Making a point: wood- *versus* stone-tipped projectiles

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What are the advantages of equipping a wooden arrow with stone, rather than just using the sharpened wooden tip? Very few it seems. In a series of well-controlled experiments the authors show that stone arrow-heads achieve barely 10 per cent extra penetration over wood. They then raise some pertinent ideas about the other advantages, social and symbolic that may have driven hunters the world over to adopt the stone tip.

Keywords: prehistory, hunting, projectiles, experimental archaeology

Introduction

Wendell Oswalt's classic cross-cultural analysis of forager technology *Habitat and technology: the evolution of hunting* begins with the following dedication: '*To the maker of man* – THE STICK' (1973). Recognising the importance of simple implements to the human technological repertoire, Oswalt suggests that that the pointed wooden *'missile stick'* (1973: 176) provided the foundation for further elaboration into multi-component (i.e. tipped) hunting weapons. Modified wooden staves from Lehringen (Movius 1950; Thieme 1997), Clacton-on-Sea (Oakley *et al.* 1977) and Schöningen 13 (Thieme 1999) date from ∼500 000-125 000 BP and are interpreted to have been used as thrusting spears. These wooden implements, and their association with large-bodied faunal remains, provide some evidence that the simple modified 'stick' was utilised early in human prehistory as a hunting implement. While alternative functional explanations are also plausible (e.g. Gamble 1986), it has been argued, based on lithic point performance and dimensional analysis (Shea *et al.* 2001; Shea 2006), that hafted projectiles were not in use until *c*. 40 000 BP. Analyses of wear and breakage patterns resulting from hafting and use have identified the use of stone-tipped spears from the Levantine Mousterian (Shea 1988; Boëda *et al.* 1999), Crimean Middle Paleolithic (Hardy *et al.* 2001) and from the Middle Stone Age of South Africa (Donahue *et al.* 2002). Further, upper limb asymmetry in Neandertal and Early Modern Humans suggest that thrusting spears, as opposed to propelled weapons (Schmitt *et al.* 2003), were predominately in use throughout the Middle and Upper Palaeolithic of Europe. These studies document a shift from simple thrusting spears to multi-component propelled weaponry. However, two distinct issues are relevant to this technological change: the shift

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from thrusting to propelled weapons (either by hand or with the aid of spear-throwers), and the shift from modified wooden staves to hafted points of stone, bone and ivory. The latter issue is our primary concern.

The near global ubiquity of stone projectile points in the archaeological record indicates that once developed/adopted, the technology endured. Few artefacts have the unique distributive characteristics of simultaneously being both relatively common in the record, yet spatio-temporally distinct in morphology, particularly in the Americas. These features, of being both familiar and diverse, have provided the ideal medium for utilising artefacts as chronological and geographic indicators. While these features may seem obvious, the arguably obsessive attention stone projectile points have received has not elucidated the reasons for their use. Numerous 'common knowledge' explanations appear to be generally accepted regarding the superiority of stone, and to a lesser extent, osseous point tips relative to sharpened staves (e.g. Guthrie 1983; Arndt & Newcomer 1986). Assumptions concerning performance (e.g. durability of the tip), lethality (e.g. length of cutting edge, depth of penetration) and aerodynamics (e.g. weight distribution, flight paths) abound. Unfortunately, few of these assumptions have been verified experimentally.

While stone has potential functional benefits, it also has costs. Experiments designed to test various functional (Bergman & Newcomer 1983; Shea 1993), manufacturing (Odell & Cowan 1986; Broglio *et al.* 1993) and morphological characteristics (Flenniken 1985; Titmus & Woods 1986; Shea *et al.* 2001; Cheshier & Kelly 2006) of stone projectile points converge upon one common conclusion; stone points break in use and break frequently. While damage type and frequency are variable between studies, it appears consistent that few stone projectile points remain in useable condition after multiple uses (Shea 1993). For example, Odell & Cowan (1986: 207) found that in a sample of 20 bifacially worked spearheads, they could be used on average three times before suffering catastrophic breakage, and averaged only 2.05 shots for bifacial arrowheads. In a sample of replicated Levallois points 59 per cent exhibited damage after simulated use as a thrusting spear with 20 per cent irrevocably broken after a single use (Shea *et al.* 2001: 811). Of 50 projectile points Cheshier & Kelly (2006: 357) fired at a deer carcass, 42 per cent broke during their first use.

Reworking/resharpening of broken edges can be accomplished with minimal effort but catastrophic breaks and point loss can be costly. While none of this is surprising, it *is* rather astonishing that so little archaeological attention has been paid to identifying the benefits of hafted stone points over sharpened wood tips considering how frequently stone projectiles break during use. While woodworking also requires time and effort, the additional costs associated with lithic raw material procurement, knapping, hafting and maintenance of stone points are costs that are presumably offset by functional or other benefits. But what are these benefits – exactly?

