

## Experimental determinations of cutmark orientation and the reconstruction of prehistoric butchery behavior

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### **Abstract:**

The frequency, anatomical location, and orientation of stone tool cutmarks have all been widely employed in reconstructions of ancient butchery practices. Cutmark orientation in particular has great potential to inform on various aspects of past behavior, and here we provide experimentally derived orientations with novice butchers in two contexts. The first models the butchery of a carcass part by a single individual, and the second the butchery of a carcass part by several individuals simultaneously. Our goal is to test the following hypothesis: do butchers working alone produce less variation in cutmark orientation than several working at once? Preliminary data indicate that, at least with the novices involved in this experiment, variation in cutmark angles does not differ significantly between the two scenarios. Although further experimental work is warranted, we suggest that while the number of individuals may play some role in determining cutmark orientations, experience and skill are also important factors.

**Keywords:** Cutmarks | Butchery | Taphonomy | Zooarchaeology | Skill

### **Article:**

#### **1. Introduction**

Cutmarks, as one of the few taphonomic traces that unambiguously link humans to the modification of animal carcasses, can reveal a great deal about the diet and subsistence practices of past peoples, and the near universal incorporation of these data into zooarchaeological analyses reflects the general consensus on this point. Much less agreement exists, however, on exactly what behaviors cutmarks do (or do not) reflect. The discord stems largely from (1) the inherently epiphenomenal nature of most cutmarks (Lyman, 1987: 260–262), (2) the myriad factors, both systematic and stochastic, that condition where, when, and how often they are created (Domínguez-Rodrigo and Yravedra, 2009, Lupo and O'Connell, 2002, Lyman, 1987: 253), and (3) divergent or incompatible analytical protocols. We believe that an actualistic approach, in both naturalistic and experimental contexts (*sensu* Marean, 1995: 65–66), offers a constructive framework for segregating key variables and their effect on cutmarks. Indeed, a rich

literature of such work has emerged that either directly or indirectly addresses many of these factors (Bartram, 1993, Binford, 1981, Braun et al., 2008, Bromage and Boyde, 1984, Bunn, 1983, Bunn, 2001, Bunn and Kroll, 1988, Capaldo, 1997, Crader, 1983, Dewbury and Russel, 2007, Domínguez-Rodrigo, 1997, Domínguez-Rodrigo, 1999, Domínguez-Rodrigo and Barba, 2005, Domínguez-Rodrigo and Barba, 2007, Egeland, 2003, Gifford-Gonzalez, 1989, Greenfield, 1999, Greenfield, 2006, Lupo, 1994, Lupo and O'Connell, 2002, Merritt, 2012, Nilssen, 2000, Padilla Cano, 2008, Pickering and Hensley-Marschand, 2008, Pobiner and Braun, 2005, Potter, 2005, Selvaggio, 1994, Shipman and Rose, 1983, Walker and Long, 1977, Willis et al., 2008).

Here, we investigate one particular characteristic of cutmarks, that of orientation. In a strictly definitional sense, a parallel or subparallel orientation of striations relative to each other has been cited as an important, though not exclusive or necessarily unique, identifying characteristic of cutmarks (Blumenschine et al., 1996: 496; Fisher, 1995: 14). Archaeologists have long used orientation as one among many attributes in reconstructions of butchery behavior (Guilday et al., 1962). Noe-Nygaard (1989: 484), for example, argued that cutmarks oriented parallel to the long axis of bones were indicative of filleting, while Binford (1984: 110) suggested that orientations could change depending on whether a carcass was fresh or supple when butchered. Lyman (1987: 325) provided a reasonable basis for such interpretations by arguing that because mark orientation “is indicative of the direction of application relative to the alignment of the involved muscles and ligaments” variation could reflect “different purposes and desired results.” This assertion found support in Binford's (1981: 136–142) now classic ethnoarchaeological study, which showed that various butchery procedures could often result in distinctive cutmark orientations. Additional actualistic work that more closely monitored the relationship between specific activities and the cutmarks they produced, while demonstrating that Binford's (1981) guides were probably oversimplified,<sup>1</sup> nevertheless identified patterns in mark orientation (Costamagno and David, 2009, Nilssen, 2000). Along with anatomical location, such data continue to be used to associate particular cutmarks with skinning, dismembering, or filleting (e.g., Stewart, 2010).

