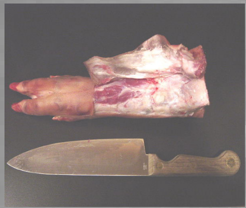

Figure 1: Porcine hind limb showing the extensor digitorum brevi muscle.

The Physics of Cutmarks

Sheridan Potter; 2004 CSU Undergraduate Research Symposium

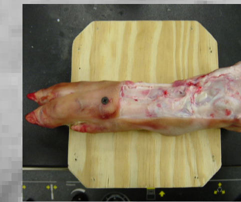

Figure 2: Porcine hind limb mounted on wooden plate after removal of muscle tissue.

ABSTRACT

Cutmarks are the most direct evidence of faunal butchery by humans; however, understanding the physical properties associated with their creation is critical when interpreting the archaeological record. By quantifying the minimum amount of force required to cut through soft tissue and the minimum amount of force required to produce a visible cutmark on the surface of bone, and then correlating those values with the maximum amount of force exerted by a human butchering with a stone tool, archaeologists will better understand the conditions conducive to creating cutmarks. A porcine metatarsal served as the specimen for the cutting experiment, while obsidian and chert flakes, and a scalpel blade were used as the cutting tools. Axial cutting force was measured with a dynamic loading cell, accurate to the nearest Newton. Cutmarks were replicated with rubber latex and were analyzed using a scanning electron microscope at varying degrees of magnification, and depth was measured to the nearest micrometer. Twenty adults (10 male and 10 female) volunteered to perform an experiment measuring the maximum amount of force that could be exerted in a kneeling position while holding a small flake and a large biface. Force was measured using a digital scale accurate to the nearest tenth of a kilogram. Results have shown that less force is required to cut through soft tissue using obsidian as opposed to chert flakes, the amount of force required to produce a visible cutmark on a bone is constant, and that on average males can exert a greater maximum force using both large and small stone tools than females.

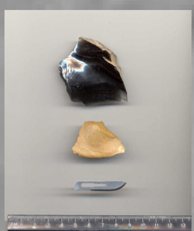

Figure 3: Cutting tools used for muscle tissue and bone. Top: obsidian flake; Middle: chert flake; Bottom: number 10 scalpel blade.

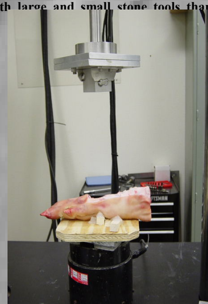

Figure 4: Mounted hind limb on dynamic loading force cell.

INTRODUCTION

In the effort to increase the accuracy of their interpretations, archaeologists employ the use of experimental actualistic studies to better understand the formational processes that result in the evidence observed in the archaeological record. Actualistic studies follow the principle of uniformitarianism, in that contemporary processes are representative of those that may have occurred in the past. The most direct evidence for butchering of faunal remains are cutmarks that are left on the cortical surface of the bone as a result of cutting tools. Much research has been conducted to increase understanding of the subsistence strategies of prehistoric humans, including experimental butchering techniques that seek to recreate cutmarks viewed on archaeological fauna. However, until the physical properties of the butchering process are understood, it will remain difficult to formulate accurate interpretations of the behavior of the butcher associated with the cutmarks on the bones. Therefore, the goals of this research project are as follows:

➢ To **quantify:**

- the *minimum* amount of axial force required to cut through muscle tissue
- the *minimum* amount of axial force required to develop a cutmark on a bone
- the *maximum* amount of axial force exerted by a person with varying stone tool sizes

MATERIALS AND METHODS

Cutting Force Measurements

A domestic pig (*Sus scrofa*) left hind limb served as the specimen for the muscle tissue and bone for the cutting force experiment (Figures 1). The limb was approximately one week post mortem and was at room temperature during the time of cutting. It was mounted to a wooden platform and then placed on a dynamic force cell that is accurate to the nearest Newton (Figure 4). The extensor digitorum brevis muscle was cut through with a number 10 scalpel blade, an obsidian flake, and a chert flake (Figure 3) with the minimal amount of force required to initiate a cut. After the muscle tissue experiment was complete, the muscle tissue was removed to expose the number four metatarsal (Figure 2), the anterior portion of which was then cut with the same scalpel blade and flakes three times in series. Data was recorded automatically from the force cell in a predesigned Excel program, and the peak forces in the graphs are observed as a downward spike (Figures 5-8). The bone was then gently boiled to remove all soft tissue for cutmark analysis (Figure 9).

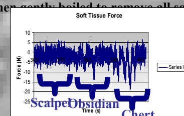

Figure 5: Graph of soft tissue cutting force.

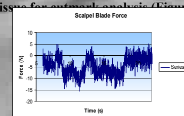

Figure 6: Graph of scalpel blade cutting force on the bone.

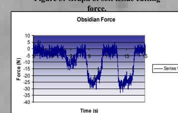

Figure 7: Graph of obsidian flake cutting force on the bone.

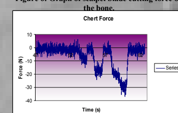

Figure 8: Graph of chert flake cutting force on the bone.

Cutmark Analysis

A rubber latex mold of the cutmarks formed by the stone tool flakes was created and was analyzed in a scanning electron microscope at varying magnifications. Depth of the cutmark was determined using a digital micron bar on computer software only for the obsidian flakes, as these were the only cutmarks that could be inclined in the SEM apparatus (Figures 10-14).

Maximum Human Force Measurements

Twenty adults (10 males and 10 females) volunteered to perform an experiment to determine the maximum amount of force that could be exerted using a small and a large stone tool (Figure 16). The individuals were asked to kneel with their knees together and feet together, with their non-dominant hand placed next to the scale and their dominant hand gripping the stone tool (Figure 17). They were then asked to press on the scale (accurate to the nearest tenth of a kilogram) with the maximum amount of force they could exert downwards. The individuals' height and weight were also recorded for later analysis.

