Document Title: A Radiographic Database for Estimating Biological Parameters in Modern Subadults

Author(s): Stephen Ousley, Suzanne Daly, Kathryn Frazee, Kyra Stull

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EXECUTIVE SUMMARY

Description of the problem

Current techniques in forensic anthropology for estimating age at death in fetuses, infants, and children are of questionable validity due to a lack of data from modern and diverse groups and a lack of optimal statistical methods. Age estimation in subadults has been based on data from clinical studies undertaken over 80 years ago to assess if children of known age showed normal growth. Skeletal collections of subadults are quite rare (Shapiro and Richtsmeier 1997), and other sources for subadult data are needed. Radiographs obtained from Medical Examiner's and Coroner's Offices (MECOs) would provide anthropologists with a means of assembling large amounts of data from modern subadults with known age, sex, ancestry, date of birth, and other demographic information. Such a radiographic database fills a void for data from subadults, data not contained in the well-known Forensic Data Bank at the University of Tennessee. A database of digital radiographs and demographic data from modern American subadults is sorely needed to provide the best means of forensic age estimation in subadults.

Whether explicitly acknowledged or not, nearly all available data concerning skeletal growth and development in the US have come from growth studies started in the later 1920's or early 1930's, such as the Fels study, which started in 1929 (Roche 1992). Applying Fels data to modern age estimation is inherently problematic: Growth data were collected to derive the "normal" development and growth of bones in children of known age, but forensic anthropologists utilize known bone lengths or the appearance of epiphyses to estimate age. Forensic anthropologists have navigated through published data often limited to medians,

The Structure of the Database

The radiographic database has two main data tables, one for individual demographic information and one for the skeletal inventory of each scan. The database was created using Advantage DB from Sybase and converted to MySQL from Oracle Corporation for web integration. Demographic information from the individuals in the database includes age on several scales (days, weeks, and years), sex, race, ancestry, and external measurements of the individuals. The demographic table structure is shown in Table 7. Birth and death dates are known but information available to the public include only year of birth and death or examination to protect private information. There were numerous physical measurements recorded. For example, over 1,400 crown-rump lengths were recorded from neonates, and from all individuals, over 9,500 weights and over 8,500 body lengths/statures were recorded.

Table 7. Fields in the demography table. Char: character field; Double: double-precision number; Integer: integer number; Memo: Memo field; ModTime: Date and time of last record change (automatic).

Field name	**Field type**	**Explanation**	**Public**
SITENo	Integer	Site number	N
CASENo	Char	Case number	N
SNCN	Char	SiteNo + Caseno (Key)	N
WebPtID	Integer	Patient identification number	Y
WebPtseq	Integer	Patient ID and Visit Sequence	Y
TotalScans	Integer	Total number of scans	Y
RACE	Char	Racial designation (OMB 15)	Y
RACE_HE	Char	OMB 15, Hispanics separate	Y
ANCESTRY	Char	Ancestry	Y
ETHNICITY	Char	Ethnicity	Y
NATIONALITY	Char	Nationality	Y
SEX	Char	Sex	Y
DOB	Date	Date of birth	N

