Atlatl Flex: Irrelevant

John Whittaker and Andrew Maginniss

The Atlatl 19(2):1-3 (April 2006)

The atlatl or spear thrower was one of the first great advances in technology, one of the first complex machines used by humans. Basically a stick with a handle at one end, and a hook or socket at the other, an atlatl acts as a lever arm, allowing a light spear to be thrown much more forcefully than by hand alone. However, in spite of experiments and a sporting revival of atlatl use in recent years, some uncertainty remains about what exactly happens during a throw.

One of the most hotly argued issues in atlatl mechanics is the effect of flexing atlatls and darts on the throw. The inertia of the dart acting against the forward motion of the atlatl flexes both the dart and the atlatl shaft, unless the atlatl is totally rigid, as some are. Many atlatlists believe that the flex of the atlatl and the flex of the dart act as springs to store potential energy which is released as kinetic energy contributing to the force and velocity of the throw. It is even suggested that flexing atlatls led directly to the invention of the bow (Cushing 1895; Farmer 1994).

With Whittaker as the atlatlist and Maginniss as the physicist, we hoped to shed some light on this question. We are in the process of working this up for a detailed publication, but since the results are interesting to other atlatlists, we will summarize them here without the details of the physics, which in the end are not so important anyway.

Bob Perkins (1995, 2000, 2004) and Richard Baugh (1998, 2002, 2003) have both considered the physics of a “springy” flexible atlatl. Baugh modeled the flexible atlatl as a rigid rod with a spring at the end, and predicted gains in velocity of up to 11%. We modeled the atlatl as a cantilever, in other words, a beam fixed at one end and free to flex and move at the other. Our model gave results similar to Baugh's: a flexible atlatl should add a reasonable amount to the velocity of the dart, around 10%.

As part of this project, we recorded throws with high speed photography. A modern digital video camera operates at 30 frames per second, but each frame is actually two overlaid images at 60 frames per second. Computer programs are available to separate these, and produce images that can be viewed at 60 frames per second. In these, some of our atlatls could be seen to flex against the inertia of the dart as the atlatl swung forward. However, the final flip of the atlatl and release of the dart takes place in less than 1/10 of a second, and we could not see exactly what was happening. We then used a digital camera with an open shutter and a strobe light in a dark room to photograph the final part of the throw at 120 images per second. For our experiments, we built three simple atlatls whose only significant differences were in the amount of flex. In the photos, flex was analyzed by drawing in a straight line of appropriate length next to the flexed atlatl. Then a distance measurement was made connecting the two distal ends. Atlatl A had no visible signs of flex. Atlatl B had 4 to 5 cm of flex on average. Finally, the flexible atlatl C had on average 13 cm of flex prior to release.

Experimental Results

In spite of our mathematical models, the results of our experiments forced us to the conclusion that atlatl flex has little or no effect on the velocity of the dart. Several lines of evidence proved this.

In our photographic record, velocities and accelerations were calculated using displacements and the 1/120 second gap between images. All three atlatl tips had a velocity of approximately 19m/s (43mi/hr) just prior to releasing the dart. There were no significant differences between the three atlatls. This suggested that atlatl flex does not have much noticeable impact upon the velocities and accelerations during the final rotation prior to release. The analysis also showed that the distal end of the atlatl accelerates dramatically after the dart is released. This could be for two reasons. First, once the dart has been released the inertia of the system decreases dramatically and makes it easier to accelerate the atlatl during the follow-through. The second reason could be that not all of the flex was released into the dart and the distal end is returning to the non-flexed position through a rapid oscillation. This is an important observation: the atlatl is springing back to its straight condition *after* the dart has left.

In fact, reexamining the physical model, we realized that it assumed that the flexed atlatl is given the opportunity to spring forward just prior to the release of the dart. This would mean that the atlatl has stopped rotational acceleration (in other words, there would be no follow-through) and the load flexing the atlatl back can then spring forward. In other words, the atlatl would have to stop or slow down enough that the flexed hook end could rebound and "catch up" to add spring force to the throw. One could imagine a throw with no follow through, and a jerky stop at the top of the throw, but this is not how good atlatlists use the tool.

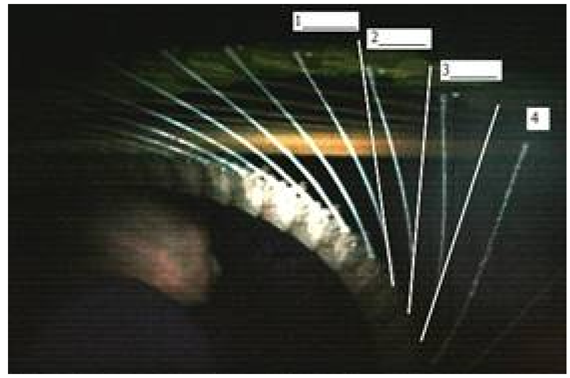

Figure 1

In Figure 1 white lines have been added to the strobe photo to indicate how much the atlatl has flexed in three of the last four images. (The fourth of these, far right, is after the dart has left the camera's view). Prior to release (2) the atlatl flex is at approximately 13cm and in the flash just after separation (3) the atlatl's flex is approximately 11.5cm. Note that in (3) the white spot at the nock of the dart is above the hook of the atlatl, showing that it has been fully released. The time when the separation occurred prior to this flash of the strobe is most likely on the order of 1/1000th of a second. This photo is visual evidence that very little to none of the potential energy stored in the flex is transferred to kinetic energy of the dart. The 1.5 cm change in flex between image 2 and image 3 could have contributed to the dart's velocity or perhaps simply occurred during the fraction of a second after release. Either way this image in and of itself shows that very little to none of the flex is released prior to the release of the dart, so it cannot be applied to dart velocity.

