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Bone Cracking in Low Humidity/High Temperature Environment

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Abstract

What causes the discrepancy in bone cracking in low humidity/high temperature environments? While cleaning bone for unrelated research in a tank of Dermestid beetles, certain bones would crack while others would not. The central theme of this research is to find out what factors made the bones crack and why some did not. Knowing the reasons for this will help in forensic cases, and the ability to control these factors could help future research. Deer humeri and femora were placed in a tank of Dermestid beetles in a room with a temperature of approximately 79 degrees Fahrenheit and approximately 24% humidity. The height, weight, circumference at the shaft, type of bone, fusion stage and whether or not they cracked were noted. The best indicator of whether a bone will crack or not appears to be the type of bone. Humeri had a cracking rate of 5% while femora had a cracking rate of 64% from the group of 40 bones. The other variables did not seem to play a roll. The reason for this, I hypothesize is the curvature of the humerus is much greater than the femur which stands up to the tension of the drying produces. The differences in the susceptibility of the two types of bone will be an important factor in future research on weathering and cracking of bone.

Keywords: Forensic Anthropology, Weathering, Bone Trauma

1. Introduction

The weathering of bones in a forensic or archeological context can be an indicator of the length of time the remains have been exposed to the elements[1]. In a forensic context it is also important to be able to decipher whether damage to bone is the result of perimortem trauma, antemortem trauma, scavenging or weathering. Being able to tell the difference between bone damage as a result of natural weathering processes and human infliction is of importance in legal cases. This paper focuses on the weathering of bone in desert like conditions with low humidity and high temperature.

Temperature and humidity are two major factors in the way that bone weathers[2]. Evaporation of moisture from the bone is to be expected as part of their natural decomposition process, but in conditions with low humidity and high temperature, the speed of the process increases[3]. The drying of bone causes it to shrink, creating stress throughout the structure of the bone. In addition, the faster the drying process, the more stress is caused[4]. When drying bone, it is recommended to keep the humidity high to lessen the chance of the bones cracking[4].

The idea for this research came when a large number of deer bones placed in a tank of Dermestid beetles for cleaning came out with cracks. There seemed to be a large discrepancy in which types of bones cracked (femora verses humeri). Knowing that the stress placed on bone through an accelerated drying process can cause cracking, this was not to be unexpected. The main focus of this research is on the reason for the discrepancy between the two types of bone in their crack rate.

2. Methods and Materials

2.1 Subjects

The bones used in this research were deer and were obtained from a local game processing facility. The only two bones used were humeri and femora, with no preference to side. A total of 40 bones were used in this study, 22 of which were femora and 18 of which were humeri. Bones were skinned at the facility and placed in an outdoor walk in refrigerator before being obtained by Western Carolina University's Forensic Anthropology program. Bones were then disarticulated and vacuumed packed before being placed in a refrigerator.

2.2 Experimental Design and Procedure

Bones were placed into a 10 gallon tank of Dermestid beetles for flesh removal in four different rounds. The tank was located in the Natural Science Building at Western Carolina University in a temperature and humidity controlled room. The room in which the bugs were kept had an average humidity level of 24% and an average temperature of 79.33 degrees Fahrenheit. The bones were kept in the tank until they were completely devoid of flesh, which normally took about a week's time. No water was added to the tank of beetles during the duration of the defleshing and the temperature and humidity were monitored using a weather read out device in the room.

After collection from the tank, the bones were brought back to the Human Identification Laboratory at Western Carolina University. Each bone was then assigned a test subject number which was written in sharpie on the bone (TS-XX). Photographs were taken of each bone with a scale included from four different views. The following measurements were taken on each bone: height (millimeters using an osteometric board), width (millimeters taken midway down the shaft at widest point), and weight (in grams, taken on a Taylor food scale accurate to the nearest gram). In addition, the type of bone and general stage of fusion (not fused, in the process of fusion, fully fused) was noted as was whether or not the bone had cracked. In Table 1 below, all the measurements and data are listed for each bone.