The ethnographic record of wooden projectile points

Pointed wooden spears (Oakley *et al.* 1977) and arrows (Mason 1893; Ellis 1997) are well documented ethnographically. Their use by foraging populations from throughout the world suggests that common knowledge explanations of projectile point superiority over wooden tips cannot be assumed in all hunting contexts. In fact the abundance of wood only hunting implements in the ethnographic record suggests that their prehistoric paucity is largely a function of preservation as opposed to technological and/or economic reasons.

Apache (New Mexico)
'More commonly, however, no flint is used; the wooden tip of the arrow is simply sharpened and fire hardened' (Opler 1996: 389).

Yuma (Arizona)
'Other arrows lacked stone points, the end merely sharpened and hardened in some fashion . . . ' (Spier 1978: 134).

Winnebago (Wisconsin)
'There were five types of arrows . . . The first two and the last were made entirely of wood, generally hickory, the last being merely a pointed stick' (Radin 1990: 62).

Siriono (Bolivia)
'Although arrows, like bows, vary in size, only two general types are made: one, called úba, with a chonta head containing a lashed barb; the other called tákwa, with a lanceolate bamboo head but no barbs . . . the bamboo-headed arrow is reserved for killing the larger game on the ground' (Holmberg 1969: 30).

Cahuilla (California)
'Arrows were made of cane, sagebrush, and arrowweed, and tipped with stone or wooden points of various sizes and shapes . . . ' (Bean 1972: 65).

Mbuti (Democratic Republic of the Congo)
'It has been argued that the Mbuti hunt is dependent upon metal arrow-points, spear blades, and knife blades. It is not. We shall see that the Mbuti frequently prefer to use the poisoned arrows that have only a fire-hardened tip . . . Old Mbuti assert that fire-hardened spears are effective even against the largest game.' (Turnbull 1965: 36).

Ute (Utah & Colorado)
'. . . spears were made of wood, with a greasewood point 6 to 8 inches long . . . Bird arrows were made with a sharpened end and ordinarily no point . . . ' (Smith 1974: 110-11).

Andaman Islanders (Andaman Islands)
'A simple form of arrow is made in both the Great Andaman and the Little Andaman consisting of a bamboo shaft with a pointed wooden head, the point being hardened in the fire' (Radcliffe-Brown 1964: 436).

Yuquí (Bolivia)
'The Yuquí bow and upper shaft of the arrows are made from black palm . . . an extremely hard, dense wood that also has great tensile strength, making it ideal not only for the arrow shaft and point, but also for the bow . . . ' (Stearman 1989: 42).

We performed a brief survey of the ethnographic record to examine the relative frequency of the use of wood *versus* other materials in the manufacture of projectile points. Our sample includes 59 groups, primarily hunter-gatherers, from Africa, Australia, Asia and the

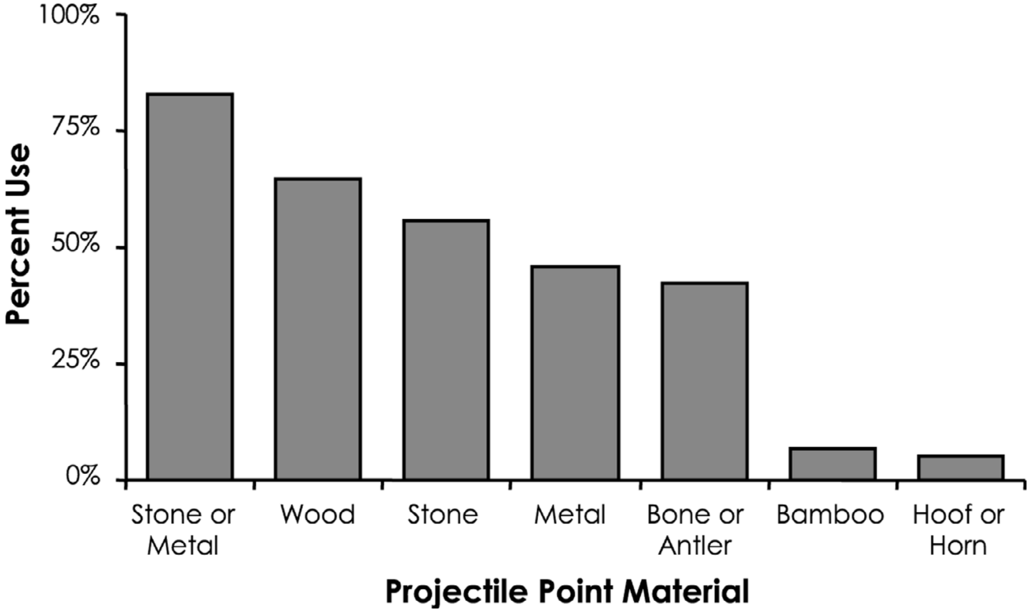

Figure 1. Percentage of hunting and gathering societies (n = 59) using projectile points of various raw materials.

