Testing the Traits of TA3: Setting a Baseline for Method Development and Performance

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Objective

This research compares age estimates for a sample of modern individuals using:

1) traditional components of the pubic symphyses, iliac auricular surfaces, and cranial sutures combined using Transition Analysis (TA)[1]
2) newly developed TA3 traits[2] located throughout the skeleton and combined via a similar statistical approach

These data provide baseline accuracy and precision information for estimates produced using TA3 traits in a similar statistical framework as the original TA method[1]. These results can be used to gauge improvements provided by alternative procedures for generating age estimates from the TA3 reference sample, including sex- and population-specific approaches.

Materials and Methods

TA[1] and TA3 trait data[2] were collected from the University of Athens Human Skeletal Reference Collection (N=199, **Fig. 2**).

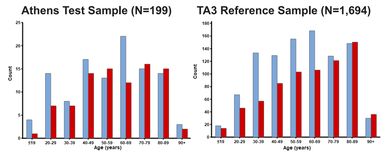

Figure 2. Age distrbution of males (blue) and females (red) in the Athens Collection test sample and full TA3 reference sample.

ADBOU 2.1.046[3] was used to calculate a maximum likelihood point age (MaxL) and associated 95% prediction interval (PI) for each individual. Estimates were calculated using data from all individuals in the reference sample ("unknown" selected for both sex and ancestry) and a uniform prior distribution.

A simplified version of the TA[1] method was used to generate estimates using data from 68 of the 80 TA3 features (10 traits provide insufficient information and are no longer under consideration by the NIJ team; 2 had definition changes between collection of the test data and release of the reference dataset).

Non-binary trait variants were converted to dichotomous pairs and only the most age-informative transition was included in this analysis. To facilitiate future comparisons with TA3 software currently in beta testing, only data from the right side of the skeleton were used.

Probabilities generated from logistic models fitted to data from the entire reference sample (**Fig. 2**) for each trait were combined into a single log-likelihood function from which a MaxL and 95% PI were calculated for each individual.

Background

Transition Analysis (TA)[1]

Accurate, unbiased, and reasonably precise age estimations for the entire adult lifespan are necessary for both forensic and paleodemographic applications.

TA[1] was developed as a statistical solution to address long-standing problems in existing adult age-estimation methods:

- fixed point estimates and intervals
- systematic age-estimation bias
- reference sample mimicry

However, because the components of traditional indicators used in TA provide insufficient data in middle and old age, the method produces wide age intervals for individuals between 45 and 75 years of age and increasingly underestimates age beyond middle age.

TA3[2]

In 2014, an NIJ grant funded an international research team to identify and characterize new age-informative traits in modern populations and investigate analytical approaches for generating age estimates.

The TA3 reference sample contains 1,694 documented individuals from four modern skeletal collections (**Table 1, Fig. 1**) scored for the 80 features described in the TA3 Trait Manual[2].

Investigation of approaches for combining data are ongoing. Of particular interest is whether methods with increased computational complexity (compared to original TA[1]) and the use of sex- and population-specific samples significantly improve accuracy and precision.

TA3 Reference Sample

Table 1. TA3 reference sample: collections and sample sizes

Skeletal Collection	Location	M	F	n
W.M. Bass Donated	Knoxville, TN, USA	232	205	437
Pretoria Bone Collection	Pretoria, South Africa	316	168	484
Chiang Mai University Collection	Chiang Mai, Thailand	258	160	418
Bocage Museum Collection	Lisbon, Portugal	170	185	355
	Total:	**976**	**718**	**1694**

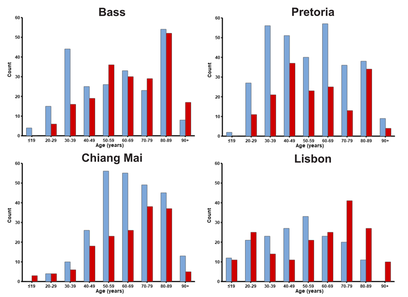

Figure 1. Age distrbution of males (blue) and females (red) evaluated from each collection within the TA3 reference sample.

Results

TA[3] produced accurate estimates (documented age fell into the 95% PI) for 73.3% of the tested individuals with an average precision (age interval length) of 34.2 years. The accuracy of the combined TA3 traits dropped marginally to 70.8%, but the precision increased to 17.2 years. In other words, changes in accuracy were not statistically significant, while the average width of the age intervals was reduced by nearly 50% (**Fig. 3**).

