

Trends and Patterns in the Ossification of Thyroid Cartilage

A Study of the William Bass Skeleton Collection
University of Tennessee at Knoxville

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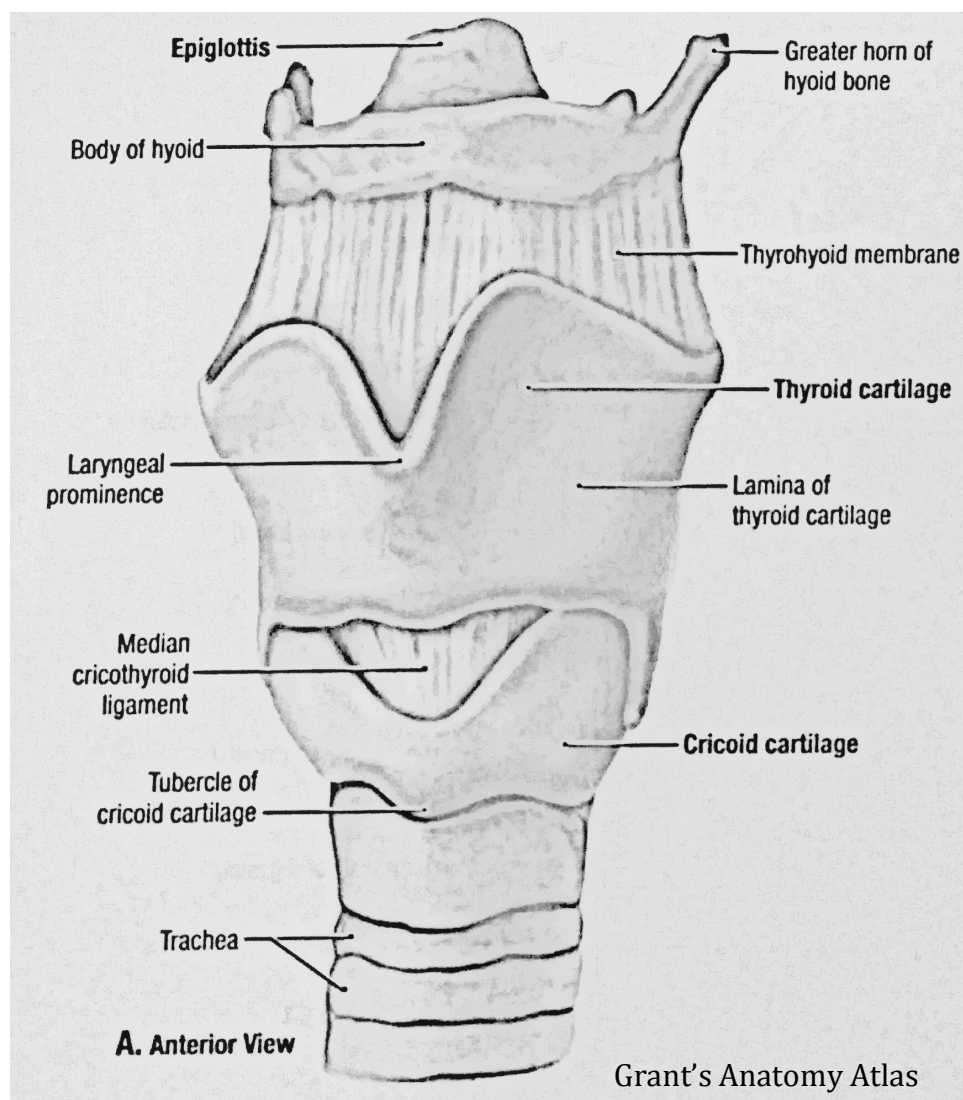
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INTRODUCTION