Americas. For each group, we recorded the presence or absence of the use of metal, stone, wood, bone/antler, bamboo and hoof/horn in the manufacture of projectile points. We only included weapons used in hunting or warfare and excluded toys and items used exclusively in ritual. A summary of these data is presented in Table 1 and Figure 1.

Briefly, wood is the single most frequently used material for the manufacture of projectile points, having been used by 64.4 per cent of the groups in our sample. Stone and metal projectile points are also very common and were used by 55.9 per cent and 45.8 per cent of hunters in our sample, respectively (Figure 1). Because metal projectile points replaced stone in many parts of the world, it seemed prudent to examine the relative frequency of the use of stone and/or metal. When these two raw materials are combined, they are present in 83 per cent of the groups in our sample. Therefore, projectiles tipped with stone or metal are slightly more common than those of wood ethnographically. Osseous materials (e.g. bone and antler) are also fairly common, occurring in 42.37 per cent of groups, while bamboo and keratinous materials (hoof/horn) were relatively rare, having been used by only 6.7 per cent and 5.1 per cent of groups in our sample, respectively. The simple finding that wooden projectile tips are used by approximately two-thirds of subsistence hunters would suggest that wood makes a perfectly effective weapon.

It should be noted that there are numerous examples of hunter-gatherers who prefer the use of metal- or stone-tipped weapons for the hunting of large game, and reserve wood-tipped weapons for small mammals and birds, particularly in North America and Africa (Ellis 1997). Although this could suggest that the benefits of stone arrowheads only outweigh their extra costs when used in the acquisition of large prey, there are numerous hunter-gatherers, such as the Mohave (Stewart 1947: 263-4), Mardudjara (Tonkinson 1978: 32), Bindibu (Thomson 1975: 106), Ache (Clastres 1972: 146) and Yagua (Fejos 1943: 50)

Table 1. Use of raw materials in projectile points by recent hunting and gathering peoples.

Group	Region	Stone	Metal	Wood	Bamboo	Antler	Bone	Hoof/ horn	Reference
Efe	Af		•						Bailey 1991: 49
Hadza	Af		•	•					Bartram 1997: 333; Woodburn 1970: 17-31
Kua	Af		•						Bartram 1997: 325-8
Mbuti	Af		•	•					Turnbull 1965: 36, 153, 157
Mikea	Af		•						Poyer *Pers. Comm.*
San	Af	•	•	•			•		Hitchcock & Bleed 1997: 346-50
Andamanese	As		•	•			•		Radcliffe-Brown 1964: 435-6
Agta	As		•	•	•				Griffin 1997: 272-86
Ainu	As		•		•				Watanabe 1972: 31
Punan	As		•	•					Hoffman 1986: 27
Bindibu	Au			•					Thomson 1975: 106
Central Australian	Au	•		•					Spencer & Gillen 1968: 575-8
Mardudjara	Au			•					Tonkinson 1978: 32
Murngin	Au	•		•					Warner 1969: 139-43, 465
Tiwi	Au		•	•					Goodale 1971: 158
Seri	MA	•	•	•					Felger & Moser 1991:126-8
Apache	NA	•	•	•			•		Mason 1893: 39
Blackfoot	NA	•	•						Ewers 1955: 156
Cahuilla	NA	•		•					Bean 1972: 65
Carrier	NA	•		•			•	•	Tobey 1981: 424
Central Eskimo	NA	•	•				•		Boas 1888: 96-100
Cheyenne	NA	•	•			•	•	•	Grinnell 1923: 178-84
Chimariko	NA	•		•					Silver 1978: 208
Chiricahua Apache	NA	•		•					Opler 1996: 388-9
Cree	NA	•				•	•		Honigmann 1981: 220
Crow	NA	•					•		Lowie 1935: 84
Dogrib	NA		•			•	•	•	Helm 1981: 307
Gila	NA	•		•					Spier 1978: 133-4
Hupa	NA	•		•					Wallace 1978: 165
Luiseño	NA	•		•					Bean & Shipek 1978: 552
Makah	NA		•				•		Renker & Gunther 1990: 427
Miwok	NA	•							Barrett & Gifford 1933
Mohave	NA			•					Stewart 1947: 263-4
Netsilik	NA						•		Balikci 1970: 39
Northern Ute	NA	•		•					Smith 1974: 109-11