DOX	Date	Date of exam	N
DOD	Date	Date of death	N
YOB	Integer	Year of birth	Y
YOX	Double	Year of exam	Y
YOD	Integer	Year of death	Y
AGEYEARS	Double	Age in years	Y
AgeWeeks	Double	Age in weeks	Y
AGEDAYS	Integer	Age in days	Y
AgeYearsTrunc	Integer	Truncated age in years	Y
HT_in	Double	Height in inches	Y
HT_cm	Double	Height in cm	Y
WT_LB	Double	Weight in pounds	Y
WT_KG	Double	Weight in kilograms	Y
WT_G	Integer	Weight in grams	Y
MOD	Char	Manner of death (Homicide, etc.)	Y
COD	Memo	Cause of death	Y
CHL_IN	Double	Crown-heel length in inches	Y
CHL_CM	Double	Crown-heel length in cm	Y
CRL_IN	Double	Crown-rump length in inches	Y
CRL_CM	Double	Crown-rump length in cm	Y
HeadC_IN	Double	Head circumference in inches	Y
HeadC_CM	Double	Head circumference in cm	Y
ChestC_IN	Double	Chest circumference in inches	Y
ChestC_CM	Double	Chest circumference in cm	Y
AbdC_IN	Double	Abdominal circumference in inches	Y
AbdC_CM	Double	Abdominal circumference in cm	Y
FootL_IN	Double	Foot length in inches	Y
FootL_CM	Double	Foot length in cm	Y
AntFont	Char	Anterior fontanelle open/closed	Y
PostFont	Char	Posterior fontanelle open/closed	Y
BrainWtGms	Integer	Brain weight in grams	Y
PATHOLOGY	Memo	Pathology description	Y
TRAUMA	Memo	Trauma description	Y
NOTES	Memo	Case Notes	Y
BIRTH_INFO	Memo	Birth Information	Y
NOTES2	Memo	Case notes 2	Y
Preterm	Char	Preterm?	Y
IUWeeks	Integer	Intrauterine weeks	Y
LastEditDate	ModTime	Date-time of last edit	N
RecordNo	Integer	Unique Record Number	Y

The radiographic inventory table includes information specific to each radiographic image including which areas of the body are seen, scan orientation, if trauma or other pathology is present, and overall quality of the image. The field names are shown in Table 8.

Table 8. Fields in the skeletal inventory table. Char: character field; Double: double-precision number; Integer: integer number; Logical: True/False; Memo: Memo field.

Field Name	**Field Type**	**Data in Field**
SiteNo	Integer	Site number
CaseNo	Char	Case number
SNCN	Char	SiteNo+CaseNo (key in demographic table)
Ptid	Integer	Patient identification
Webfilename	Char	Image filename (key)
WebPtID	Integer	Patient identification number
WebPtseq	Integer	Patient ID and Visit Sequence
ScanNo	Integer	Scan number
TotalScans	Integer	Total number of scans
ScanSuff	Integer	Scan suffix
RECR	Char	Recorder
EntryDate	Date	Date entered
Vault	Char	Vault present
Midface	Char	Midface present
Dentition	Char	Dentititon present
Mandible	Char	Mandible present
LClav	Char	Left clavicle present
RClav	Char	Right clavicle present
CervVerts	Char	Cervical vertebrae present
ThorVerts	Char	Thoracic vertebrae present
LumbVerts	Char	Lumbar vertebrae present
RShJoint	Char	Right shoulder joint present
RHumP3rd	Char	Right humerus proximal third present
RHumM3rd	Char	Right humerus middle third present
RHumD3rd	Char	Right humerus distal third present
RElbJoint	Char	Right elbow joint present
RRadP3rd	Char	Right radius proximal third present
RRadM3rd	Char	Right radius middle third present
RRadD3rd	Char	Right radius distal third present
RUlnP3rd	Char	Right ulna proximal third present

RUlnM3rd	Char	Right ulna middle third present
RUlnD3rd	Char	Right ulna distal third present
RWrist	Char	Right wrist area present
RHand	Char	Right hand present
LShJoint	Char	Left shoulder joint present
LHumP3rd	Char	Left humerus proximal third present
LHumM3rd	Char	Left humerus middle third present
LHumD3rd	Char	Left humerus distal third present
LElbJoint	Char	Left elbow joint present
LRadP3rd	Char	Left radius proximal third present
LRadM3rd	Char	Left radius middle third present
LRadD3rd	Char	Left radius distal third present
LUlnP3rd	Char	Left ulna proximal third present
LUlnM3rd	Char	Left ulna middle third present
LUlnD3rd	Char	Left ulna distal third present
LWrist	Char	Left wrist area present
LHand	Char	Left hand present
Sacrum	Char	Sacrum present
Lilium	Char	Left ilium present
Lisch	Char	Left ischium
Lpubis	Char	Left pubis
Rilium	Char	R ilium
Risch	Char	R ischium
Rpubis	Char	Right pubis
LHipJoint	Char	Left hip joint
LFemP3rd	Char	Left femur proximal third
LFemM3rd	Char	Left femur middle third
LFemD3rd	Char	Left femur distal third
LKnee	Char	Left knee area
LTibP3rd	Char	Left tibia proximal third
LTibM3rd	Char	Left tibia middle third
LTibD3rd	Char	Left tibia distal third
LFibP3rd	Char	Left fibula proximal third
LFibM3rd	Char	Left fibula middle third
LFibD3rd	Char	Left fibula distal third
LAnkle	Char	Left ankle area
LFoot	Char	Left foot
RHipJoint	Char	Right hip joint
RFemP3rd	Char	Right femur proximal third
RFemM3rd	Char	Right femur middle third
RFemD3rd	Char	Right femur distal third