Although the “CSI Effect” has the general public under the notion that identification of the deceased is so simple it can take place during a commercial break, the reality is that this process is much more difficult. DNA testing has proven an invaluable technique for identifying unknown victims, however this process is often lengthy and costly, not to mention that DNA evidence is not always available. In cases where only skeletal remains are available, the difficulty level of making an identification increases. In order to make the identification of skeletal remains more accurate and efficient, it is crucial to study the skeletal remains of known individuals, and to document the frequencies and degrees of variable skeletal characteristics based on sex, age, and race. By doing this, investigators can then compare and contrast an unknown victim’s characteristics against data from known individuals’ characteristics. For example, prognathism (the projection of the facial skeleton) is much more prevalent in African American populations than in European American populations, thus if a victim shows a high degree of prognathism, previous research allows one to conclude the individual is likely black. While no single skeletal characteristic is ever enough to estimate the sex, age, or race of an individual alone, combined with other characteristics, the smallest element can be useful. This paper proposes that the ossification of the human thyroid cartilage, after being further studied, can become one of these useful traits during the identification process. If there are significant differences in the ossification process between the sexes and age groups, then the knowledge of these patterns will be useful when generating a biological profile.

LITERATURE REVIEW

Made up of two laminae, the thyroid cartilage protects the vocal cords and also forms the main part of the anterior wall of the larynx. The two laminae meet at the midline of what is commonly referred to as the Adam's apple, with the posterior borders of each drawn up to form a superior cornu and down to form an inferior cornu; the laminae also serve as attachment sites for several muscles in the neck (Mupparapu & Vuppalapati, 2005:198).



The human body contains several kinds of cartilage and some of these cartilages calcify, and then ossify during an individual's lifetime. Although many people use the terms 'calcification'

and ‘ossification’ interchangeably, they are in fact two different processes with calcification always preceding ossification (Mupparapu & Vuppalapati, 2005:196). The types of cartilages that make up the larynx are called hyaline cartilage and they are prone to calcification and ossification; this is especially true of the thyroid cartilage (Mupparapu & Vuppalapati, 2002:576).

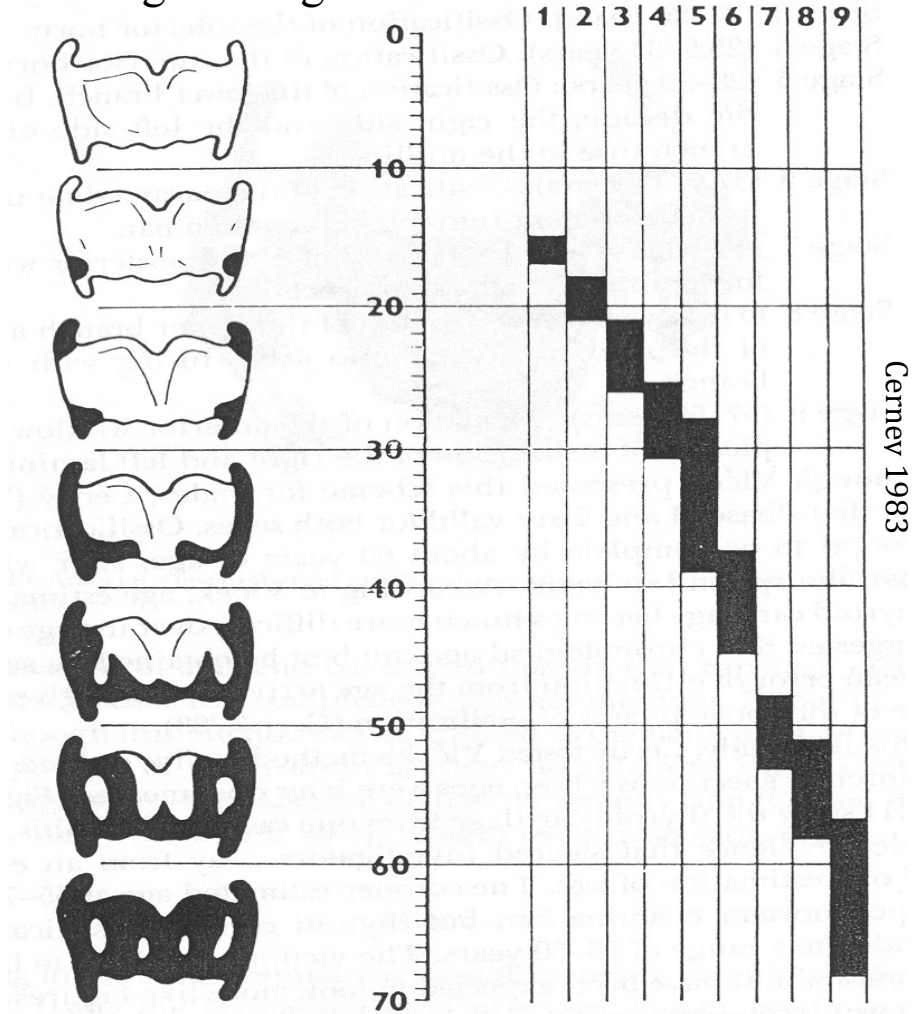
The thyroid cartilage calcifies and ossifies due to a normal process of mineralization which usually begins after adolescence and will gradually increase with age; however, according to Mupparapu and Vuppalapati (2002:576) the reasons behind the mineralization and ossification process of the thyroid cartilage are not well understood. There are some studies that point out a relationship between matrix vesicles associated with “needle-like crystals” and areas of mineralized cartilage; the authors of these studies believe that these matrix vesicles “mediate the mineralization of the human thyroid cartilage” (Kirsch & Claassen, 2000:2-3). That being said, there is still much research to be done on the process of thyroid cartilage ossification. Although the process of calcification and ossification is not completely understood, the fact that they do occur is still important and undoubtedly useful for researchers and, eventually, investigators.