From a slightly different perspective, Stiner et al. (2011) have noted that among modern humans, the butchery of carcasses for distribution is typically performed by one or just a few individuals, a process that often results in cutmarks that are well-aligned relative to each other. This is a potentially important observation given that the procedure of butchery (as reflected by the cutmarks) guides how meat is distributed and/or shared. Interestingly, an analysis of faunal remains from the late Lower Paleolithic levels at Qesem Cave (modern Israel) revealed that the site's cutmarks tend to be oriented in a more “chaotic” fashion than those from later (Middle and Upper Paleolithic) time periods (Stiner et al., 2009, Stiner et al., 2011). A provocative interpretation of this finding is offered (Stiner et al., 2011: 230):

“Hypothetically, we may be seeing evidence of a simpler or less evolutionarily derived pattern of meat consumption that was social but less canalized than those typical of ... later humans. The evidence ... at Qesem Cave might reflect, for example, more hands (including less experienced hands) removing meat from any given limb bone, rather than receiving shares through the butchering work of one skilled person. Several individuals may have cut pieces of meat from a bone for themselves, or the same individual may

have returned to the food item many times. Either way, the feeding pattern from shared resources appears to have been more individualized than is typical of later cultures, with limited or no formal ‘apportioning’ of meat.”

This is an extremely intriguing scenario and highlights the great potential that cutmark orientation has for uncovering aspects of prehistoric behavior that may otherwise remain obscure. While our goal here is not to evaluate all aspects of this multifaceted model, it does serve as a convenient point of departure for isolating a few specific variables. So, with this in mind, we present experimental data that document cutmark orientations in two contexts, the first in which a single individual butchers a carcass part, and the second in which several individuals are involved simultaneously in the butchery of a carcass part. In doing so, we aim to test, at least preliminarily, the following hypothesis: do butchers working alone produce less variation in cutmark orientation than several butchers working at once?

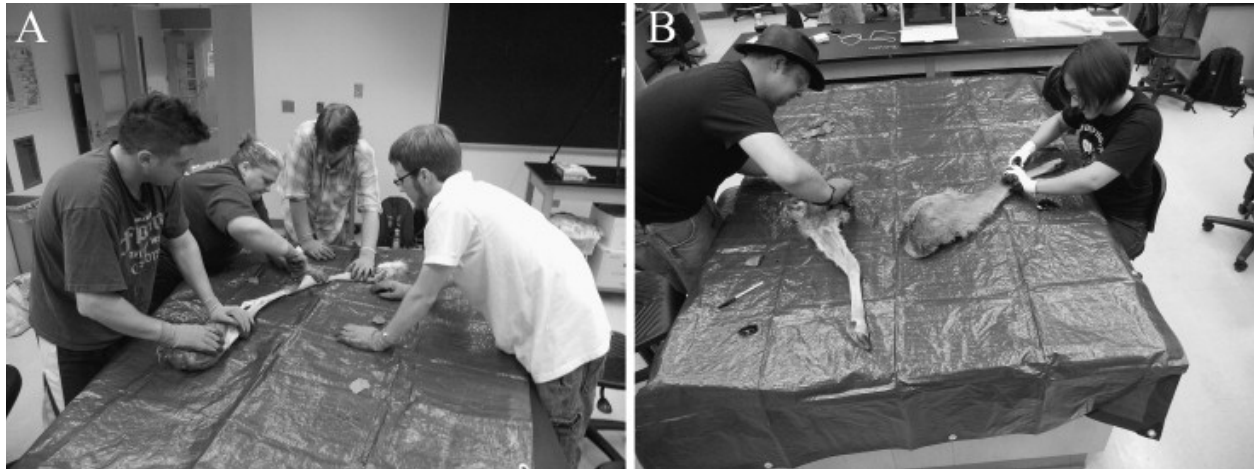
## 2. Materials and methods

A total of five controlled butchery events were conducted, and all involved the processing of complete fore- or hindlimb units from white-tailed deer (*Odocoileus virginianus*), a Size Class 2 animal in Brain's (1974) well-known scheme. The limbs were disarticulated from the thorax beforehand, stored in a freezer with all skin and flesh intact, and then set out to thaw 24 h before the experiments. The butchers were undergraduates with two months of zooarchaeology coursework and no prior experience with animal butchery.

Two experimental scenarios were modeled (Table 1), and all events were video recorded. The first involved an individual working alone to butcher a single limb (two events; Fig. 1), while the second involved a group of four individuals working simultaneously to butcher a single limb (three events; Fig. 1). Apart from a request that they remove as much flesh as possible, a process that necessitated the skinning of at least the upper (humerus and femur) and intermediate (radius-ulna and tibia) limb bones, the participants were given no instructions on how to butcher or when to stop. Some participants ceased butchering once all the major muscle masses had been removed while others continued to fully disarticulate the limbs and even remove tendons. The groups of four were given complete freedom to pursue any strategy they deemed appropriate; no specific direction regarding how, or whether, to divide labor was given at any time. Each individual or group was provided with a collection of unmodified stone flakes that could be discarded, replaced, and/or reused at any time. The long bones from one of the two single butcher events and one of the three multiple butcher events were broken by the participants with an anvil and hammerstone to create fragments that would more realistically mimic those found in an archaeological context. All bones and bone fragments were then collected and bagged by event and cleaned of residual soft tissue following the protocol of Mairs et al. (2004).

