INTRODUCTION

The purpose of my study is to examine the progress of epiphyseal union of cervical vertebral centra as an age estimation method for unknown teenage and young adult skeletons. Existing skeletal age estimation methods work well for children or adults. The proposed study focuses on teenagers and young adults, a developmental period for which more information is needed.

For subadult skeletons, age estimation is based upon known changes due to growth and development. Methods include dental eruption, the progress of long bone epiphyseal union, and third molar root development. Dental eruption is the most accurate because it is under tight genetic control (20). Most deciduous teeth have erupted by 2 years old, with most permanent teeth erupting between 10 and 12 old (20). Age estimation from the dentition is usually performed in one of two ways. Either the dentition is compared to a chart depicting the mean stage of development for a given age, or each individual tooth is compared to this chart (8)(11).

Epiphyseal union, another method of subadult age estimation, refers to end caps of bone, epiphyses, fusing to the main piece of bone, or diaphysis. Epiphyses fuse in a genetically pre-determined sequence, which correlates closely with age (20). For the long bones (i.e., arms and legs), epiphyses typically fuse by age 18 or 19 (18) (13). However, the epiphyses of the vertebral centra fuse as late as the mid-twenties, thus providing more age information for younger adults.

Third molar root development is another subadult age estimation method. The third molar, or wisdom tooth, is the most variable tooth in terms of eruption (20). However, root development is complete by age 18, making it useful in determining if an unknown individual is older or younger than 18 years of age (15).

Adult skeletal age estimation methods are based upon morphological changes of certain bone features which are known to correlate to certain decades of life. The features are the pubic symphysis, auricular surface of the ilium, and sternal rib ends.

The pubic symphysis in a young adult exhibits a rough and grooved surface; as age progresses, these grooves become less distinct, due to erosion and general deterioration (19). However, because morphological change is not under as tight genetic control as growth and development, age estimation ranges provided by this method are wider, often spanning 10 years at the 95% confidence interval (20).

Another feature of the pelvis that changes with age is the auricular surface of the ilium. As age progresses, the auricular surface erodes, loses its billowy texture, and exhibits a coarser granularity (12). As with the pubic symphysis, age estimation from the auricular surface is variable between individuals, and is best used in conjunction with other methods (16).

The sternal rib end of the fourth rib is another feature of the adult skeleton that undergoes changes which correspond to age; however, these changes vary according to the sex of the individual (9). The changes in the rib end consist of a progression from flat and billowy to pitted and ragged as age progresses (7)(17).

One other method of adult age estimation is assessment of ectocranial suture closure. The sutures are evaluated on scale of 0-3, with 0 representing open sutures, and 3 representing the completed obliteration of the suture lines (14). Because the rate of suture closure is variable between individuals (10), this method is only able to indicate whether an individual was a young, middle aged, or older adult.

Age estimation from the epiphyses of the vertebrae is an important method for forensic age identification. The epiphyses of the long bones are fully united by the late teenage years (6),

and adult age estimation ranges are potentially broad. This leaves a gap in our ability to age late teenage or young adult individuals. The vertebral epiphyses remain active into the mid-twenties, and can provide age data for this group. The proposed study expands upon prior research on vertebral ring epiphyseal union for thoracic and first two lumbar vertebrae (4). This study was initially done because the thoracic and first two lumbar vertebrae are easily accessible at autopsy. However, now there is a need for data on the entire vertebral column. Here I document union for the cervical vertebrae to compare the timing and progress of these unions to the data gathered on the thoracic and first two lumbar vertebrae, and to determine if correlations between progress of union and age are similar, better, or more varied between the two sets of data.

The vertebral centrum, or body, is the flat rounded portion of the vertebra and comprises the majority of the vertebra (Fig. 1)(1). Different parts of the vertebrae undergo fusion throughout the years of growth and development, but the union of the epiphyseal rings to the superior and inferior aspects of the centrum, which begins around puberty and typically ends around 25 years of age, is the last to occur (5). Because the sequence and timing of these unions is under tight genetic control, the degree of fusion correlates closely with age.