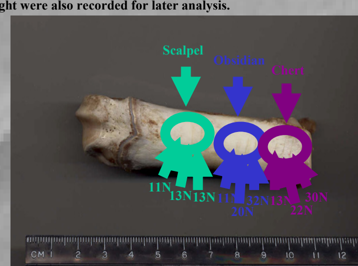

Figure 9: Porcine metatarsal after boiling to remove soft tissue. Cutmarks are circled based on cutting tool used to create the cutmark, and the force associated with each cutmark is indicated by the arrow.

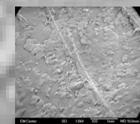

Figure 10: Cutmark from chert flake, force= 13N.

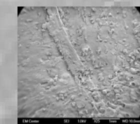

Figure 11: Cutmark from chert flake, force= 22N.

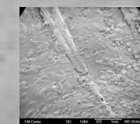

Figure 12: Cutmark from chert flake, force= 30N.

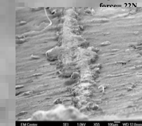

Figure 13: Cutmark from obsidian flake, force= 20N.

Figure 14: Cutmark from obsidian flake, force= 32N.

RESULTS AND DISCUSSION

The following results were obtained from comparing the minimum amount of force required to cut through muscle tissue in relation to the amount of force required to produce a visible cutmark on the bone:

Minimum Force to Cut Soft Tissue	Minimum Force to Form a Cutmark on Bone
• Scalpel = < 10 N	• Scalpel = < 11 N
• Obsidian = 10 N	• Obsidian = < 11 N
• Chert = 11-15 N	• Chert = < 13 N

SEM analysis determined the [...] e between 65-80 µm. This approximation was measured using the digital micron bar in the computer software, based on estimates of the tilted cutmarks. It was not possible to determine the exact depth of all cutmarks.

Maximum human force measurements were converted to Newtons by multiplying the kilogram quantity by 9.8 m/s^2, as this is the force due to gravity. These values were then plotted against the mass of the individual and Excel was used to calculate the means of each, as well as linear regression analysis (Figures 15, 18-23). Coefficient determinate factors and correlation coefficients are represented on the graphs.

Clearly this experiment has only laid the foundation for much future work to be conducted regarding the force measurements. Multiple experiments should be repeated using varying soft tissue types, such as muscle, tendons and ligaments, along with varying species of animals. Also, other stone tool raw materials should be used, such as basalt or other chert types. Furthermore, the sample size of individuals should be increased to reduce the variability in the maximum force measurements.

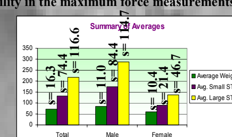

Figure 15: Graph of averages of individuals' weight in kilograms and maximum forces exerted with stone tools. STF= stone tool force. s= standard deviation of the mean associated with each average.

Figure 16: Stone tools used for maximum human force measurement. Top: large chert biface; Bottom: small obsidian flake.

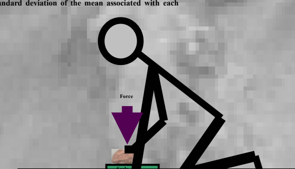

Figure 17: Diagram representing position that individuals were asked to kneel in for maximum human force measurement.

CONCLUSIONS

Based on the results of the cutting force measurements, cutmark depth analysis, and maximum human force measurements, the following conclusions can be made from this experiment:

➢ Chert requires *slightly* more force to cut through soft tissue than Obsidian (< 5 N)

➢ Minimum force required to cut through muscle tissue *under these experimental conditions* meets or exceeds minimum force required to produce a visible cutmark on bone for stone tools

➢ Force required to produce a visible cutmark on bone *may* not vary with stone tool raw material (< 11-13 N)

➢ Depth of cutmark in correlation with force *may not* follow a linear regression (~65-80µm for 20-32N)

➢ Maximum force of large or small stone tools exceeds minimum force to cut through muscle tissue and produce a visible cutmark on a bone by:

- ➢ **13 times** for small stone tools (total individual)
- ➢ **22 times** for large stone tools (total individual)

➢ 1.65 times more force can be exerted with large stone tools than small stone tools (total individual)

➢ Males generally exert greater forces with both large (110%) and small (96.8%) stone tools than females

➢ Females have a more positive correlation between body mass and maximum force exerted than males

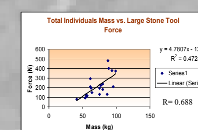

Figure 18: Graph of total group individuals' mass vs. large stone tool force.

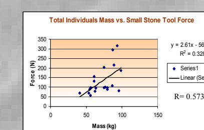

Figure 19: Graph of total group individuals' mass vs. small stone tool force.

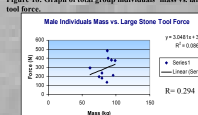

Figure 20: Graph of male individuals' mass vs. large stone tool force.

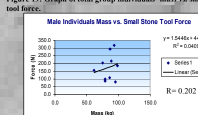

Figure 21: Graph of male individuals' mass vs. small stone tool force.

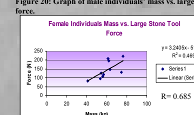

Figure 22: Graph of female individuals' mass vs. large stone tool force.

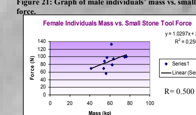

Figure 23: Graph of female individuals' mass vs. large stone tool force.

ACKNOWLEDGEMENTS

This experiment would not have been possible without the generous help of the following individuals and departments at Colorado State University: Dr. Donna Wheeler's Biomechanical Engineering Laboratory; Dr. John Chandler and the Electron Microscopy Center; the Department of Animal Science Meat Laboratory.

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