**Table 1.** Summary of experimental butchery events.

Event#	Limb unit	Number of butchers	Broken for marrow?
1	Hindlimb	4	No
2	Hindlimb	4	No
3	Hindlimb	4	Yes
4	Forelimb	1	No
5	Forelimb	1	Yes

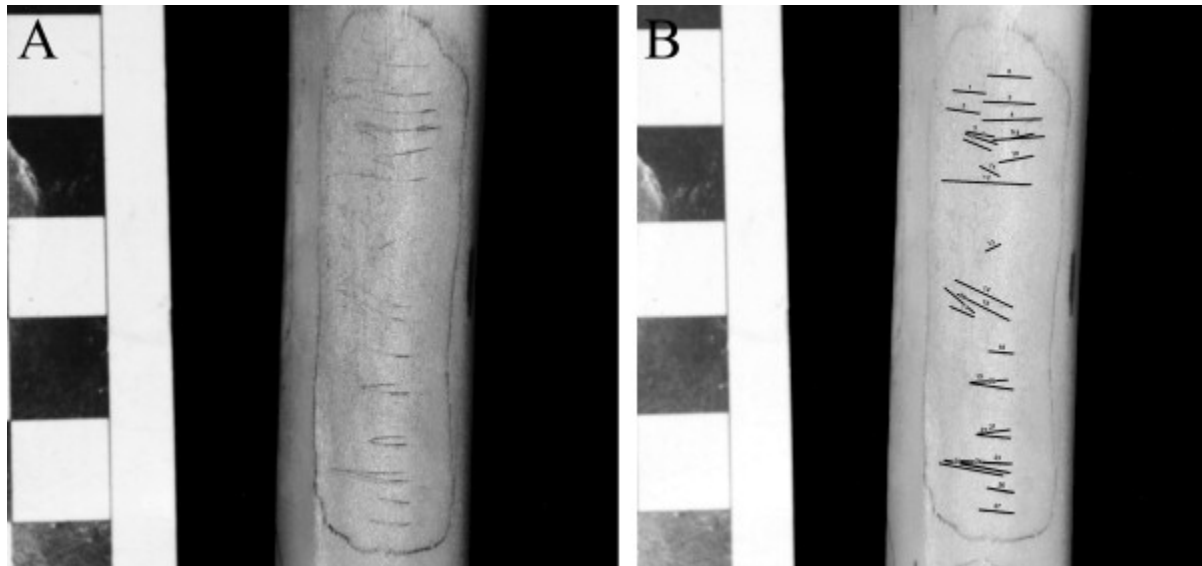


**Fig. 1.** Photographs showing setup for (A) multiple butcher and (B) single butcher experiments.

Surface marks were identified with hand lenses (10 $\times$ ) and, in some cases, with a binocular microscope (10–40 $\times$ ). Three different types of modification were identified. The first were classic linear slicing cutmarks that possessed deep, V-shaped cross sections. Scrape marks were also present and manifest as clusters of deep, closely spaced parallel striations, many with a “shaved” surface contour that covered relatively expansive portions of cortical surface (see also Blumenshine and Selvaggio, 1988: 765). Real-time observations of the butchery events and review of the video recordings revealed that these marks were created when participants either removed periosteum or scoured bits of flesh from bone diaphyses. The final type of modification was percussion marks, which appeared either as pits with emanating microstriae or isolated patches of subparallel, superficial scratches. Only the slicing cutmarks were considered in this analysis and, in most cases, these could be distinguished morphologically from scrape and percussion marks. Ambiguous marks that could not be confidently identified, either with knowledge of the location of anvil and hammerstone placement, which was carefully recorded for those bones that were fractured, or by referencing the video recordings, were eliminated from the analysis.

Cutmark-bearing bone surfaces were stained with pencil lead and then photographed with a mounted Canon EOS Rebel digital camera. Several photos of each modified surface were taken under various lighting angles to produce images that allowed individual marks to be readily discerned. A single image was sufficient to capture the cutmarks on smaller hammerstone created fragments that preserved less than half the original diaphyseal circumference. For larger fragments and complete bones, separate images of each aspect (i.e., cranial, caudal, medial, lateral) or sections of each aspect (e.g., the proximal half of the cranial surface) were required to document all the marks with sufficient resolution and contrast (Fig. 2). This is important because while cutmarks and their associated angle differences were, by definition, calculated in reference to a constant axis if they appeared on the same image, this was not necessarily so for those cutmarks that appeared on the same specimen but different images. Great care was therefore taken to consistently orient those specimens that required multiple photographs to ensure that the resulting angles were recorded relative to the same axis. Complete bones and epiphyseal ends with attached portions of shaft were oriented anatomically in each image with the proximal end

up (see Fig. 2) and smaller fragments with cutmarks on a single face were oriented with the natural long axis vertical.



**Fig. 2.** Cranial aspect of experimentally butchered tibia showing (A) raw image of cutmarks and (B) traced cutmarks for orientation measurements.