Table 1. *Continued*

Group	Region	Stone	Metal	Wood	Bamboo	Antler	Bone	Hoof/ horn	Reference
Omaha	NA	•		•					Fletcher & LaFlesche 1992: 451
Owens Valley Paiute	NA	•		•			•		Liljeblad & Fowler 1986: 429
Panamint	NA			•					Mason 1893: 28
Point Barrow Eskimo	NA	•	•			•	•		Murdoch 1892: 201-7
Shasta	NA	•		•			•		Silver 1978: 218
Siberian Eskimo	NA	•					•		Hughes 1984: 250
Tanaina	NA	•	•			•			Townsend 1981: 626
Tanana	NA	•				•	•		McKennan 1981: 569
Tareumiut	NA	•				•	•		Oswalt 1967: 158
Tlingit	NA	•	•				•		De Laguana 1990: 209
Inland Tlingit	NA						•	•	McClellan 1991a: 473
Tutchone	NA		•	•		•	•		McClellan 1991b: 496
Ute	NA	•	•	•					Pettit 1990: 40
Washo	NA	•		•					Barrett 1917: 16, Plate VI
Western Apache	NA	•	•	•					Ferg & Kessel 1987: 50-52
Winnebago	NA	•		•					Radin 1990: 62
Yurok	NA	•					•		Meyer 1971: 263
Ache/Guayaki	SA			•			•		Clastres 1972: 146
Lengua	SA		•	•					Hawtrey 1901: 294-5
Orejones	SA		•	•			•		Nicholas 1901: 620-1
Pumé	SA		•	•			•		Greaves 1997: 297-9
Siriono	SA			•	•				Holmberg 1969: 26-34
Yagua	SA			•					Fejos 1943: 50
Yuqui	SA			•	•				Stearman 1989: 42-3
Frequency		**33**	**27**	**38**	**4**	**9**	**24**	**3**	

Notes: Regional abbreviations: Af = Africa, As = Asia, Au = Australia, MA = Mesoamerica, NA = North America, SA = South America.

who use only wooden projectile points and use them in the hunting of both large- and small-bodied animals. There are also examples of the use of wooden-tipped weapons in warfare (e.g. Griffin 1997: 278). In sum, the ethnographic record of hunter-gatherers indicates that wooden-tipped arrows are commonly used and are perfectly effective for a wide variety of prey. At a minimum, these findings question the common assumption that hafted projectile points of materials other than wood necessarily have superior functional attributes. It seems that whatever benefits hafted stone, bone and metal points provide, wooden weapon tips are

Table 2. Arrow attributes and experimental results.

	Arrow attributes			Penetration depth (mm)	
Arrow no. (Shot no.)	Projectile point material	Mass (g)	Length (cm)	Ballistics gel (mm)	Hide-covered ballistics gel (mm)
1 (1)	Wood	22.1	82.7	222	216
2 (1)	Wood	22.4	82.2	210	211
3 (1)	Wood	19.2	82.6	206	192
4 (1)	Wood	23.1	82.6	210	208
5 (1)	Wood	24.6	82.2	210	203
6 (1)	Wood	25.1	82.7	216	210
6 (2)	Wood	25.1	82.7	216	203
Mean* ± *s		**22.7 ± 2.1**	**82.5 ± 0.2**	**212.7 ± 5.5**	**206.1 ± 7.6**
7 (1)	Stone	24.4	84.5	222	240
8 (1)	Stone	21.8	84.3	232	208
9 (1)	Stone	26.2	84.3	238	213
9 (2)	Stone	26.2	84.3	238	225
10 (1)	Stone	24.1	84.1	222	232
11 (1)	Stone	25.8	84.5	240	214
12 (1)	Stone	25.6	84.0	252	240
Mean* ± *s		**24.7 ± 1.6**	**84.3 ± 0.2**	**235.0 ± 10.6**	**224.5 ± 13.1**

sufficient for hunting multiple types of prey in a diverse array of environmental and cultural contexts.

Methods

In order to establish the efficacy of wooden-tipped projectiles, two simple experiments were conducted. Importantly, our experiments were designed to establish penetration depths and accuracy of wooden- and stone-tipped arrows when fired under controlled conditions. The experimental arrows consisted of six with wooden tips and six with hafted stone projectile points. Wood-tipped arrows consisted of sharpened cedar target arrow blanks averaging 82.5cm in length and weighing an average of 22.7g (Table 2, Figure 2). Six side-notched projectile points were hafted to cedar arrows (Table 2, Figure 2). Manufactured by expert flintknapper Allen Denoyer, the six chert projectile points were consistent in length, width and thickness with finished arrows averaging 84.3cm in length. Arrows were fired from a remotely triggered compound bow (Figure 3), maintaining a 60lbs draw weight. The draw weight is within the range of native bows used in North America (Hamilton 1982).

For the penetration experiments, we used a ballistics gel target 1.1m distant from the arrow tip. The target, ballistic gel molded in the shape of a human torso, was used to simulate body tissue and was draped with caribou hide for half of the shots to more accurately simulate animal prey (Figure 4). Wooden- and stone-tipped arrows were shot twice (two arrows were fired an additional two times) at the ballistic gel target with and without hide, and depth of penetration measured. After each shot, the aim of the bow was slightly adjusted to ensure a fresh target surface for each shot.