While I believe that fusion for the cervical vertebrae will correlate closely with age, similar to Albert et al 2010, I hypothesize that these unions will correlate less accurately with age at death. Although the cervical vertebrae do not differ greatly from the thoracic or lumbar vertebrae, and consequently follow a similar pattern, it is because there are fewer epiphyses that the degree of fusion may not yield an age estimate as precise as one obtained from more epiphyses. For the 12 thoracic vertebrae at first two lumbar vertebrae, there are up to 28 epiphyses, one on the superior and inferior aspect of each centrum. However, for the 7 cervical

vertebrae, only C2-C7 have centra, and C2 only has an inferior aspect, for a total of 11 epiphyses.

METHODS

Data will be collected from the Robert J. Terry Anatomical Skeletal Collection which is housed at the Smithsonian Institution's National Museum of Natural History. The collection comprises 1728 skeletal specimens of known sex, ancestry, and age at death. My sample will be composed of 55 individuals, including 48 black individuals, seven white individuals, 32 males, and 23 females, the same 55 individuals examined in the study conducted by Albert et al (4), which will allow me to directly compare my data on the cervical vertebrae, to the data collected on the thoracic and first two lumbar vertebrae of the same individuals.

For 6 of the 7 cervical vertebrae (Fig. 2)(2), I will examine the degree to which the epiphyseal ring has fused to the centrum of the vertebra on the superior and inferior aspects, with the exception of C2 which has only an inferior aspect. Progress of union will be measured using the phase system (Fig. 3&4) from Albert and Maples (3)(See attached data sheet). Phase 0 (Fig. 3) is "no epiphyseal union" and is characterized by an absence of the epiphyseal ring, and a billowed surface of the centrum. Phase 1(Fig. 3) is "beginning union" and is characterized by an epiphyseal ring that has begun to fuse in some places, although distinct gaps between the ring and the centrum exist. Phase 2 (Fig. 4) encompasses "nearly completed union and recently completed union" and is characterized by more than 50% of the ring being fused and the absence of gaps, or by complete fusion, where the ring may still be distinguished as separate. Phase 3 (Fig. 4) is "completed union" and is characterized by an inability to distinguish the epiphyseal ring from the centrum to which it has fused (3).

Data will be analyzed to determine if the epiphyses fuse in a predictable sequence, at what ages certain degrees of fusion occur, and if the timing of unions differs between the sexes. A correlation between degree of fusion and age at death will be calculated. Additionally, the data collected will be compared to data on the thoracic and lumbar, to determine which may be the better age indicator.

RESULTS AND CONCLUSIONS

Findings from this study will be useful in one of two ways: either a high correlation between union and age at death will be found, thereby improving age estimation for unknown teenage and young adult skeletons, or the correlation will not be significant, which will provide the academic community with a point from which to continue research, knowing that cervical vertebrae do not enhance current age estimation methods. Results of this study will have significance for forensic identification, but will also benefit bioarchaeology. Estimation of ages for unknown individuals from ancient populations adds knowledge to the field of paleodemography, which studies population statistics for ancient peoples. Specific age estimates of ancient individuals would allow paleodemographers to more accurately calculate vital statistics, such as the mortality rate, or average age at death, of a population, which will give us a more accurate picture of our human past.

