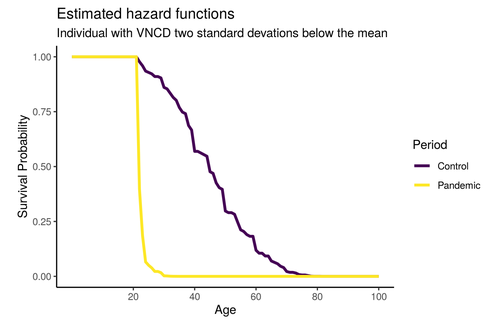


Results

Different stress markers have different impacts on risk of death, and the size and direction of these relationships varied during the 1918-1920 pandemic.



High values above increase the risk of dying from the baseline for an individual's age class, but only during pandemic years.



Discussion

Our results demonstrate the differential effects of these skeletal lesions in the pandemic versus the control group. Overall, there lesions are associated with increased risk of death, however this **pattern is not consistent over time**. Our results question the utility of these skeletal lesions as immutable indicators of frailty. A more rigorous approach to the concept of frailty in modern populations can improve our understanding of disease, mortality, and the determinants of health in the ancient world. These results suggest that **frailty should not be considered in isolation from the physical and social environment**. We must continue to question the interpretation of skeletal lesions and develop more sophisticated methods for their analysis.

Acknowledgements

We would like to thank Lyman Jellema and Dr. Yohannes Haile-Selassie for access to the Hamann-Todd collection. This research was made possible through a grant from the ASU Center for Bioarchaeological Research.

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