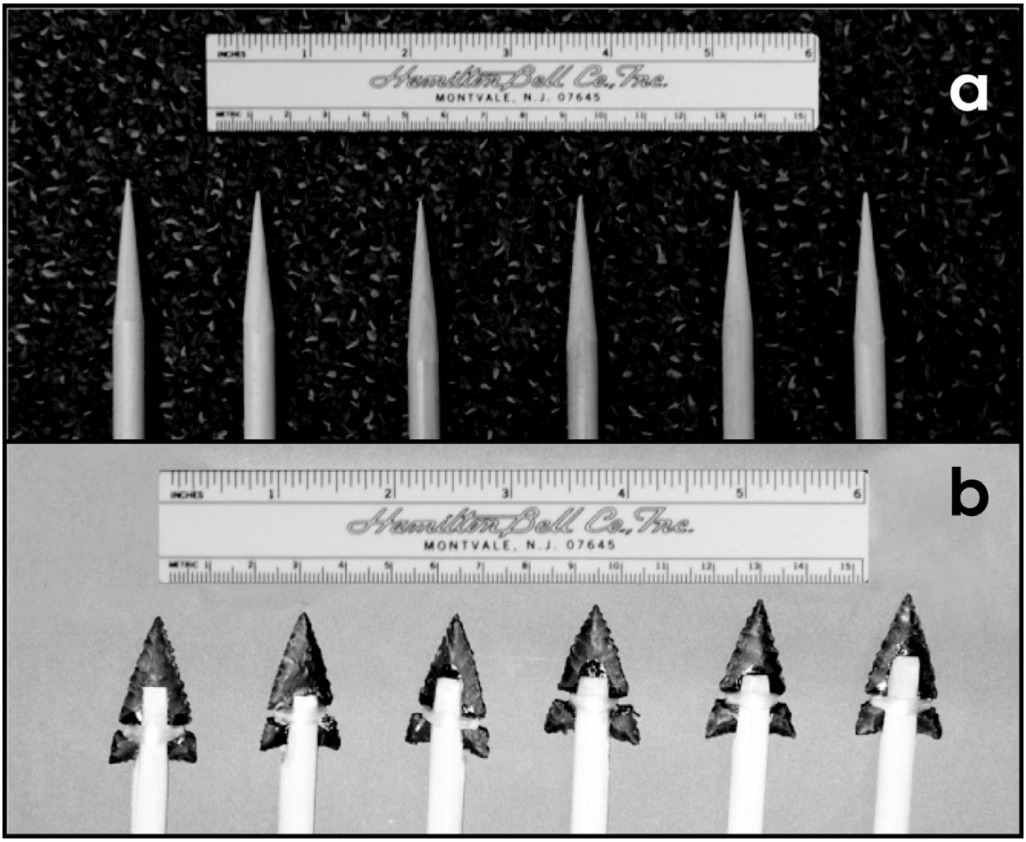

Figure 2. Experimental wood- (a) and stone-tipped (b) arrows.

For the accuracy experiment, the bow was fired at a target at a distance of approximately 16.75m. Each arrow was shot once for a total of 12 shots, and vertical and horizontal deviations from a fixed point on the target were measured. Accuracy was assessed as the amount of spatial dispersion within the six shots of each arrow type.

Results

For both target types, chipped stone projectile points, on average, exhibited greater penetration. For pure ballistics gel, arrows tipped with chipped stone penetrated to a mean depth of 235mm compared to 213mm for wood-tipped arrows (Figure 5), and this difference was significant (unpaired t-test: $t = 4.880$, $df = 12$, $p < 0.001$). For ballistics gel draped with hide, stone-tipped arrows penetrated on average 225mm, and wood-tipped arrows penetrated a mean 206mm. Again, this difference was statistically significant (unpaired t-test: $t = 3.180$, $df = 12$, $p = 0.008$). Although these results support the hypothesis that the addition of a chipped stone projectile point to an arrow improves its penetration ability, it is worth noting that both types of weaponry penetrated to significant depth (>200mm), and that stone points penetrated on average only 9-10 per cent deeper than wooden points.