Results of this research may be presented at the 2011 American Academy of Forensic Sciences conference. Subsequently, I hope to write a paper for publication in the *Journal of Forensic Sciences*.
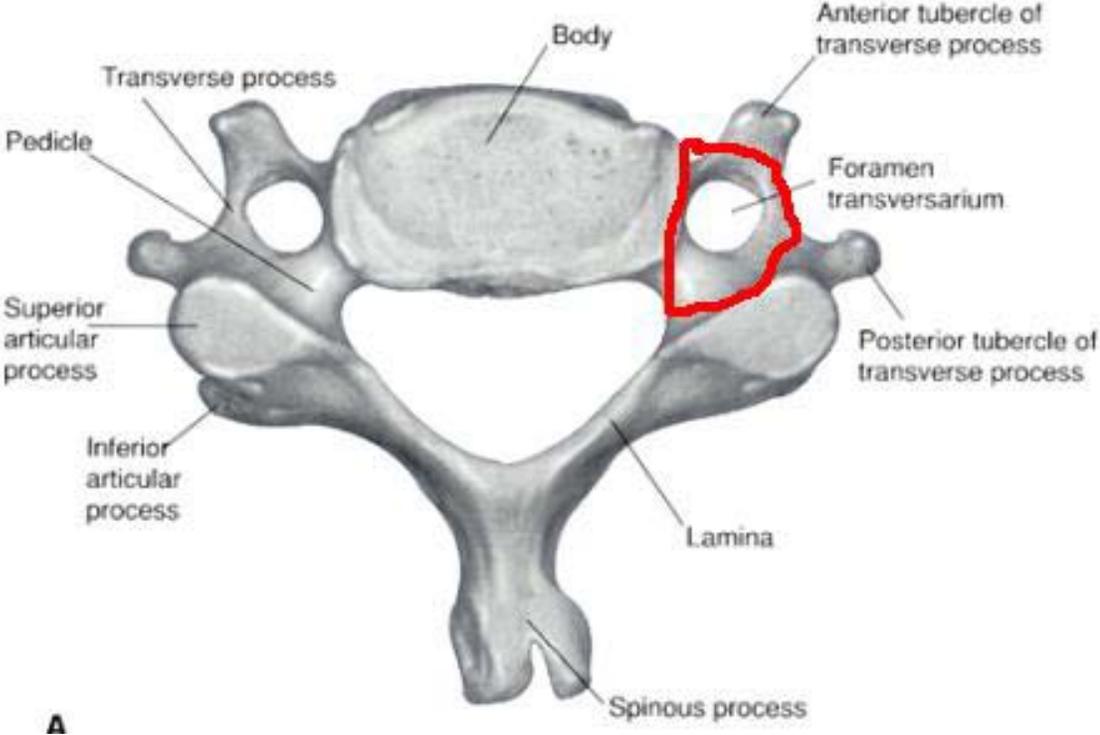
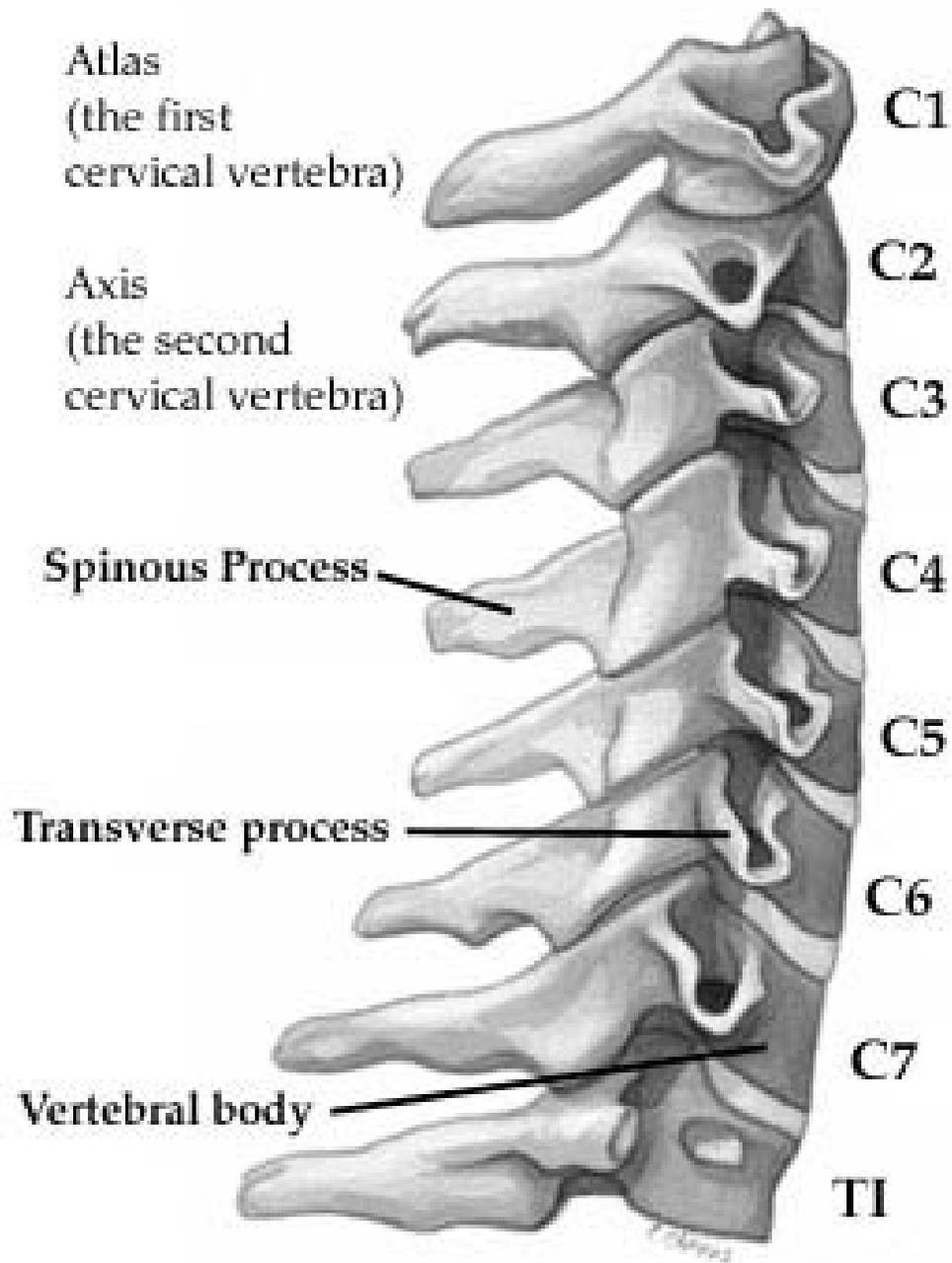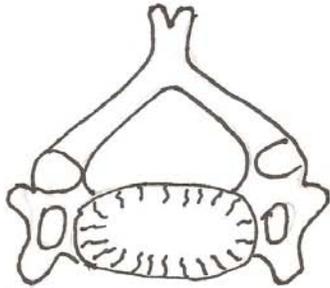Figure 1: Anatomy of a typical cervical vertebra (6)

