HOW Hard Does It Hit?

A Study of Atlatl and Dart Ballistics

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INTRODUCTION:

Anybody who has tried an atlatl and dart knows that it's a powerful combination (ancient people used it to hunt mammoth, after all). But nobody ever seems to know exactly HOW powerful it is -- on the internet, you will find pages that say it's anywhere from 3 times to 100 times more powerful than a spear thrown by hand. That's a lot of difference, and nobody ever says (or shows) how they came by their figure.

To settle it (and to find out which was nearest the truth), I sat down and made some calculations about different projectile weapons, including atlatl darts. In the end, I came up with three variables for comparison -- how hard it hits (**kinetic energy**), how hard it is to stop (**momentum**), and how effectively it penetrates (**sectional density**). These are explained in more detail later.

There are many other factors, of course. The sharpness of the point, its shape, and its diameter all make a difference. A wider blunt point will expend most of its energy simply pushing through the skin, while a narrower sharp one will slice through easily and go in deeper. And while an arrow is good for close range, it simply doesn't have the effective range of a .30-06. An atlatl has an even shorter effective range.

Since there can be (and have been) an infinite number of variations on projectile shape, weight, speed, range, etc., there is no realistic way to account for them all. That being the case, I'm just looking at these three main factors. That will give at least a general guideline to an atlatl's hunting effectiveness.

PROJECTILES:

I used a number of projectiles, both ancient and modern, in order to show where each ranks in terms of kinetic energy, momentum, and sectional density. NOTE: These are average weights, speeds, and diameters.

- Light Spear (equivalent to a javelin): 2 pounds, 50 mph, 1" diameter
- Heavy Spear (equivalent to a Roman pilum): 5 pounds, 25 mph, 1 1/2" diameter
- Light Atlatl Dart: 3 ounces, 85 mph, 1/2" diameter
- Heavy Atlatl Dart: 6 ounces, 70 mph, 5/8" diameter
- Primitive Arrow: 500 grains, 165 fps, 3/8" diameter
- Modern Hunting Arrow: 540 grains, 220 fps, 11/32" diameter
- .357 Magnum handgun bullet: 125 grains, 1450 fps, .357" diameter
- .30-06 rifle bullet: 180 grains, 2600 fps, .30" diameter

As you can see, bullets and arrows are measured in grains and feet per second (fps). Darts and spears are measured (if ever) by ounces and miles per hour. Since we need to use the same units of measurement to get any meaningful results, here are the conversion factors I used.

- 1 pound = 16 ounces = 7000 grains
- 1 ounce = 437.5 grains = 0.0625 pounds
- 1 mile per hour = 1.47 feet per second

KINETIC ENERGY:

- ***Kinetic energy = $^1/_2$ x Mass x Velocity^2***

(Mass is the weight of the object (in pounds) divided by the pull of gravity (32.2 ft./sec/sec). Velocity is the change in position divided by the time in which the change occurs (the rate of speed).)

When an object is in motion, it has kinetic energy. When it strikes something, that energy is transferred. This is the basic *force of impact* - how hard the weapon strikes the target. Kinetic energy is measured in "foot pounds" (the energy needed to exert a one pound force for a distance of one foot).

KINETIC ENERGY CALCULATIONS
In Descending Order

Projectile:	Weight:	Velocity:	Kinetic Energy
.30-06 Rifle	180 grains	2600 fps	2701 ft. lbs.
.357 magnum Pistol	125 grains	1450	583
Light Spear	2 pounds	73.5	167
Heavy Spear	5 pounds	37	106
Heavy Dart	6 ounces	103	62
Modern Arrow	540 grains	220	58
Light Dart	3 ounces	125	45
Primitive Arrow	500 grains	165	29

Kinetic energy was calculated as follows:

Light Dart:

KE = 1/2 x (lbs. / gravity) x (velocity in fps)^2
KE = 1/2 x (.1875 / 32.2) x (125 fps x 125 fps) =45 foot pounds

.357 Magnum:

KE = 1/2 x ((125 / 7000) / 32.2) x (1450 fps x 1450 fps) = 583 foot pounds

Kinetic energy is very dependent on velocity. A bullet, because it is moving so fast, has incredible amounts. A .30-06 has nearly 100 times the kinetic energy of a primitive arrow. And yet Native Americans used those primitive arrows to hunt not only deer, but bison as well.

A rough guide for hunting effectiveness based on kinetic energy (this is an archery chart) is:

Kinetic Energy	**Hunting Usage**
< 25 ft. lbs.	Small game
25 - 41 ft. lbs.	Medium Game (deer, antelope, etc.)
42 - 65 ft. lbs.	Large Game (elk, black bear, wild boar, etc.)
> 66 ft. lbs.	Toughest Game (bison, cape buffalo, grizzly, etc.)

As you can see, both the light dart and the heavy dart seem weak compared to firearms, but they have more kinetic energy than primitive arrows. Looking at the Hunting Usage chart, you can see a heavy dart would be sufficient to bring down even the toughest game -- assuming it is in the effective range. For an atlatl, the effective range is perhaps 50 yards, but over 30 yards they will start losing velocity, which means less kinetic energy.

Kinetic energy is often used as **the** standard for projectile effectiveness, but a baseball (5.12 ounces moving at 95 mph) has 87 foot pounds of kinetic energy. It actually strikes harder than an atlatl dart, but I can't really see hunting a bison with a fast ball. While kinetic energy determines how **hard** an object strikes, it doesn't determine how far it penetrates. That's where momentum comes in.