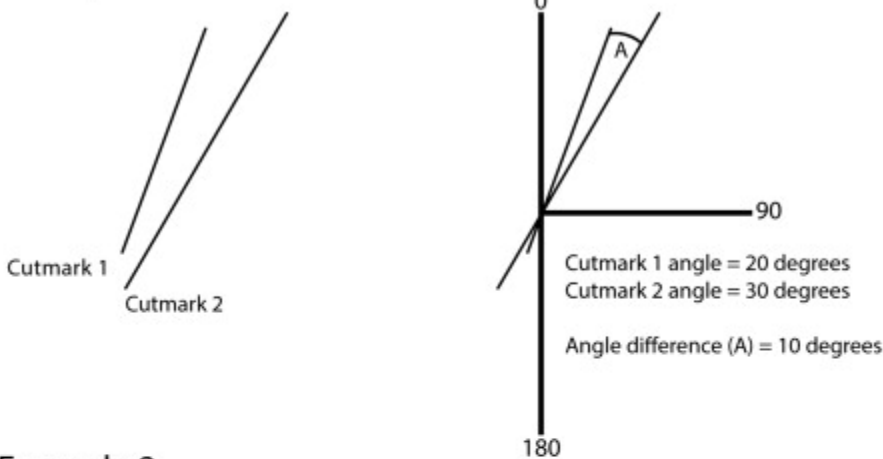
The photos were saved as high resolution JPEG files and opened in Adobe Photoshop. Each physical specimen and its corresponding photo were scanned visually side-by-side to make certain that all cutmarks were visible and, when necessary, the photo's contrast was adjusted to better highlight individual marks. The program's straight line tool was then used to trace each cutmark, a process carried out independently by two observers (CPE and KRW). The “beginning” and “end” of those marks that exhibited some curvature were connected by and treated as straight lines. The only cutmarks that were not traced were those located on the proximal or distal faces of the epiphyses (i.e., those that could not be captured with lenses oriented perpendicular to the cortical surface). CPE and KRW subsequently compared their tracings, and only those cutmarks on which both analysts agreed were included in the study's analytical sample.

The oriented and traced files were imported into an ERSI ArcMap 10.2 project for angle measurement. A short-integer “azimuth” field was created, and each cutmark from an image was assigned a unique number and retraced from left to right with the polyline feature (see Fig. 2). Orientations were determined on a 0–180° plane with the ArcGIS add-in EasyCalculate ([http://www.ian-ko.com/free/free\\_arcgis.htm](http://www.ian-ko.com/free/free_arcgis.htm)). The database file (.dbf) of orientations from each image was finally exported into a spreadsheet file (.xlsx) for manipulation.

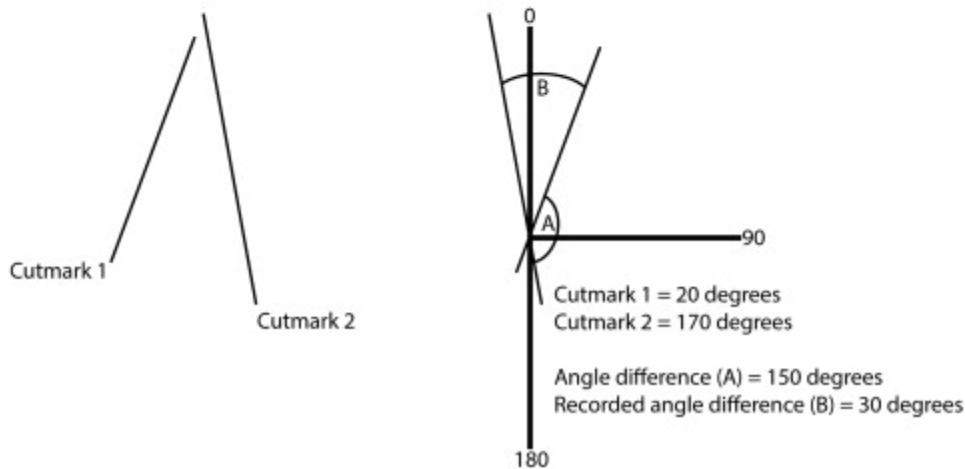
Fig. 3 shows how cutmark orientations and angle differences were derived. Variation in cutmark orientation was estimated in two ways. The first followed that of Stiner et al., 2009, Stiner et al., 2011 and was based on angle differences between adjacent cutmarks. In this case, differences were calculated between each mark and its nearest neighbor as one moved from top to bottom along each specimen. We use Stiner et al.'s (2009: 13210) Mean Difference of Adjacent Angles (MDAA) term to refer to this measure. As an alternative technique, we also computed the

difference between every possible two-way combination of cutmarks. Thus, the differences were calculated between cutmark 1 and cutmark 2, cutmark 1 and cutmark 3, cutmark 1 and cutmark 4, and so on, after which those between cutmark 2 and cutmark 3 (the difference between cutmark 1 and cutmark 2 having already been acquired in the previous step), cutmark 2 and cutmark 4, and so on, were calculated. As an example, this procedure for the complete femur from Event 1, which preserved 165 cutmarks, resulted in a total of 13,366 pair-wise orientation differences. This method, which we felt may provide a more accurate and comprehensive estimate of variation, is referred to as Overall Mean Difference (OMD).