Table 1: Data for all test subjects

Subject #	Height (mm)	Width (mm)	Weight (g)	Cracked?	Fusion	Bone Type
TS-01	235	17.18	156	Yes	In Fusion	Femur
TS-02	260	20.92	206	Yes	In Fusion	Femur
TS-03	235	19.22	165	No	In Fusion	Femur
TS-04	190	17.15	116	No	In Fusion	Humerus
TS-05	200	15.73	102	No	In Fusion	Humerus
TS-06	200	19.18	167	No	In Fusion	Humerus
TS-07	233	21.20	179	Yes	Fused	Femur
TS-08	243	17.91	180	Yes	In Fusion	Femur
TS-09	181	15.88	103	No	In Fusion	Humerus
TS-10	185	19.25	100	No	Fused	Humerus
TS-11	230	19.90	191	Yes	In Fusion	Femur
TS-12	178	19.43	150	No	In Fusion	Humerus
TS-13	180	17.26	112	No	Fused	Humerus
TS-14	181	17.66	116	No	Fused	Humerus
TS-15	230	19.01	162	Yes	In Fusion	Femur
TS-16	175	16.34	93	No	Fused	Humerus
TS-17	225	18.18	130	No	Fused	Femur
TS-18	223	19.57	168	No	Fused	Femur
TS-19	200	18.40	156	No	In Fusion	Humerus
TS-20	180	17.06	105	No	Fused	Humerus
TS-21	253	21.75	227	No	In Fusion	Femur
TS-22	250	21.55	208	Yes	Fused	Femur
TS-23	210	24.28	182	No	Fused	Humerus

TS-24	195	22	127	No	Fused	Humerus
TS-25	185	15.665	69	Yes	In Fusion	Femur
TS-26	225	18.30	163	No	Fused	Femur
TS-27	240	19.24	150	Yes	In Fusion	Femur
TS-28	202	21.73	125	Yes	In Fusion	Humerus
TS-29	190	23.70	124	No	Fused	Humerus
TS-30	181	22.01	87	No	In Fusion	Humerus
TS-31	240	19.67	192	No	Fused	Femur
TS-32	211	25.19	183	No	In Fusion	Humerus
TS-33	240	22.55	170	No	In Fusion	Femur
TS-34	255	19.13	217	Yes	In Fusion	Femur
TS-35	226	17.75	125	Yes	Fused	Femur
TS-36	235	18.79	173	Yes	Fused	Femur
TS-37	185	17.64	71	Yes	In Fusion	Femur
TS-38	235	19.81	174	No	In Fusion	Femur
TS-39	180	20.16	88	No	Fused	Humerus
TS-40	255	22.50	263	Yes	Fused	Femur

After the data was recorded, the bones were placed in a plastic bag and placed back in the refrigerator to prevent molding in the event they had to be reexamined.

2.3 Analysis

The number of bones that cracked of each type was divided by the total number of bones of that type to come up with a crack rate. The range for each of the measurements taken was then found for each bone type for both cracked and uncracked to examine if the measurements played a factor in whether or not the bones cracked. The ranges are explained in Figure 1 below.

Bone Data (Femora)

Total Number: 22
Total Cracked: 14 (64%)
Total Not Cracked: 8 (36%)
Min Height: 185 mm — Max Height: 260 mm
Min Width: 15.65 mm — Max Width: 22.55 mm
Min Weight: 69 g — Max Weight: 263 g

Stats of Just Cracked Femora
Min Height: 185 mm — Max Height: 260
Min Width: 15.65 mm — Max Width: 22.50 mm
Min Weight: 69 g — Max Weight: 263 g

Stats of Just Un-cracked Femora
Min Height: 223 mm — Max Height: 253 mm
Min Width: 18.18 mm — Max Width: 22.55 mm
Min Weight: 130 g — Max Weight: 227 g

Bone Data (Humeri)

Total Number: 18
Total Cracked: 1 (5%)
Total Not Cracked: 17 (95%)
Min Height: 175 mm — Max Height: 211 mm
Min Width: 15.73 mm — Max Width: 25.19 mm
Min Weight: 87 g — Max Weight: 183 g

Stats of Just Cracked Humeri
Min Height: 202 mm — Max Height: 202 mm
Min Width: 21.73 mm — Max Width: 21.73 mm
Min Weight: 125 g — Max Weight: 125 g

Stats of Just Un-cracked Humeri
Min Height: 175 mm — Max Height: 211 mm
Min Width: 15.73 mm — Max Width: 25.19 mm
Min Weight: 87 g — Max Weight: 183 g

Figure 1: Measurement Ranges

3. Results

The results show a high incidence of cracking (64%) in femora compared to a very low rate (5%) in humeri. All cracks extended from the ends of the bones across the entire length of the shaft with no preference to anterior/posterior or lateral/medial aspects. In both humeri and femora the cracks were vertical with little to no curvature. The discrepancy cannot be explained by weight, height or width of the bone. There were humeri and femora with similar weights, heights and widths in the study. The bones were also from the same geographic location, same species, and same age group.