Atlas
(the first
cervical vertebra)

Axis
(the second
cervical vertebra)

Spinous Process

Transverse process

Vertebral body

C1

C2

C3

C4

C5

C6

C7

TI

Figure 2: The seven cervical vertebrae (7)

PHASE 0
No Union

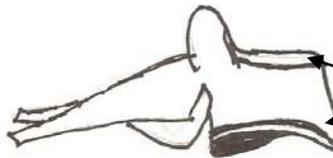Billowy texture, no epiphysis present

SUPERIOR   LATERAL

PHASE 1
Beginning
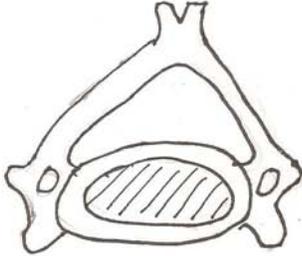# Union
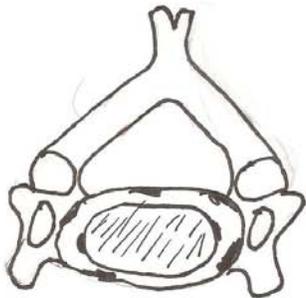
Epiphyses present
Not yet fully attached

SUPERIOR   LATERAL

Figure 3: Phases of Epiphyseal Union (0 & 1)

PHASE 2
Recently
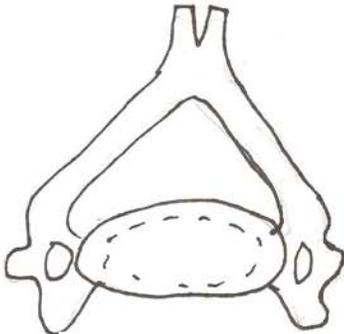# Complete Union
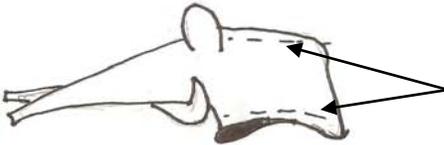
SUPERIOR   LATERAL

Epiphyses completely attached to centrum

PHASE 3
Completed
Union

SUPERIOR   LATERAL

Fused epiphysis, attachment site obliterated

Figure 4: Phases of Epiphyseal Union (2&3)

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Vertebral Centra Morphological Changes

Data Collection Sheet

Specimen Collection #: _____   Research identification #: _____

Age at death: _____   Sex: F (1) or M (2)

Ancestry: _____

	Superior	Inferior	Osteophytic lipping
C2			
C3			
C4			
C5			
C6			
C7			