RKnee	Char	Right knee area
RTibP3rd	Char	Right tibia proximal third
RTibM3rd	Char	Right tibia middle third
RTibD3rd	Char	Right tibia distal third
RFibP3rd	Char	Right fibula proximal third
RFibM3rd	Char	Right fibula middle third
RFibD3rd	Char	Right fibula distal third
RAnkle	Char	Right ankle area
RFoot	Char	Right foot
Orientation	Char	AP, ML, or Oblique view?
RefScaleText	Logical	Reference scale present?
Trauma	Logical	Trauma present?
Pathology	Logical	Pathology present?
VisCaseNo	Logical	Visible case number present?
Quality	Char	Scan Quality: Poor, Good, Very Good
Enhanceable	Logical	Can image be enhanced?
UnknownSide	Logical	Is side unknown?
Notes	Memo	Image notes

The radiographic database will complement the Forensic Data Bank at the University of Tennessee, which has proven indispensable in numerous forensic applications involving modern adults (Jantz and Moore-Jansen 1987; Ousley and Jantz 1997). Like the Forensic Data Bank, the radiographic database will be supplemented by additional cases in the future, continually adding up-to-date information from subadults of various ethnic backgrounds. It is a certainty that new methods of analyzing subadult remains will come from the radiographic database, as has happened with the Forensic Data Bank.

In order to preserve decedent and patient confidentiality, the original case numbers have been modified and the dates of birth, exam, and date of death or exam will not be available to the public. When researchers wish to study bone healing in the longitudinal clinical records, pseudo-dates with the correct time intervals will be used.

Research Findings

There have been four theses at Mercyhurst College and University that utilized the scans collected during the NIJ grant. The scans have been limited to internal use thus far because of privacy concerns and because in many cases, the demographic data were not ready for analysis.

Fojas (2010a, 2010b) examined age estimation using the appearance of the distal radial epiphysis . Scheuer and Black (2000) cite an age of appearance at 1 to 2 years of age, but Schaefer et al. (2009) add that if the epiphysis is if present, the individual is greater or equal to 4 months old, and if absent, the individual is less than 2.5 years old, based on results from previous studies. Fojas used logistic regression to derive 95% confidence intervals for age and found: if the epiphysis is present, the individual is at least 29 weeks (7 months) old; if absent, the child is less than 79 weeks (one year, eight months) old. These ages can be compared to Graham's republished ages from Garn of six months to two years, four months for boys and five months to 1 year, eight months for girls. Boys have apparently experienced a greater secular increase in the development of the distal radius. There were some indications of different rates depending on race and sex (blacks were advanced compared to whites and girls were advanced compared to boys), but they were not statistically significant and more study is needed.

Waldock (2011) analyzed the maximum length of the radius calculated from scans in the radiographic database. Her most significant results were that the ages estimated using Merchant and Ubelaker (1977), Ubelaker (1978), and Maresh (1970) tended to show more positive bias (produced greater and greater overestimates) the older the child was, beginning at age 2, similar to the results of Schillaci (2012). By age six, the bias was estimated to be three years.