According to Scarfe and Farman (2010:6), thyroid calcification is a progressive condition, and usually complete calcification of this cartilage can be found in individuals aged 70 and above. Mupparapu and Vuppalapati (2005:200) also note a significant increase in the presence of ossified thyroid cartilage after the third decade of life and a continuing, gradual increase as individuals age. Despite the fact that previous research has usually yielded results in older individuals, there are several unique cases of adolescents showing signs of thyroid ossification.

Mupparapu and Vuppalapati (2002:576-578) discovered a case of early thyroid ossification after taking a cephalometric radiograph of a 14-year-old boy that revealed an ossified superior cornu of the boy's thyroid cartilage. Although uncommon, thyroid ossification in adolescents is not unheard of. These rare cases are important because they emphasize the fact that one cannot assume the age of an individual based on one characteristic alone, and remind us that there is always variability in every biological process.

Though variability is inevitable, a recent study has shown that there may be a more precise pattern in the ossification process of the thyroid cartilage than previously thought (Dang-Tran, et al., 2010:677-683). It has been observed that the ossification pattern often begins at the posterior borders of the thyroid cartilage, and that the process of ossification is not always symmetrical, but tends to be bilateral (Dang-Tran, et al., 2010:679). This study also mentions some differences in the ossification process based on sex, stating that, "the female process was similar to the male process in the early stages..." however women, "seldom showed complete ossification" (Dang-Tran, et al., 2010:679). The fact that there is similar pattern and trend of thyroid cartilage ossification in almost all of the individuals from these studies shows that, with further research, this process can undoubtedly be used in determining age, and may play a role in estimating sex as well. Currently, there are no studies showing significant racial differences in the thyroid cartilage ossification process (Dang-Tran, et al., 2010:682).

Typical Cartilage Changes:



Dang-Tran and his coauthors note that the ossification process is “less extensive in women than men,” a statement that agrees with Mupparapu and Vuppalapati’s (2005:200) results.

Conversely, although men often display a higher degree of thyroid cartilage ossification, most studies have also produced results that show females have a higher frequency of ossification (Dang-Tran, et al., 2010:679; Mupparapu & Vuppalapati, 2005:200). That is to say, men will often display more complete ossification when it occurs, but statistically women will show more signs of ossification as a population. Between the sexes, hormonal differences play a large role in the aging process, and these hormonal factors may contribute to the different frequencies and degrees of ossification between males and females (Dang-Tran, et al., 2010:682).

HYPOTHESES

Based on previous research studies the initial review of publications on this topic, the following hypothesis was proposed:

H1. The degree of thyroid cartilage ossification will be more significant in individuals aged 50 and above; there will be little to no evidence of thyroid cartilage ossification in preadolescents and young adults.

When considering these hypotheses it is important to note that the research will likely be somewhat bias due to the low number of individuals below age 30. Discussion of the limitations presented by the test group, and plans to combat these limitations, can be found in the material and methods section of this thesis.

Further research may be able to focus on differences in the patterns and trends of thyroid cartilage ossification between the sexes and among varied racial groups.