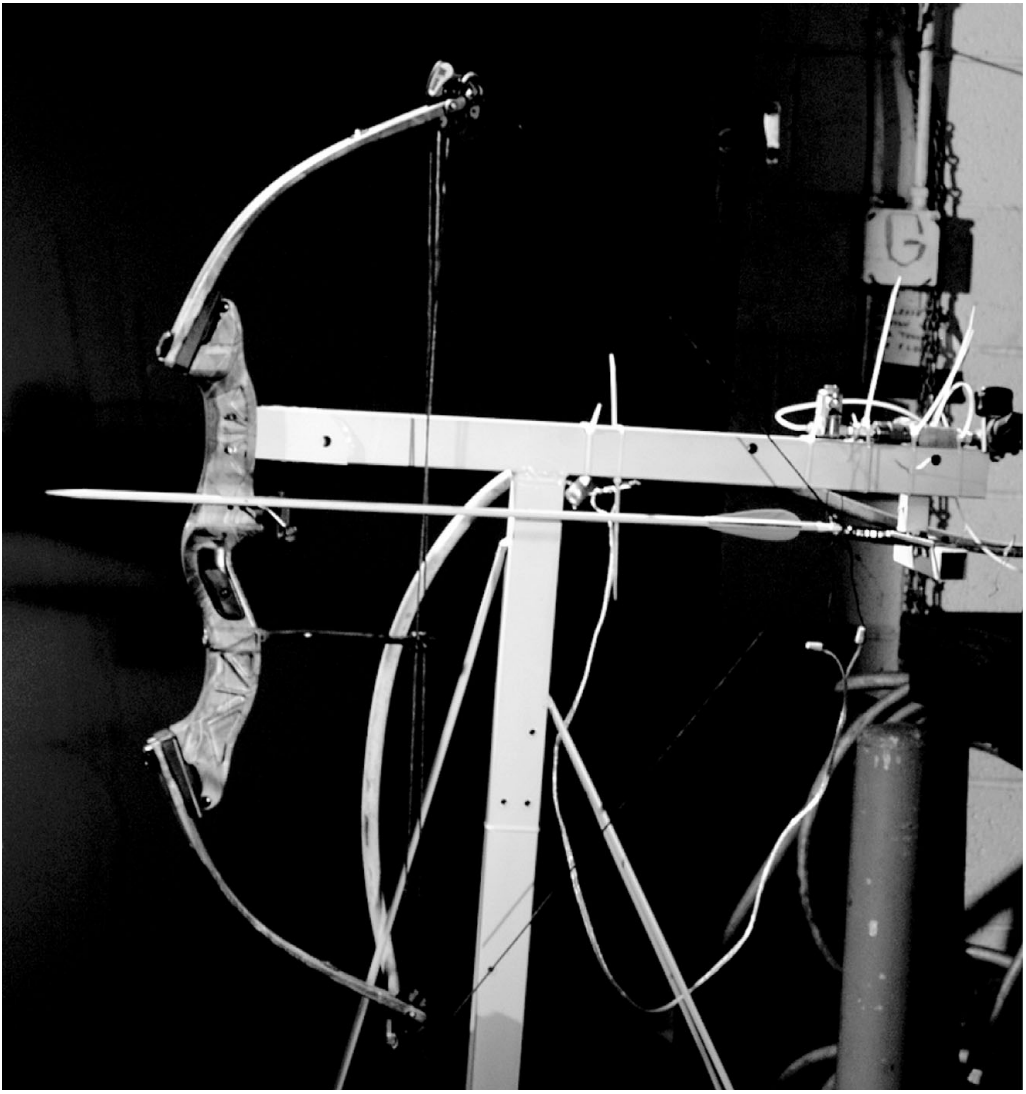

Figure 3. The compound bow used in the experiment with an arrow loaded. The bow was mounted to a steel frame, and the arrow was fired remotely using a quick-release mechanism.

In fact, both types of points in some tests managed to penetrate the entire thickness of the ballistics gel torso (Figure 4).

Because the stone-tipped arrows have slightly greater mass than the wood-tipped arrows, it is possible that the greater penetration observed for the former is due to greater momentum, rather than some property inherent to the stone tip itself. To test this hypothesis we examined correlations between mass and penetration depth for each group of shots and found no significant relationship. These findings support the hypothesis that adding a chipped stone projectile point to arrows does slightly improve the ability of the arrow to penetrate.