### Example 1



### Example 2



**Fig. 3.** Schematic representation of how cutmark angles were measured.

The unit of analysis for OMD was a complete bone or, for hammerstone-broken bones, individual cutmarked fragments. While MDAA was also calculated by fragment when possible, the difficulties of determining adjacency on specimens with multiple surfaces that could not be captured on a single photo required that it be computed by aspect for complete bones and hammerstone generated fragments with the entire diaphyseal circumference preserved. So, for example, the cutmarks and their attendant orientation differences on the cranial, caudal, medial, and lateral aspects of a complete humerus, or humerus fragment preserving the distal epiphysis

and a length of attached shaft, were treated as separate units of analysis (that is, like individual fragments). For those cutmarks that appeared on more than one surface, the aspect on which a majority of the mark appeared was recorded.

The resultant datasets displayed a variety of statistical distributions that, in some cases, violated assumptions of normality and homogeneity of variance. Rather than perform assorted transformations on some datasets and not others, we used the raw data throughout and present statistical tests in both their parametric and non-parametric forms. Independent sample *t*-tests (which assume normally distributed data), Mann–Whitney *U*-tests (which assume homogeneity of variance), and Mood's median tests (which assume neither normality nor homogeneity of variance) were all used to explore differences in central tendency, for instance. If divergent results were produced, we relied on the most appropriate test given the nature of the dataset under discussion. All statistical analyses were carried out with SPSS. Given the possible effects of surface area on cutmark frequencies and orientations, specimen size was estimated with length \* breadth calculations. These values were multiplied by four for complete bones and fragments preserving complete diaphyseal circumferences.

### 3. Results

Novice butchers produced anywhere from zero to nearly two hundred individual slicing cutmarks on the six major long bones from the various limb units (Table 2). Table 3, Table 4 provide summary statistics for OMD and MDAA, respectively. Among the complete bones (Table 5), OMD is significantly higher for the multiple butcher events (Events 1 and 2) than the single butcher event (Event 4). The same pattern holds for the hammerstone-broken multiple butcher event (Event 3) relative to the hammerstone-broken single butcher event (Event 5). The low estimates of effect size for the *t*-test (Cohen's *D*) and Mood's median test (Phi) suggest that, while multiple butchers tend to create higher OMD values than single butchers, the magnitude of that difference is very slight and likely driven by the extremely large sample sizes. There is also a significant positive relationship between OMD and both the number of angle differences ( $r = 0.378, p = 0.075; r_s = 0.549, p = 0.007$ ; the non-parametric rank test is probably the better predictor here because of data non-normality) and surface area ( $r = 0.459, p = 0.027; r_s = 0.516, p = 0.012$ ), which indicates that greater numbers of cutmarks and higher surface areas increase the chances of sampling more marks with divergent orientations. The number of angle differences and surface area do not differ significantly between the single and multiple butcher events, however (Table 6), so while these variables affect OMD values across all experiments, they cannot account for the differences documented between single and multiple butchers.

When pooling angle differences by Event, in only one instance do MDAA values on complete bones differ significantly between the single and multiple butcher scenarios (Table 7; the Mann–Whitney test should be given priority given the datasets' violations of normality but not homogeneity of variance). In this case, however, it is the single butcher event (Event 4), not the multiple butcher event (Event 2), that shows higher MDAA values. Another way to examine the MDAA data is to use the means from each fragment (or aspect), pool them by scenario, and compare the distributions of means. We do so in Table 8, and Fig. 4 shows these data graphically. Although the multiple butcher scenarios produce higher MDAA values, this difference is not statistically significant. There is a weak, yet statistically significant, positive

relationship between the number of angle differences and MDAA ( $r = 0.136, p = 0.335$ ;  $r_s = 0.278, p = 0.046$ ), and no relationship exists between surface area and MDAA ( $r = 0.278, p = 0.046$ ;  $r_s = 0.230, p = 0.101$ ). (The non-parametric rank tests should be given more weight in this situation because of data non-normality). Thus, while sample size may explain a small proportion of MDAA variation, surface area does not appear to be a significant factor.