MATERIALS AND METHODS

In order to test the proposed hypotheses human skeletal remains were analyzed for signs of thyroid ossification. The analysis was conducted using skeletal remains from the Bass Skeletal Collection at the University of Tennessee at Knoxville. This collection began in 1981 under Dr. William Bass and is mainly made up of individuals who have chosen to donate their bodies for research in physical and forensic anthropology. Although this collection is presently the largest contemporary human skeletal collection, consisting of almost 1,200 individuals, it does present several limitations. These limitations include the low percentage of individuals under the age of 50, the high percentage of white individuals, and the dominance of male individuals. Due to these limitations, only white, male individuals were assessed for signs of patterns and trends in the ossification of thyroid cartilage based on age.

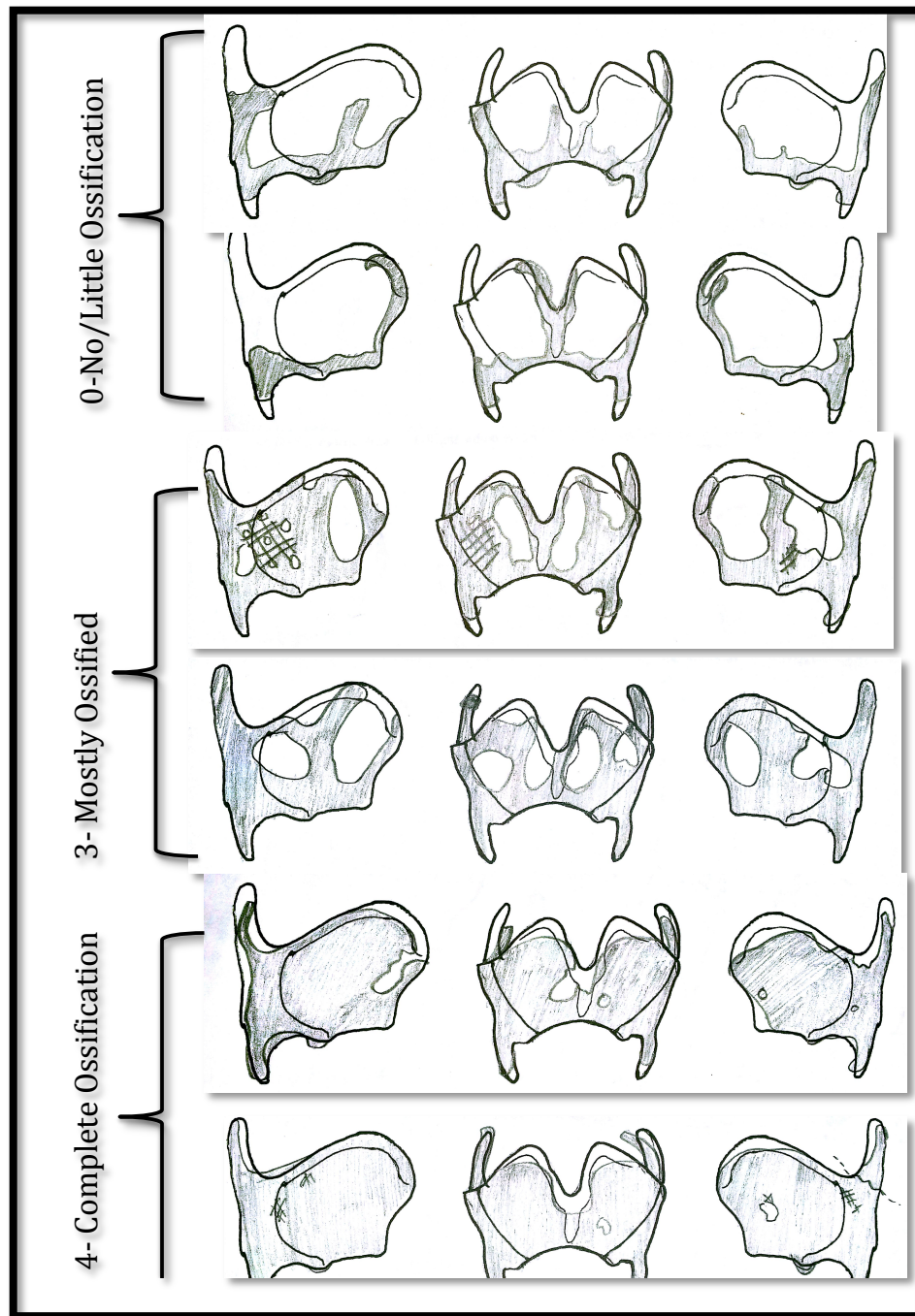
The methods of recording data was similar to previously conducted studies, however this research is different from past studies in that the current test group consisted solely of deceased individuals; many of the studies previously mentioned were conducted using radiographs on living test groups. Because of this difference, it is also important to note that the absence of an ossified thyroid cartilage does not necessarily mean that there was no ossification. Most individuals from the Bass collection are first placed at the Anthropological Research Facility, which is an outdoor research facility used to study postmortem processes. Many times, small and fragile bones can be lost during the recovery process, or scavenged by rodents during the decaying period. Since the start of this program, there has been an increase in measures to prevent the loss of any skeletal material, including the introduction of a screening process and