Diefenbach (2012) examined the appearance of ossification centers of the elbow and may be the first researcher to incorporate uncertainty into estimating age rather than merely providing point estimates. She confirmed secular changes in development through earlier point estimates for centers appearing than they should according to the oft-cited literature. Differences between males and females were not statistically significant and were small compared to the uncertainty in estimation (Figure 5).

Clinical applications for the radiographic database are illustrated by Ertl (2012), who assessed numerous ossification centers from birth through nine months of age from over 900 infants. She derived updated guidelines for normal growth and newly calculated probabilities incorporating confidence intervals (Figure 6), which should reduce the false negative findings in lagging children due to secular changes, and reduce the false positive findings in accelerated children due to secular changes and quantified uncertainty. Based on her data and results, a computer program will be written for doctors to analyze pediatric radiographs in order to detect developmental anomalies requiring intervention.

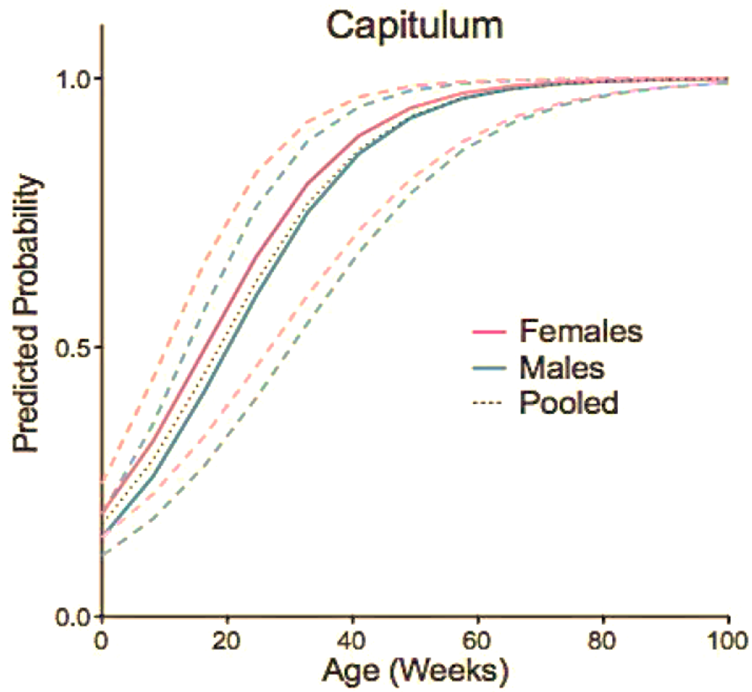

Figure 5. Probability of capitulum appearance, by sex, using logistic regression (solid lines) and incorporating lower and upper 95% bounds in the probabilities (dashed lines). From Diefenbach (2011).

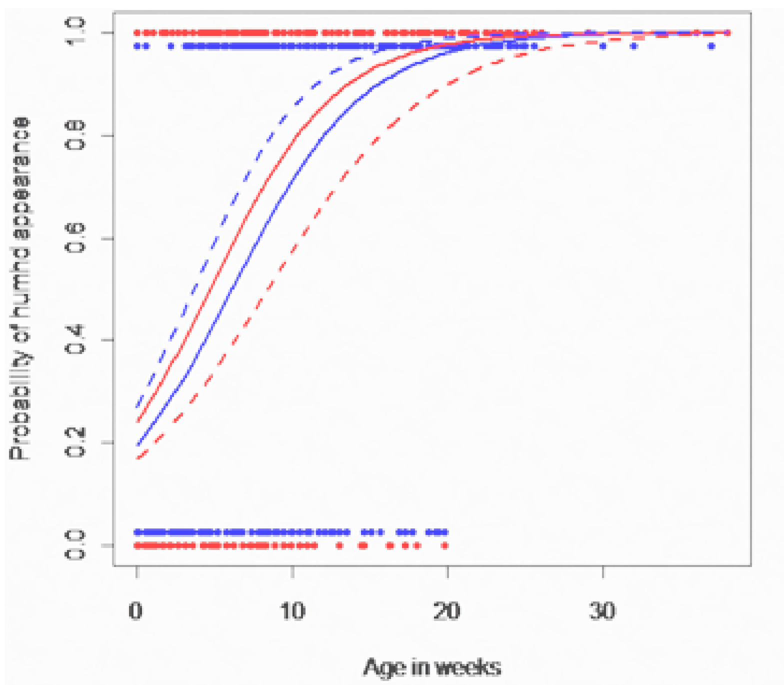

Figure 6. Probability of appearance of the humeral head for males (blue) and females (red) with lower confidence bounds for males and upper confidence bounds for females (dashed lines). From Ertl (2012).