**Table 2.** Cutmark frequencies for experimental events.

Event	Element	Cutmarks
1	Femur	164
	Tibia	157
	Metatarsal	171
2	Femur	58
	Tibia	147
	Metatarsal	2
3	Humerus	61
	Radius	87
	Metacarpal	7
4	Humerus	188
	Radius	68
	Metacarpal	27
5	Humerus	155
	Radius	121
	Metacarpal	0

**Table 3.** Summary statistics for Overall Mean Difference (OMD) values.

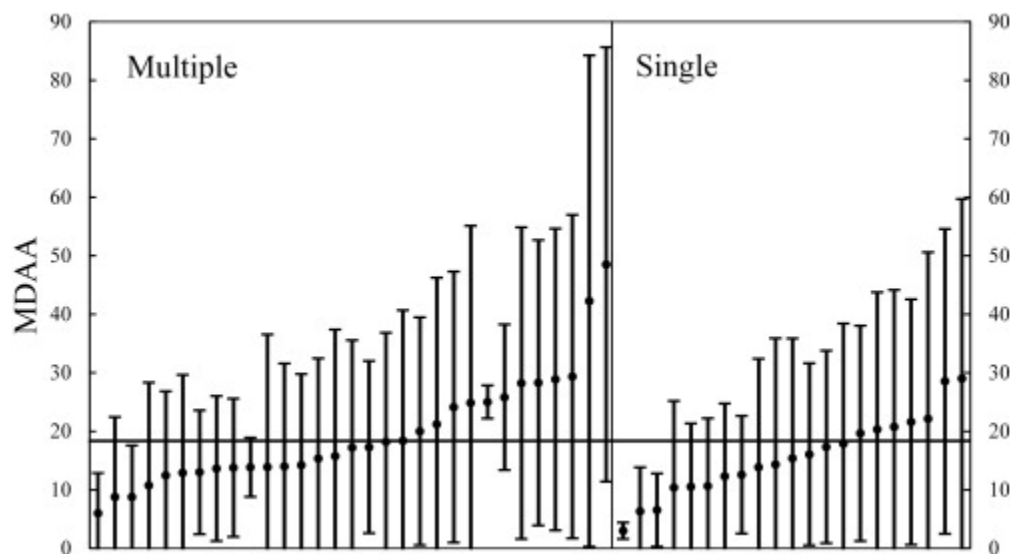
Event	Broken?	Element	N	Mean	Median	S.D.
<b>Multiple butchers</b>						
1	No	Femur	13,366	40.75	39	36.43
		Tibia	12,246	43.72	44	26.57
		Metatarsal	14,535	33.76	29	24.34
		Total	40,147	39.12	36	26.08
2	No	Femur	1653	42.06	40	30.43
		Tibia	10,731	39.86	37	25.76
		Metatarsal	1	2	2	–
3	Yes	Total	12,385	40.15	37	26.44
		Humerus	1159	28.05	25	20.78
		Radius	1840	39.33	36	27.01
		Metacarpal	11	20.45	31	16.16
4	No	Total	3010	34.92	30	25.37
		Humerus	17,578	38.49	35	25.55
		Radius	2278	39.69	37	25.27
		Metacarpal	378	21.06	19	15.11
5	Yes	Total	20,234	38.30	35	25.47
		Humerus	2889	34.80	25	29.43
		Radius	5952	27.06	22	21.21
		Total	8841	29.59	22	24.48
<b>All events</b>						
		Total	84,617	37.93	34	25.97



**Table 4.** Summary statistics for Mean Difference of Adjacent Angle (MDAA) values.

Event	Broken?	Element	N	Mean	Median	S.D.	
<b>Multiple butchers</b>							
1	No	Femur					
		Cranial	46	18.8	11	18.64	
		Caudal	29	29.34	22	27.64	
		Medial	37	28.86	20	25.79	
		Lateral	48	15.33	10	17.12	
		Tibia					
		Cranial	36	28.28	23.5	24.39	
		Caudal	9	13.89	4	22.66	
		Medial	34	17.29	15	14.71	
		Lateral	72	18.39	7	22.30	
		Metatarsal					
		Caudal	15	24.13	12	23.16	
		Medial	75	14.21	9	15.58	
		Lateral	81	28.22	19	26.63	
Event total		482	21.35	12	22.41		
2	No	Femur					
		Medial	41	24.85	6	30.26	
		Lateral	12	48.5	54.5	37.12	
		Tibia					
		Cranial	43	13.63	10	12.39	
		Caudal	36	13.78	9.5	11.80	
		Medial	4	8.75	3	13.68	
		Lateral	63	15.76	8	21.64	
		Event total		199	18.65	9	23.34
		3	Yes	Humerus			
Fragment 1	12			8.75	7	8.81	
Fragment 2, Cranial	9			12.89	5	16.74	
Fragment 2, Caudal	5			6.00	3	6.86	
Fragment 2, Medial	24			14.00	10	17.57	
Fragment 2, Lateral	4			42.25	42.5	41.98	
Radius							
Fragment 3, Cranial	13			13.00	10	10.58	
Fragment 3, Medial	5			21.20	11	25.02	
Fragment 3, Lateral	6			13.83	15	5.04	
Fragment 4	1			9.00	9	–	
Fragment 5	2			25.00	25	2.83	
Fragment 6, Cranial	16			12.44	5.5	14.39	
Fragment 6, Caudal	10			17.20	11.5	18.35	
Fragment 6, Lateral	10			25.80	27	12.45	
Metacarpal							
Fragment 7	4			10.75	3	17.58	
Fragment 8	1	7.00	7	–			
Event total		137	15.71	10	17.01		
<b>Single butcher</b>							
4	No	Humerus					
		Caudal	34	20.74	10.5	23.40	
		Medial	66	28.52	17	26.04	
		Lateral	83	21.58	14	20.96	
		Radius					
		Cranial	24	15.38	7.5	20.45	
		Medial	2	3.00	3	1.41	
Lateral	39	16.05	12	15.55			