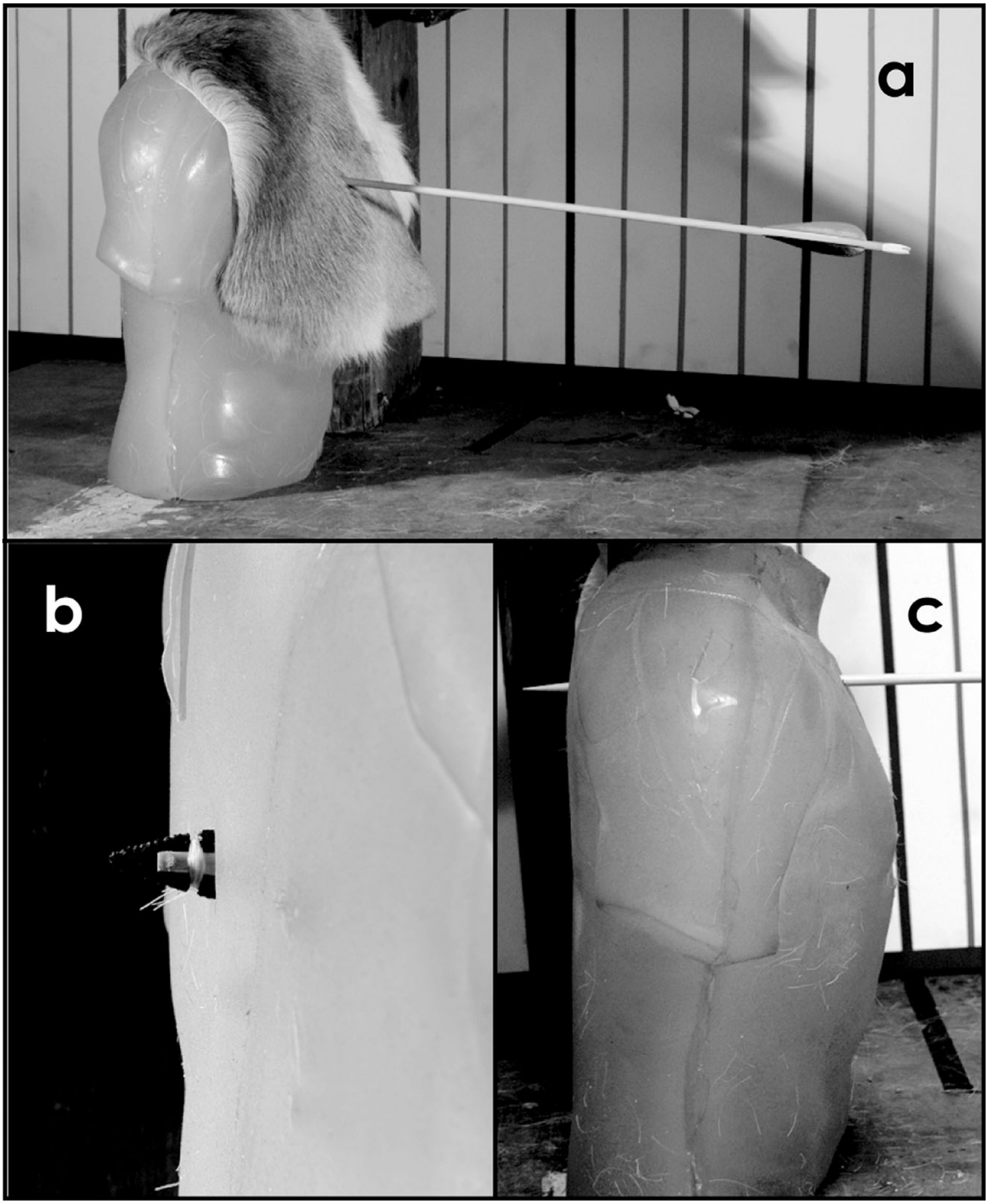

Figure 4. The ballistics gel target with embedded arrows: a) target draped with caribou hide with arrow embedded; b) stone-tipped arrow penetrating through to the back of the target; c) wood-tipped arrow penetrating through to the back of the target (target lacking hide).

In the accuracy experiment, wood- and stone-tipped arrows performed virtually identically (Table 3, Figure 6). Scatters of similar spatial scale were produced by both types of arrows. Wood-tipped arrows produced a scatter approximately 15cm in radius, and stone-tipped arrows produced a scatter with a radius of approximately 13cm. An un-paired

Table 3. Accuracy experimental results.

Shot no.	Projectile point material	X-Coord (cm)	Y-Coord (cm)	Distance from centroid (cm)
1	Wood	−6.6	0.7	9.3
2	Wood	1.4	23.1	16.7
3	Wood	−3.1	−4.6	7.1
4	Wood	−1.5	0.6	14.0
5	Wood	−5.7	−1.5	1.0
6	Wood	3.5	−4.3	1.2
Mean ± s		***−2.00 ± 3.9***	***2.32 ± 10.4***	***8.12 ± 6.7***
7	Stone	10.7	−5.4	4.9
8	Stone	2.2	14.3	21.1
9	Stone	3.7	−9.2	7.0
10	Stone	−9.1	−10.8	1.8
11	Stone	2.7	−1.7	5.4
12	Stone	1.7	−1.2	8.6
Mean ± s		***2.00 ± 6.3***	***−2.32 ± 9.0***	***8.19 ± 6.4***

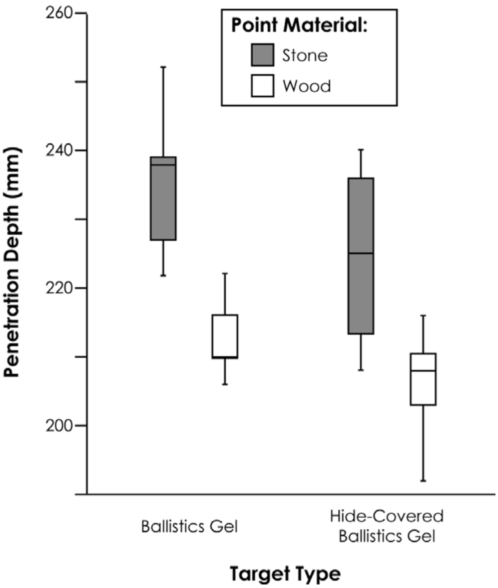

Figure 5. Box plot illustrating penetration depths for wood- and stone-tipped arrows for both types of target.

t-test using distances from the centroid of each group of shots showed no significant difference in dispersion, providing no support for the hypothesis that wood- and stone-tipped arrows differ in terms of accuracy ($t = 0.018$, $df = 10$, $p = 0.986$).