MOMENTUM

- ***Momentum = Mass x Velocity***

Momentum is the tendency of an object in motion to STAY in motion. Anyone who has pushed a car in neutral and then tried to stop it will understand this -- the more momentum it has, the more resistance it will take to stop it. Momentum is measured in "slug feet per second".

MOMENTUM CALCULATIONS
In Descending Order

Projectile:	Weight:	Velocity:	Momentum
Heavy Spear	5 pounds	37 fps	5.75 slug-ft/sec
Light Spear	2 pounds	73.5	4.57
.30-06 Rifle	180 grains	2600	2.08
Heavy Dart	6 ounces	103	1.20
.357 magnum Pistol	125 grains	1450	.80
Light Dart	3 ounces	125	.73
Modern Arrow	540 grains	220	.52
Primitive Arrow	500 grains	165	.37

Momentum was calculated as follows:

Light Dart:
Momentum = (.1875 pounds / 32.2) x 125 fps = ..73 slug-feet/second.

.357 Magnum:
Momentum = ((125 grains / 7000) / 32.2) x 1450 fps = .80 slug-feet/second.

Flesh normally has a density of about 1 gram per cubic centimeter. Hide is more dense, bone is about twice that (2 g/cc), and organs are less dense. Projectiles with a lower momentum, like the arrows, may have trouble penetrating thick hide and can be stopped fairly easily if they hit bone. Projectiles with a lot of momentum, like the spears, will go through hide, flesh, bone, and organs, penetrating until they encounter enough resistance to stop them. More momentum also means the projectile is less likely to be deflected by branches or underbrush, so it can be used in different types of terrain.

In addition, momentum is a factor in "knockdown". A heavy atlatl dart has enough momentum to knock a 40 pound animal completely off its feet and will definitely affect a larger animal. Objects with less momentum, like the arrows or the .357 magnum, will have a much smaller effect. (Movies and TV shows lie -- a handgun bullet simply will **not** knock a person off their feet. The difference in mass is too great. And if you **did** have a handgun that could do that, the recoil force would shatter the wrists of the shooter.)

You can see that the darts are much more effective in terms of momentum. Mass and velocity are equally important in momentum, and darts have quite a bit of mass. It would take more resistance to stop them, which means they would be more effective at penetrating deeply enough into the target to hit a vital area.

But penetration also depends on **where** you hit. If you hit an animal in the ribs, most of the momentum will be lost getting through them. If you hit it in the stomach, the dart will penetrate much deeper. Arrows, with such low amounts of momentum, simply had to be aimed to where they could penetrate deeply enough.

But momentum alone isn't enough for calculating penetration -- if you filled a 5 gallon pail full of sand and fired both the .357 magnum and the primitive arrow at it, the bullet would be stopped by the sand, while the arrow would pass through completely. Our baseball, with 1.31 slug-feet/sec. of momentum, would simply bounce off. What makes the difference? Sectional density.

SECTIONAL DENSITY

- ***Sectional Density = Weight /Diameter^2***

(Weight is measured in pounds; diameter is measured in inches.)

A ping-pong ball thrown at a pop can will bounce off. A BB will go right through. What makes the difference? The sectional density. Even though they may weigh the same, in a BB the weight is much more concentrated. Since it is striking a smaller area on the target, more of the momentum is conserved, and it will penetrate deeper. Other factors being the same, a denser projectile will always penetrate more effectively than a lighter one. Sectional density is measured in pounds per square inch.

SECTIONAL DENSITY CALCULATIONS
In Descending Order

Projectile:	Weight:	Diameter	Sectional Density
Heavy Spear	5 pounds	1.5"	2.222 lbs/in2
Light Spear	2 pounds	1"	2.000
Heavy Dart	6 ounces	.625"	.960
Light Dart	3 ounces	.5"	.750
Modern Arrow	540 grains	.344"	.653
Primitive Arrow	500 grains	.375"	.508
.30-06 Rifle	180 grains	.30"	.285
.357 magnum Pistol	125 grains	.357"	.140

Sectional Density was calculated as follows:

Light Dart:
SD = .1875 pounds / (.5" diameter x .5" diameter) = .750 pounds per square inch

.357 Magnum:
SD = (125 grains / 7000) x (.357" x .357") = .140 lbs/in^2

Sectional density is why the arrow passes through the sand, the bullet is stopped by it, and the baseball bounces off. The primitive arrow, with .508 lbs/in^2, is denser than a bullet., which means the momentum is conserved more efficiently. The baseball, with its high kinetic energy and momentum, has a sectional density of only .039 lbs/in^2. The weight is spread out over such a large area that the momentum is easy to stop, meaning there is no penetration.

Atlatl darts are very effective in terms of sectional density. The weight of the long shaft is concentrated in the small diameter, making them more efficient than either arrows or firearms (even the mighty .30-06). This means that the momentum is conserved better, which means the darts will penetrate better.

CONCLUSION:

No one of the three factors we looked at is an indicator of hunting effectiveness by itself. All the weapons listed have been used for killing, and all have proven themselves effective. Atlatl darts do not have as much kinetic energy or momentum as firearms, but have a better sectional density. They are higher in all three factors than arrows, and arrows are known to be very effective weapons. There is very little you can't bring down with a well-placed arrow.

Is an atlatl as powerful as a .30-06? No. It has less kinetic energy (force of impact) and less momentum (penetration). It doesn't have anywhere near the effective range and is much harder to aim. But for tens of thousands of years, it was the primary hunting weapon on earth. Dart points have been found in mammoth bones, and they have been tested on modern elephant carcasses with impressive results. While it may not be **as** effective as a rifle, it is certainly effective enough. Just how dead do you need your supper?

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