Event	Broken?	Element	N	Mean	Median	S.D.
5	Yes	Metacarpal				
		Medial	26	10.62	5	11.58
		Event total	274	20.64	12	21.76
		Humerus				
		Fragment 9	30	22.13	6.5	28.44
		Fragment 10	1	5	5	–
		Fragment 11	8	29.00	17	30.69
		Fragment 12	8	10.38	4.5	14.78
		Fragment 13	10	17.30	12.5	16.45
		Fragment 14, Cranial	3	6.33	2	7.51
		Fragment 14, Medial	27	14.33	5	21.55
		Fragment 14, Lateral	9	12.56	8	10.06
		Fragment 15, Cranial	10	20.3	13.5	23.44
		Fragment 15, Caudal	29	6.55	5	6.25
		Fragment 15, Medial	17	17.88	11	20.51
		Radius				
		Fragment 16, Cranial	46	13.85	7	18.52
		Fragment 16, Medial	4	10.5	7.5	10.85
		Fragment 16, Lateral	56	12.29	7.5	12.44
		Fragment 17	11	19.64	9	18.41
Event total	269	14.71	7	18.77		
<b>All events</b>		Total	1361	18.93	10	21.39



**Fig. 4.** Means (points) and standard deviations (lines) of MDAA values from the experimental sample arranged in order of increasing mean value. Each data point represents a single bone fragment (for marrow-broken experiments) or aspect of a complete bone or fragment with the entire diaphyseal circumference preserved. Solid horizontal line represents the overall mean from all data points (= 17.95).



**Table 8.** Pair-wise statistical analyses (independent sample *t*-test, Mann–Whitney *U*, Mood's median) for mean MDAA values between multiple and single butcher scenarios.

<i>N</i>	Means	<i>t</i> -test	df	<i>p</i> -value	Cohen's <i>D</i>	Medians	Mann–Whitney <i>U</i>	<i>p</i> -value	Chi-square	df	<i>p</i> -value	Phi
31, 21	19.52, 15.66	-1.607	50	0.114	-0.455	17.2, 15.4	262	0.236	0.080	1	1.000	0.039

**Table 9.** Pair-wise statistical analyses (independent sample *t*-test, Mann–Whitney *U*, Mood's median) between OMD and MDAA values.

<i>N</i>	Means	<i>t</i> -test	df	<i>p</i> -value	Cohen's <i>D</i>	Medians	Mann–Whitney <i>U</i>	<i>p</i> -value	Chi-square	df	<i>p</i> -value	Phi
1361, 1361	37.60, 18.93	20.514	2626.59	0.000	0.786	34, 10	499,756.5	0.000	341.682	1	0.000	0.354

A glance at the two estimates of angle variation shows that OMD produces higher average angle differences (Table 3, Table 4). For a statistical comparison, and to manage the enormous discrepancy in sample sizes for the two measures, a random subsample of values from the OMD dataset equivalent in size of that of MDAA ( $n = 1361$ ) was drawn.<sup>2</sup> The resulting pair-wise comparisons show that OMD does in fact document significantly more variation in angle orientation than MDAA (Table 9).