While the average difference between penetration depths (an additional 21mm of depth for stone points fired without hide, and 18mm for stone points fired through hide) are statistically significant, are these differences significant from a hunters perspective? Put another way; is 10 per cent of extra depth, for a weapon already capable of piercing 20cm into a prey animal, worth the additional raw material, manufacturing and maintenance costs?

Discussion

In a more comprehensive ethnographic study of stone projectile use delivered by bow and arrow hunters, Christopher Ellis found that '*. . . stone-tipped projectiles are used almost exclusively on "large" game*' (Ellis 1997: 40). With large game defined as prey in excess of 40kg, the additional penetration depth afforded by stone could be beneficial. Ellis further addresses the issue of stone point use by identifying a sample of ethnographic accounts in

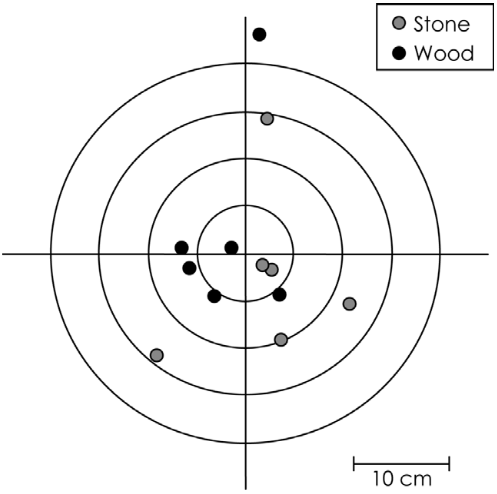

Figure 6. Scatter plot showing results of accuracy experiment. Points represent locations of wood- and stone-tipped arrow shots fired from a fixed bow at a target from a distance of 16.75m. Target circles in 50mm intervals.

which native informants claim that stone points cause more lethal wounds (1997: 50-51). Ethnographic accounts are also provided, however, that attest to the problematic issue of stone-point brittleness with regards to breakage due to missed shots and the need to keep stone points protected when not in use (1997: 56-9).

Based on our experiments and the work of others, a few possibilities regarding the use of hafted stone projectile points can be posited: 1) stone tips provide functional, yet currently unidentified, economic advantages that outweigh their added costs; 2) stone tips have approximately equivalent performance characteristics as wooden staves, but serve additional social/symbolic functions. While we began this experimental approach to projectile performance in an effort to avoid the common assumption that stone points are somehow 'better' simply because they are present in many archaeological contexts (a similar argument could be made suggesting faunal skeletal material is obviously 'better' than faunal tissue based on its presence in the archaeological record), we will tentatively provide our own speculative comments regarding the above mentioned options.

Thrusting and hand thrown spears are preferentially used ethnographically (and supported by limited archaeological evidence) to dispatch large game at short-range (Churchill 1993). Stone-tipped projectiles are preferentially utilised ethnographically to dispatch large game when used to tip bow-propelled arrows (Ellis 1997). If it is assumed that stone tips deliver more lethal wounds by enhancing the rate of blood loss, for example, their benefits may exceed their costs when the potential gain from dispatching a hunted animal is large. In other words, though technologically costly, if the use of stone points even modestly increases the likelihood of successfully felling large game, their added costs may be worthwhile when large game are regularly pursued.

Conversely, it is also worth considering the possibility that the ubiquity and unique distributive features of stone (and also bone/antler/ivory) projectile points in the archaeological record is the result of their advantages over woodened staves in realms beyond lethal efficacy (i.e. as social signs/symbols). Because they require greater effort and skill to produce, hafted projectiles provide a medium for expressing self and/or group identity, essentially a form of costly signaling (Bliege-Bird & Smith 2005). Numerous studies have identified hunting behaviour, expressed through differences in skill, capture rates, participation and subsequent distribution of resources, as a means of reinforcing and manipulating social relationships. Why should these inter- and intra-group differences not also extend to hunting technology?

Considering the ease of sharpening a wooden arrow or spear tip, which requires no shaft preparation for hafting points, no hafting materials and no additional point materials, their frequent use in ethnographic contexts is not surprising. Further, the results of our experiments clearly suggest that their use in prehistoric contexts should be considered likely and that the use of the humble 'stick' does not necessarily reflect a lack of technological skill or limited hunting ability. Depending on the hunting strategies utilised, prey species targeted and raw material economies of both past and present subsistence hunters, it is certainly possible to envision contexts in which the supplementary costs associated with projectile point manufacture might be worthwhile. However, the particular advantages of hafted stone points remain unclear. We still cannot answer under what conditions an additional 10 per cent of penetration depth, under our experimental conditions, matters.

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