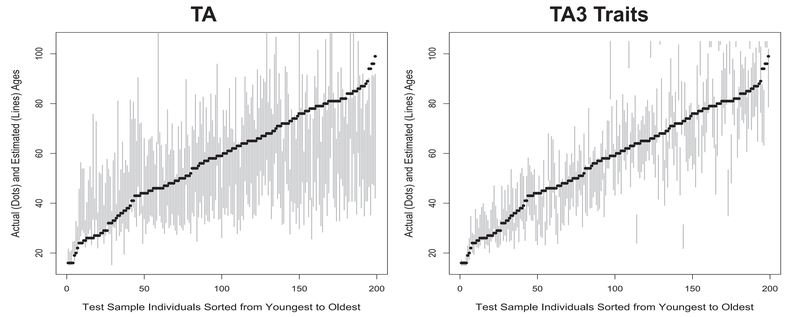

Figure 3. Age estimates produced by original TA[3] and a combination of new TA3 traits[2] for the same sample. Individuals are ordered by documented age [black dots] and shown with their estimated 95% age interval [gray lines].

The use of TA3 trait variants that collectively provide information throughout the entire adult lifespan essentially resolves the systematic over- and under-estimation of age that typically occurs for individuals under and over the age of 50 years, respectively (**Fig. 4**). See Galimany and Getz in this poster session for more information about the age-informative value of TA3 traits.

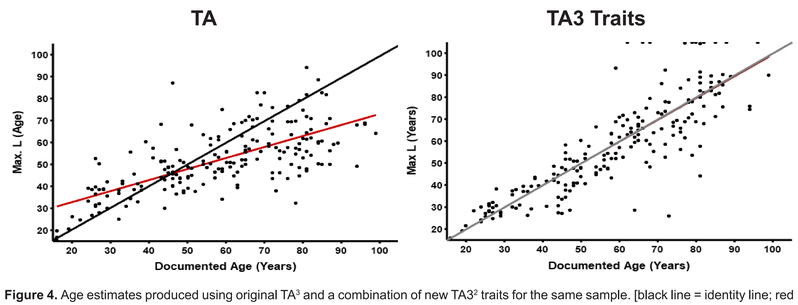

Figure 4. Age estimates produced using original TA[3] and a combination of new TA3[2] traits for the same sample. [black line = identity line; red line = fitted regression]. Estimating age using the TA3 traits produces no systematic age-estimation bias and the regression is indistinguishable from the identify line.

Discussion

Combining probability distributions from traits by assuming that each provides independent information when this is not true will produce artificially narrow age intervals[1]. The original TA method includes a statistical correction for this issue, while the simplified method used here to combine the TA3 traits does not. This makes this significant increase in precision without a correspondingly large reduction in accuracy particularly promising.

Individuals in the Athens sample are from a population not represented in the TA3 reference sample and estimates were produced using non-sex- and population-specific probabilities from every trait present in each individual and a uniform prior distribution. Given this, these results provide a baseline for the minimum performance that can be expected using the TA3 traits.

Conclusions

A broad array of traits that collectively inform age throughout adulthood results in unbiased estimates with increased precision in all portions of the adult lifespan. Improved accuracy with similar precision is likely achieveable using alternative methods for trait selection and integration.

The TA3 traits and NIJ reference sample provide a foundation for a promising future for adult age estimation.

More Information

For updates related to TA3 and the work presented here, including the trait scoring manual, beta software, online application development, and training opportunities, visit: **saramgetz.com**

References

[1] Boldsen JL, Milner GR, Konigsberg LW, and Wood JW. "Transition Analysis: A New Method for Estimating Age From Skeletons," in Paleodemography: Age distributions from skeletal samples, eds. Hoppa RD and Vaupel JW (Cambridge University Press, 2002), 73-106.

[2] Milner GR, Boldsen JL, Ousley SD, Getz SM, Weise S, and Tarp P. 2019. Transition Analysis 3 (TA3) Trait Manual. Public Distribution Ver. 1.NIJ Award # 2014-DN-BX-K007.

[3] ADBOU Transition Analysis Software (Ver. 2.1.046). https://www.statsmachine.net/software/ADBOU2/

Acknowledgements

Access to Reference Collections:
Dawnie Steadman and Lee Jantz—WM Bass Donated Collection (University of Tennessee)
Erika L'Abbé and Marius Loots—Pretoria Bone Collection (University of Pretoria)
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Susana Garcia—Bocage Museum Collection (Lisbon Natural History Museum and University of Lisbon)
Efstratios Valakos and Panagiota Papazafiri—Athens Donated Collection (University of Athens)

TA3 Data Collection:
George R. Milner **Sara M. Getz**
Jesper L. Boldsen **Svenja Weise**
Stephen D. Ousley **Peter Tarp**

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