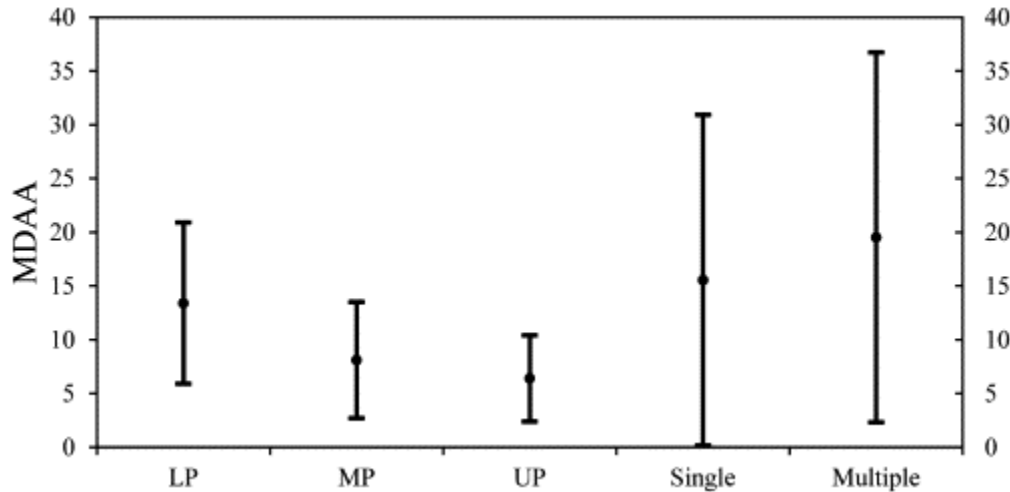
#### 4. Discussion and conclusions

Based on two measures of angle differences derived from undergraduate novices, there is little support for the contention that multiple butchers produce more variation in cutmark orientation than do single butchers. While statistically significant differences were in fact identified among the OMD values, their magnitude (as estimated by effect size) was so minuscule as to be essentially meaningless. In addition, OMD appears susceptible to the effects of both sample size (that is, the number of angle differences) and surface area. Pair-wise tests of MDAA failed to detect a significant difference between the single butcher and multiple butcher scenarios, and sample size and surface area had little or no effect on these values. We suggested above that OMD, because it compares each angle with all the other angles on a single specimen, may give a more complete picture of variation. However, this potential advantage is offset by extremely small effect sizes (which render statistically significant results of little value) and the measure's evident sensitivity to other confounding variables such as surface area. In terms of reliability, then, MDAA is probably the more preferable of the two measures.

Further experimentation, particularly with larger samples and different carcass sizes, tool types, and group composition, is certainly warranted. It is also worthwhile to explore how (or if) the surface morphology of individual bones impacts mark orientation. We should point out, too, that our results do not necessarily invalidate the reconstruction offered for Qesem Cave's Lower Paleolithic occupants. We suspect, for instance, as did Stiner et al. in the quote from the introduction (see also 2009: 13211), that skill and experience play a key role in this context. While researchers have commented on the importance of these factors in determining the production and location of butchery marks (Domínguez-Rodrigo, 1997: 674; Fisher, 1995: 55; Guilday et al., 1962: 64; Haynes and Krasinski, 2010: 185–186; Willis et al., 2008: 1440), their effect on mark orientation has received much less attention. It seems that novice butchers, whether working alone or in groups, produce great (see below) yet comparable variation in cutmark angles. The video recordings reveal that individuals altered their posture and the orientation of the limb, often after a few seconds of thought, presumably in order to better access joints, muscle insertions, and fascia. Perhaps the frequency and magnitude of these adjustments decrease as an individual gains experience. Orientation may thus provide an alternative measure of butcher skill or, perhaps, help determine if group-level variation in carcass handling can be identified. Studies of ethnoarchaeological collections processed by knowledgeable butchers under various circumstances may be especially valuable (for example, the collections from Abe, 2005, Bartram, 1993, Binford, 1978).

As an initial effort in this direction, we compare our experiments to archaeological MDAA data provided by Stiner et al. (2009: Table 5) for three Paleolithic cave faunas: Qesem Cave, mentioned above, and Üçağızlı Caves I (Upper Paleolithic) and II (Middle Paleolithic), both in

modern Turkey. The experimental scenarios exhibit much greater variability in cutmark orientation (Fig. 5), and independent sample *t*-tests confirm that the MDAA values for the pooled single and multiple butcher scenarios are significantly higher than any of the three Paleolithic assemblages (Table 10). If additional work demonstrates that cutmark angles reflect skill or experience to some extent, it might then be reasonably argued that these Paleolithic butchers were more experienced than our novices (a not unsurprising conclusion). For the time being this must remain speculative: ultimately, only further work among and between butchers of various skill levels will resolve this. We nevertheless remain optimistic that detailed analysis of butchery marks, and orientation in particular, will continue to reveal a great deal about past behaviors.



**Fig. 5.** Means (points) and standard deviations (lines) of MDAA values from the experimental sample and three Paleolithic samples. For the archaeological samples, each data point represents the mean of MDAA values from several fragments; for the experimental samples, each data point represents the mean of MDAA values from single bone fragments (for marrow-broken experiments) or aspects of a complete bone or fragment with the entire diaphyseal circumference preserved. Abbreviations: LP = Lower Paleolithic; MP = Middle Paleolithic; UP = Upper Paleolithic; Single = single butcher experiment; Multiple = multiple butcher experiment.

**Table 10.** Pair-wise statistical analyses (independent sample *t*-test) for mean MDAA values between experimental and archaeological data.

Pairing	<i>N</i>	Means	<i>t</i> -test	df	<i>p</i> -value	Cohen's <i>D</i>
Experimental, Lower Paleolithic	52, 38	17.96, 13.4	2.616	88	0.011	0.588
Experimental, Middle Paleolithic	52, 78	17.96, 8.1	8.02	128	0.000	1.436
Experimental, Upper Paleolithic	52, 16	17.96, 6.4	5.18	66	0.000	1.479

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