new methods to reduce animal scavenging; that being said, donations from the early stages of this program will likely grant less opportunity to study ossified thyroid cartilage, as they were recovered before these methods were put in place. To eliminate the problem of not knowing whether an individual displayed no signs of ossification or if the ossified thyroid cartilage was lost through the research process, the sample was selected to be limited to represent individuals known to have displayed signs of thyroid cartilage ossification.

Due to the available sample group, the absence of ossified thyroid cartilage is not significant evidence enough to assume that there was no ossification present in that individual, and so I will not be able to accurately calculate the frequencies of ossification based on age if every individual without evidence of thyroid cartilage ossification is included in my research. Instead, research will focus on the differences in the degree of ossification based on age solely utilizing individuals presenting evidence of thyroid cartilage ossification.

To remove any bias, the individuals' ages were unknown during the analysis stage of research. A group consisting of 72 white, male individuals noted to have displayed signs of thyroid cartilage ossification during the pick-up process of the remains at the Anthropological Research Facility. Throughout the research process it became clear that three of the listed individuals were not able to be used in the research for various reasons. In addition, seven samples were highly fragmented postmortem and so these samples were also removed from the final results group. After these changes, the final sample group consisted of sixty-two white males with ages ranging from 26-29. The remaining individuals were analyzed separately to avoid any confusion or combining of the remains. To collect the data from the randomly selected group of individuals who presented

evidence of thyroid cartilage ossification, the remains were analyzed and the degree of ossification was recorded using a number system as follows: *0-No/little ossification; 3-Mostly ossified 4-Complete ossification*. The symmetry of the ossification was also noted by marking either *1-Right side ossified; or 2-Left side ossified*.



The ossified thyroid cartilages were each analyzed and recorded by shading the present elements of cartilage on the following document:

Specimen: _____ - _____ D		Age: _____
Level of Ossification:		
0-No/little ossification	1-Right side ossified	2-Left side ossified 3-Mostly 4-complete
		
Observations:		

It was also noted whether or not the hyoid and cricoid was present to see if there is any correlation between thyroid cartilage ossification and the aforementioned skeletal elements.

After recording the observations of the individuals, the above documents were collected to be compared and contrasted. Individuals with the same numerical value assigned during analysis were group together and similarities and differences within each grouping were noted. These groups were created without the age of each individual being known in order to avoid any bias affecting the assignment of groups.

