Telomeres and maximum lifespan in birds

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ABSTRACT

Identifying physiological mechanisms that underlie senescence across taxonomic groups remains a central question in life history evolution. Telomeres are highly-conserved, repetitive nucleotide sequences that protect the ends of linear chromosomes. Telomeric DNA in many cells shortens over time due to the end-replication problem and damaging events such as oxidative stress. Many studies have reported that this shortening is linked to cellular survival and in some cases, organismal survival. However, we know much less about how telomere dynamics relate to aging rates and maximum lifespans across species. We previously reported that avian species who lose less telomeric repeats as they age have longer lifespans than those who lose more. Here, we investigated telomere length in cross-sectional samples from more than twenty known-aged bird species to determine how telomeres relate to species maximum lifespan. All telomere analyses were measured in erythrocytes in our laboratory using the Telomere Restriction Fragment assay. Similar to our previous report, we found that in this larger sample of species, birds with longer lifespans lose less telomeric repeats per year compared to those species with shorter lifespans. Because closely related lineages share many traits in common, our larger sample of species will also allow us to use comparative analyses to control for shared phylogenetic history.

BACKGROUND

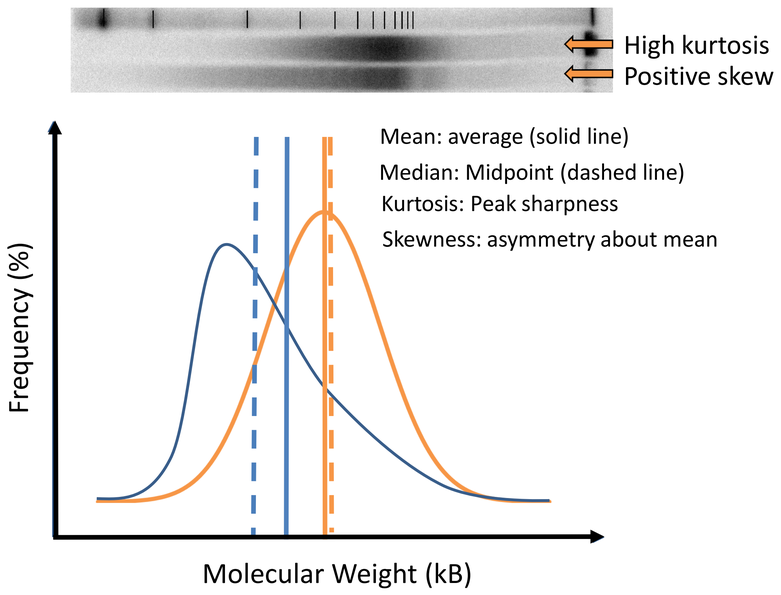
- Telomeres are conserved nucleotide sequences that protect the linear ends of chromosomes.
- Telomeres shorten during DNA replication and from oxidative stress. Once telomeres reach a critical length they signal cellular senescence, which contributes to age-related disease and the aging phenotype.
- Work in humans, laboratory model organisms, and natural populations report that rates of telomere shortening can predict mortality.
- Interestingly, previous work from our lab and others suggests that proper telomere maintenance is also strongly correlated with inter-specific rates of aging. Bird and mammal species that lose less telomere sequences each year also have longer species maximum lifespans.

OBJECTIVE

- We measured telomere distributions in a cross-sectional sample of known-age individuals across the lifespan range in 16 avian species to explore how telomeres relate to maximum lifespan.