Web Site

A web site has been constructed, and is still under construction, for the database. The web site will allow visitors to query the demographic information in the database and download the related radiographic images. It will be functioning by March 15, and more or less finished by April 1, 2013, though it will be updated often. The interactive query system for the database is accessible at: http://math.mercyhurst.edu/~sousley/databases/radiographic_database/

4. CONCLUSIONS

The radiographic database established through a grant from the NIJ complements data from adults compiled in the Forensic Data Bank at the University of Tennessee, Knoxville, which was established through a grant from the NIJ in 1986 (Jantz and Moore-Jansen 1987; Ousley and Jantz 1997). The radiographic database will continue to grow through ongoing contributions from medical examiners and clinics from around the country. This growth will be facilitated by the increased use of digital radiography. The creation of such a database will not only provide the basis for assessing growth and development in modern American children in the clinical setting and offer the most reliable sex and age standards with statistically determined age prediction intervals in the forensic setting, but will also open up further methods of analysis for other forensic and clinical needs.

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6. DISSEMINATION OF RESULTS

Dissemination has been achieved through presentations at professional conferences. Presentations include Frazee et al. (2009), which covered our preliminary findings of the state of radiographic documentation, and a poster by Stull et al. (2009) on challenges to estimating age from bone lengths at the annual meeting of the National Association of Medical Examiners; posters by Ousley et al. (2010a; 2010b) highlighting the creation of the radiographic database and collection efforts at the annual meetings of the American Academy of Forensic Sciences and American Association of Physical Anthropologists; and a poster by Hunt and Ousley (2013) highlighting the connection of the radiographic database to the Forensic Data Bank, at the annual meeting of the American Association of Physical Anthropologists. At least two publications are planned initially, one an overview of the database, and another providing updated standards for estimating age in subadults, to be submitted to *Journal of Forensic Sciences, Radiology, Paediatrics*, and/or *American Journal of Physical Anthropology*.

Ongoing dissemination will be primarily through a web site managed by Mercyhurst University. After the grant is finished, a copy of the database, software, and images will be sent to the NIJ, and approximately ten additional copies will be sent to other institutions, primarily large medical examiner offices and universities with well-established forensic programs. The database will be made available on DVD to other interested institutions at cost. But the database, software, and analytical methods will continue to be updated and improved, so the web site will be the best medium for sharing resources. Through the web site, researchers will be able to download data and images to derive new forensic methods and evaluate published findings on their own, greatly improving the validity and reliability of new methods and conclusions. Software will be available for free on the web site and a certain number of radiographic scales will be provided to offices for free upon request. Additional software applications will be practical once new methods for estimating age, sex, and ancestry are established, and can be incorporated into Fordisc (Jantz and Ousley 2005) and/or created as an independent computer program.

Through the use of the database and software, and presentations and publications, it is expected that more clinicians, medical examiners, and coroners will voluntarily contribute radiographic scans to the database. Hopefully, if free software for age estimation is available, the medical examiners and coroners will realize that they can benefit from contributing radiographic data to the data bank. Participants compiling and mailing digital radiographs on a DVD will be an especially simple way to contribute new information. Scanned radiographs of subadult teeth from dentists are another obvious addition to the database. Having a central repository for radiographic data will greatly enhance its applicability and scope. The Department of Anthropology/Archaeology or Applied Forensic Sciences at Mercyhurst will provide the necessary administrative oversight and staff support to incorporate new information into the database.

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