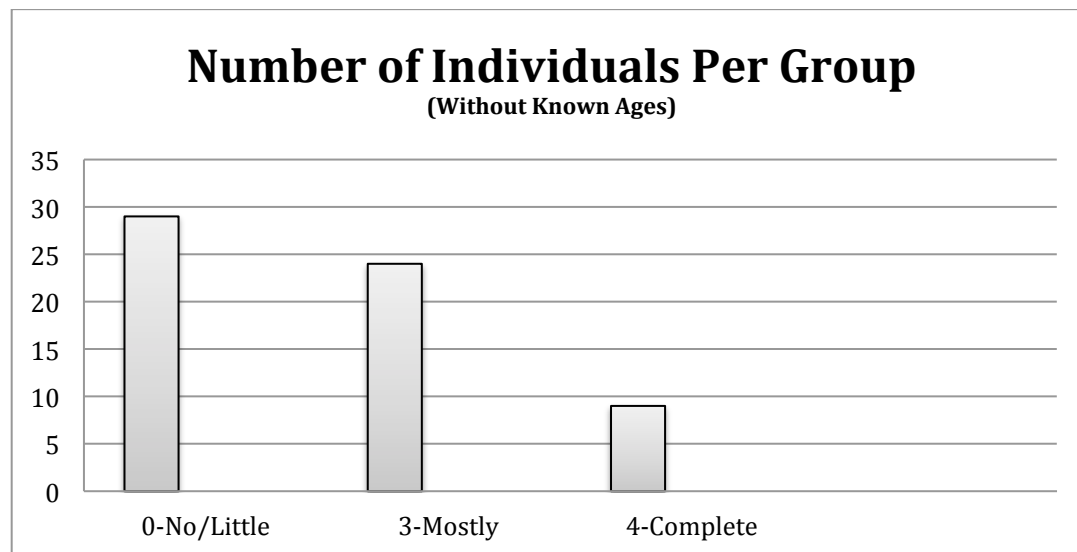
After the initial groups were created and analyzed, the known ages of each individual were revealed. Each specimen was subsequently labeled with the corresponding age. The original documents were then analyzed to see if the blind groupings, based off of degree of ossification, corresponded with one another regarding the actual age of each individual. After making note of the original groupings individuals were regrouped based on age (i.e. 40s, 50s, 60s, etc.) and the similarities and differences of the degree of ossification of each individual within said age groups were reanalyzed.

RESULTS

The average age of the sample group was 61.079, which was rounded to sixty-one years of age.

Again, all individuals in the sample are known white males. The youngest individual included in the sample was thirty-six years of age while the oldest individuals were eighty-nine. Seven individuals from the original sample group were removed from this section due to high degrees of fragmentation from postmortem damage.

Before the actual ages of the individuals were known, they were divided as follows:



Grouping of Specimens Before Knowledge of Actual Ages:

<i>No/Little Ossification</i>	<i>Mostly Ossified</i>	<i>Complete Ossification</i>
10-88; 05-99; 02-03; 50-03; 39-04; 04-05; 38-06; 38-09; 82-09;	10-87; 12-87; 02-89; 12-90; 22-93; 20-95; 19-99; 27-99; 43-01; 07-02; 20-02; 51-03; 03-04; 08-04; 36-04; 10-05; 37-05; 65-05; 66-05; 90-05; 26-06; 71-06; 82-06; 100-08	05-83; 01-87; 03-90; 18-91; 05-93; 36-93; 02-96; 10-96; 01-97; 09-97; 03-98; 04-99; 22-01; 29-01; 09-02; 38-03; 64-03; 24-04; 45-04; 03-05; 32-05; 58-05; 93-05; 60-06; 76-06; 84-06; 29-07; 89-07; 15-08;

The known ages of each individual were separated into the following age groups:

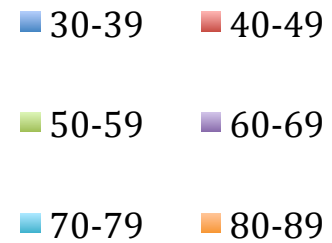
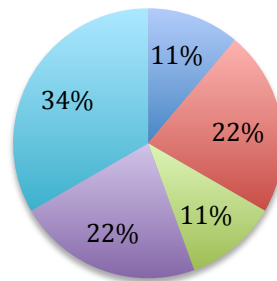
30-39	40-49	50-49	60-69	70-79	80-89
01-87	66-05	38-09	39-04	38-06	71-06
02-89	03-90	84-06	24-04	65-05	12-87
05-99	89-07	12-90	20-95	76-06	36-04
15-08	82-09	90-05	50-03	64-03	29-01
100-08	10-05	05-93	37-05	04-05	82-06
	22-01	58-05	09-02	22-93	26-06
	05-83	45-04	51-03	19-99	02-96
	10-88	32-05	93-05	02-03	27-99
	29-07	36-93	20-02	10-87	03-98
		09-97	38-03	01-97	03-05
		04-99	10-96	03-04	60-06
		08-04			
		18-91			
		43-01			
		07-02			
Total= 5	Total= 9	Total= 15	Total= 11	Total= 11	Total= 11