Whether or not a femur would crack did not seem to depend on any of the data taken and was statistically close to a 50/50 coin flip. The humeri on the other hand showed statistically significant odds of not cracking (95%) with only 1 of 18 cracking. While there may be determining factors for whether or not a femur or humerus cracks, it is beyond the scope of this research.

One discrepancy worth noting, and that will be covered in the discussion section, is the morphology of the bone types. The femora have a very slight curve to the shaft while the humeri have an 'S' shape to their shaft. See Figure 2 for comparison of bone curvature between humeri and femora.

Figure 2: Comparison of bone curvature. The humeri pictured are not cracked while the femora pictured are cracked.

4. Discussion

The femora and humeri showed a large discrepancy in their rates of cracking with femora cracking at a rate of 64% and humeri cracking at a rate of 5%. Since there were femora and humeri that shared the same height, width, weight, and fusion state, those variables more than likely did not determine whether or not a bone cracked. The bones were all placed in the same environment with a mix of femora and humeri in each batch. Whether or not a femur would crack did not seem to rely on its weight, height, width or fusion state as there were bones on all ends of the spectrum that cracked and did not crack. Further research will be needed to determine the reason certain femora cracked and certain femora did not. Likewise, no reason for the single humerus (TS-28) that cracked could be found. It is possible that TS-28 had internal structural weaknesses or prior injuries (not visible to the naked eye) that caused it to crack.

The main difference that could be observed between the two types of bones was the general morphology. The femora have a very slight curve to their shaft but are generally straight, while the humeri have an 'S' shaped curve to their shafts. The differences in crack rates could be due to shape of the shaft. The 'S' shaped curve might hold up better to the pressure exerted on the bone during the rapid drying process. According to Carl Friedrich Gauss and his theory of

Theorema Ergregium curvature of an object increases its strength [5]. When an object has a curve to it that object is better able to withstand force. Research has also been done by Theor Biol on the curvature of long bones in mammals. Their findings suggest that bone curvature introduces greater stability which is supported by the findings in this research[6]. While both the femora and humeri have some degree of curvature, the humeri has a much more exaggerated curve, giving it greater strength and stability.

Another example of the strength and stability that an 'S' shaped curve provides is in the spinal columns of bipeds, specifically in humans. The human vertebral column is shaped like an 'S' to be able to stand up under the pressure of our weight[7]. According to Spinalhealt.net "*The physics of the spine state that resistance of a curved column is directly proportional to the square of the number of curves plus one*"[7]. If the same logic is used for the curvature of the humerus, then that means that the humerus having two curves ($2^2+1= 5$) can withstand five times the force than if it were straight. The femur on the other hand having only a slight curve (we'll give it a curvature of 1) ($1^2+1=2$) can only withstand two times the force than if it were straight.

Using this prior research and equations, the findings in this research make sense in light of the morphology. The humeri's double curve allows it to withstand the force that an accelerated drying process exerts on it better than the femora's single (and slight) curve.

These results may not have direct implications for human humeri (human humeri have considerably less curvature than deer) and femora but there could be implications for human bones such as the clavicle. The clavicle is similar in its curvature to the deer humeri and possibly could be have in a similar matter. Human studies would need to be done on femora and humeri to see if the same results occurred.

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6. References Cited

1Bird, Katelyn MD., "Bone Weathering Helps Determine Time of Death," BU School of Medicine, http://www.bumc.bu.edu/busm/2016/04/07/bone-weathering-helps-determine-time-of-death/

2 Behrensmeyer, Anna K, "Taphonomic and Ecologic Information from Bone Weathering," Paleobiology Vol. 4 No. 2 (Spring 1978): pp 150-162.

3Cleaning Technologies Group, "Drying – The Effect of Temperature on Relative Humidity," John's Corner, http://www.ctgclean.com/tech-blog/2013/05/drying-the-effect-of-temperature-on-relative-humidity/

4Stevene, "Seasoning Bones: How to avoid cracking in drying bones," Paleotechnics, https://paleotechnics.wordpress.com/2014/09/18/seasoning-bones-how-to-avoid-cracking-when-drying-bones/

5Bhatia, Aatish, "How a 19th Century Math Genius Taught Us the Best Way to Hold a Pizza Slice," Wired, http://www.wired.com/2014/09/curvature-and-strength-empzeal/

6Biol, Theor J, "Bone Curvature: Sacrificing Strength for Load Predictability," Journal of Theoretical Biology Vol. 131 Issue 1 (March 1988): pp 75-92.

7Spinalhealth.net. "A Brief Tour of Spinal Anatomy," Spinal Health, http://www.spinalhealth.net/ana.html