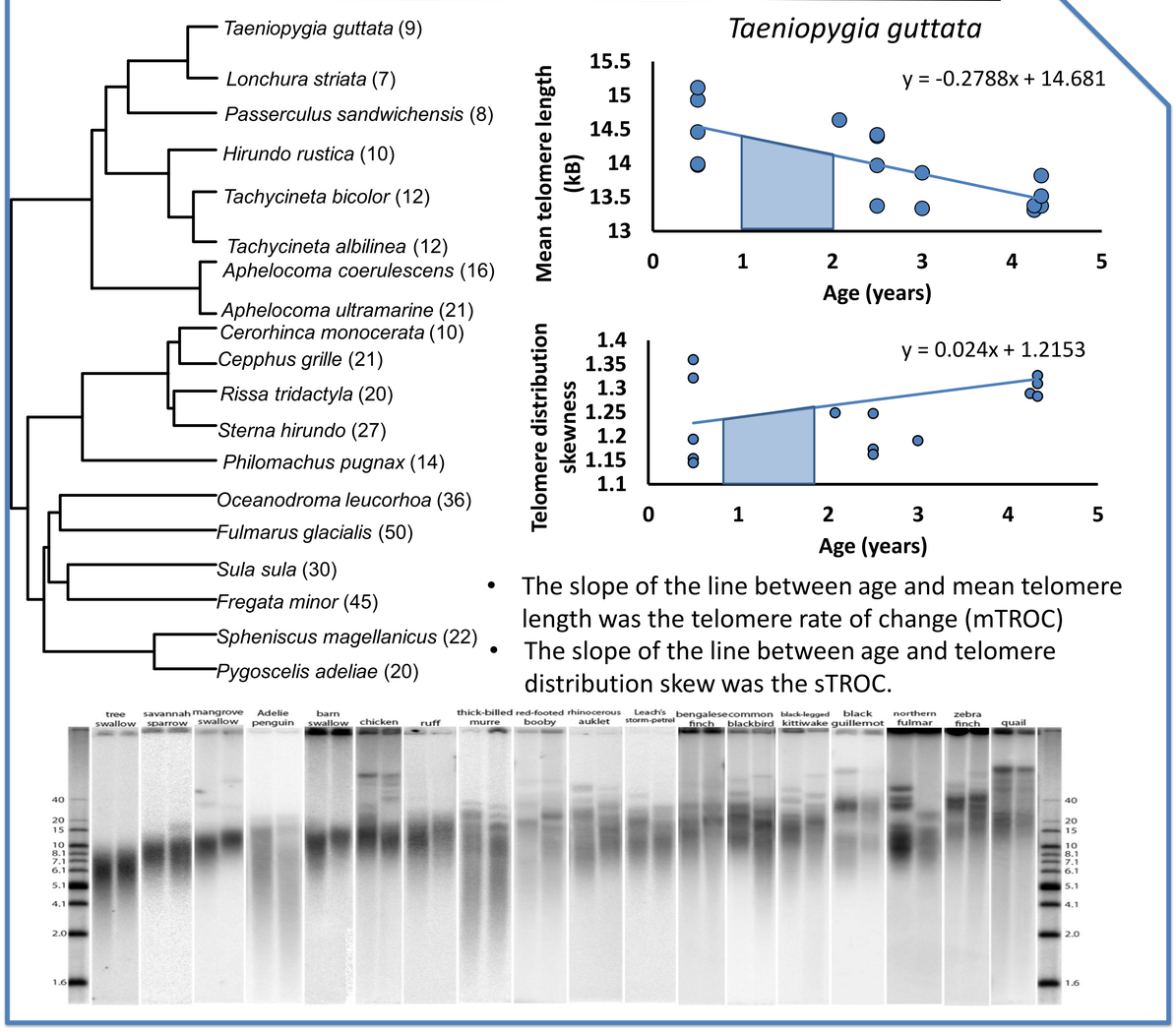
METHODS: TELOMERE DISTRIBUTIONS

- We measured telomeres in erythrocytes using the Telomere Restriction Fragment (TRF) assay allowing us to measure the entire telomere frequency distribution within the sample.



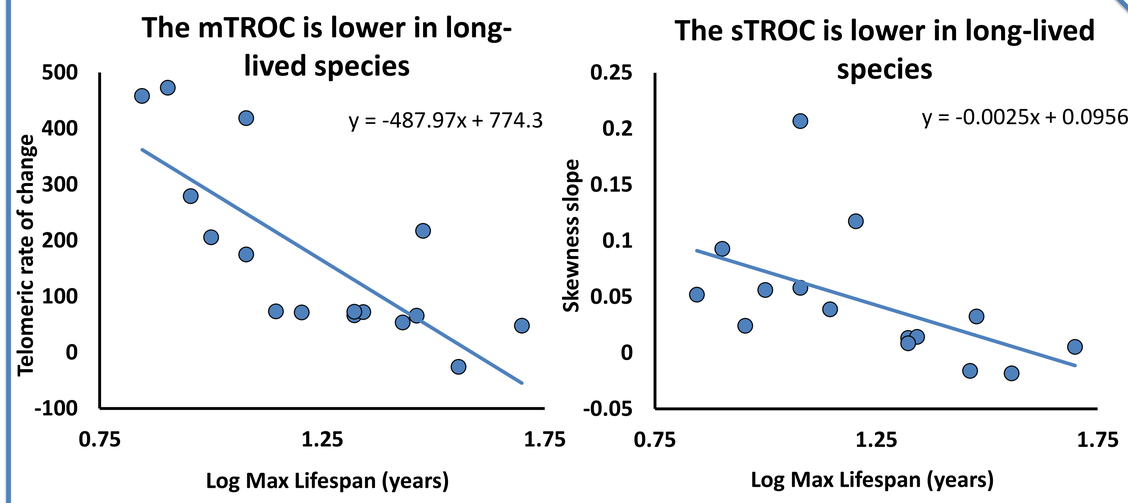
- We explored how different characteristics of the telomere frequency distributions varied by species' maximum lifespan (controlling for body mass and phylogeny).
- Individuals with telomere distributions that have larger means/medians, high kurtosis, and negative skews would have a functionally 'healthier' telomere distribution.

METHODS: SPECIES AND ANALYSES



- The slope of the line between age and mean telomere length was the telomere rate of change (mTROC)
- The slope of the line between age and telomere distribution skew was the sTROC.

RESULTS AND DISCUSSION



- There was a significant negative relationship between TROC and species maximum lifespan (t = -2.81, P = 0.015). However, after controlling for phylogeny, the relationship shifted to a trend (t = -1.96, P value: 0.074).
- Thus, species with a larger TROC (i.e. faster rates of telomere shortening) have shorter maximum lifespans.
- There was a significant negative relationship between SKEWNESS and species maximum lifespan (t = -2.40, P = 0.035). However, after controlling for phylogeny the relationship was no longer significant (t = -1.33, P value: 0.211).
- When not accounting for phylogeny, species with a larger sTROC (or those species whose telomere distribution becomes positively skewed more rapidly with age) had shorter maximum lifespans.
- Taken together, our data suggest that long-lived species have telomere distributions that appear to accumulate short telomeres at a slower rate compared to short-lived species. While contingent on future comparative analyses, it is possible that better telomere maintenance may be one molecular mechanism allowing for the evolution of long lifespans.

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