The original groups were highlighted to illustrate the groups based on age:

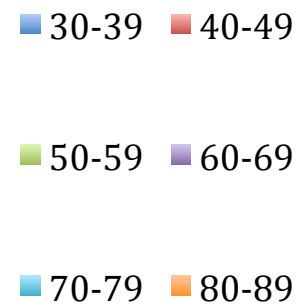
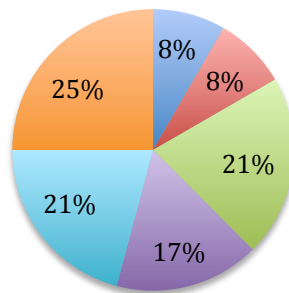
<i>No/Little Ossification</i>	<i>Mostly Ossified</i>	<i>Complete Ossification</i>
10-88; 05-99; 02-03; 50-03; 39-04; 04-05; 38-06; 38-09; 82-09;	10-87; 12-87; 02-89; 12-90; 22-93; 20-95; 19-99; 27-99; 43-01; 07-02; 20-02; 51-03; 03-04; 08-04; 36-04; 10-05; 37-05; 65-05; 66-05; 90-05; 26-06; 71-06; 82-06; 100-08	05-83; 01-87; 03-90; 18-91; 05-93; 36-93; 02-96; 10-96; 01-97; 09-97; 03-98; 04-99; 22-01; 29-01; 09-02; 38-03; 64-03; 24-04; 45-04; 03-05; 32-05; 58-05; 93-05; 60-06; 76-06; 84-06; 29-07; 89-07; 15-08;

The original groups, which were based off of the degree of ossification present, were then analyzed to find the percentages of each age group.

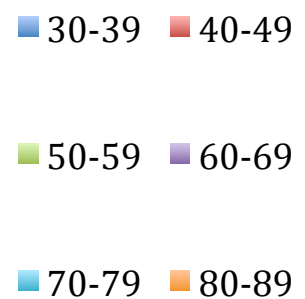
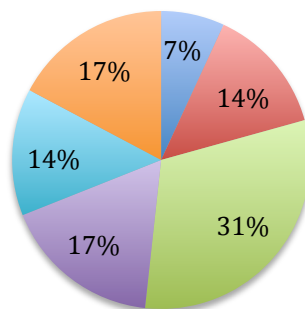
No/Little Ossification



Mostly Ossified



Complete Ossification



DISCUSSION

Based off the results yielded from this study, it is likely that the ossification of the thyroid cartilage is based on age; in effect, the older an individual the more likely the higher degree of thyroid cartilage ossification. However, the degenerative processes of the human body yield much more variation and are less predictable than developmental processes and so this process is not as easily anticipated. Also, as discussed earlier, there are several case studies that have proven that complete ossification of the thyroid cartilage is possible in younger individuals.

In accordance with the stated hypothesis, the group of *No/Little Ossification* yielded no individuals from the 80-89 age group and the *Complete Ossification* group yielded only seven percent from the 30-39 age group. The results yielded evidence to support the fact that the degenerative process of thyroid cartilage ossification appears to be associated with age.

Eight-four percent of the individuals in the original group of *Mostly Ossified* were individuals aged 50-89, significantly higher than the sixty-seven percent in the *No/Little Ossification* group. It is quite evident from the results that the older an individual, the more likely that individual will display a higher degree of thyroid cartilage ossification.

With a different sample group, future studies could include differences in the patterns and trends of thyroid cartilage ossification between males and females. Furthermore, additional research could examine if there are any significant variances between different ethnic groups.

CONCLUSION

In conclusion, research on thyroid calcification and ossification is important because knowledge of this process in relation to age, sex and race, may bring investigators one step closer to more accurate identifications of unknown individuals. Previous studies on this topic have yielded results which allow researchers to assume there is a correlation between an individual's age and sex, and the rate and degree of thyroid cartilage ossification. Further research on this topic will help solidify these findings and perhaps will unearth a correlation between race and thyroid cartilage ossification. Again, this trait characteristic alone will never allow investigators to pin point the age, race or sex of an unknown individual, but in conglomeration with other identification techniques, more accurate results will be produced

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