In fact, there is nowhere near enough time for the atlatl to release the potential energy of the flex and convert it into additional dart velocity. For example, it would take atlatl C around 1/10th of a second to release all of its flex into the dart. This 1/10th of a second is calculated using the period of oscillation, the time it takes for a spring to go all the way up and then return to its original position. For an atlatl propelling a dart only the first quarter of the period is of interest. This is the time it takes for the atlatl to go from the flexed position to the equilibrium position with zero flex. However, the entire flick of the wrist and rotation of the atlatl takes only 1/10 second, during which time the atlatl is being flexed by the rotational acceleration of the atlatl working against the inertia of the dart. For the flex to apply force to the dart, the atlatl would have to stop its rotational acceleration and spring forward in the very short interval between the end of the rotation and the departure of the dart. There is simply not enough time for this to happen. And as we have seen, in the images which show the atlatl and dart moments after release, the atlatl is still almost completely flexed *after* the dart has left, and therefore the flex could not have been converted into kinetic energy of the dart.

As a final test, the velocity and acceleration measurements taken from the strobe images, and velocity data from motion images of throws showed no significant differences between the three atlatls.

So What is the Role of Atlatl Flex?

Both theory and experimentation make it very clear that atlatl flex makes little or no contribution to the dart's velocity. This contradicts much previous research and the intuition of most atlatlists. Most experiments and subjective observation note the fact that the atlatl flexes like a spring. The atlatlists therefore assume that the flexed atlatl will transfer some of this stored energy into the dart, contributing to its forward motion. This assumption is wrong. It turns out that the atlatl does flex like a spring, but very little of this potential energy is transferred to the dart.

If atlatl flex doesn't contribute to the dart's final velocity, does it have any purpose at all? One possible function of atlatl flex is that it could help to reduce error from human induced irregularities in the throw. It might buffer some of the jerkiness of a throw, producing smoother, more regular acceleration. There have been some attempts to compare the accuracy of atlatls of differing flexibility. VanderHoek (1998) found no significant differences, but such tests are largely inconclusive because measuring the accuracy of a throw involving so much human error is fraught with difficulties. Perkins (1993, 2002; Perkins and Leininger 1989) argues that the flex of the atlatl not only stores energy, but times the separation of the springy dart from the atlatl. Since we have shown that the atlatl is still flexed after the dart has left, that cannot be the case either.

How About Dart Flex?

While we focused on atlatl flex, the role of dart flex is also hotly debated by atlatlists. The flex of the atlatl is often hard to see, but the flex of the dart is very visible. During the final flick of the wrist and rotation of the atlatl, the distal end of the atlatl forces the connecting proximal end of the dart up as the atlatl is raised while keeping the point of the dart on target. The dart bends by approximately half of the atlatl's length. Then upon release darts often oscillate on their flight towards the target. Questions similar to those regarding atlatl flex quickly arise. As in the case of atlatl flex, one might want to see if the dart's flex can significantly accelerate the dart and therefore increase the dart's final velocity, as Perkins (1993, 1995, 2000a, 2000b) believes. Perkins and Leininger (1989) explain that waves sent down the dart shaft reflect and provide a springing force which increases the dart's velocity.

A simple experiment to give a sense for how insignificant this additional velocity would be can be performed by planting one end of a dart on a solid surface, compressing the other end, and then releasing the flexed dart to jump off of the surface. The dart does not hop off of the surface very quickly or very far, which shows that very little kinetic energy is transferred to the dart through its flex. Most of a dart's flex is perpendicular to the shaft and there is only a small distance of spring compression parallel to the shaft, which is in the direction of the dart's motion. This gives the dart very little distance to push off with during the time that the dart oscillates. The flex of the dart does store a certain amount of energy, but it is mostly released as latitudinal oscillations of the dart (Baugh 1998; Cundy 1989).

Dart flex should not significantly increase velocity, but it is necessary. We tried some casual experiments with rigid darts. These were made from plastic tomato stakes, of two sizes, 149 cm long, 1.1 cm diameter, weighing 120 gm, and 183 cm long, 1.5 cm diameter, weighing 254 grams. When thrown with the normal flipping motion of the atlatl, these rigid darts could not be kept on target. The proximal end (nock) was pulled down, while the tip rose, and the dart soared away uncontrollably, sometimes even tumbling end-over-end. Fletching and balancing these darts with weight well forward improved performance only to the extent that after a period of wild flight they might stabilize and land point first. It was however possible to throw the heavy rigid dart accurately for short distances using a throw where the rotation was arrested, as suggested by Howard (1974). This is not the correct way to throw flexible darts, but we suspect that this is how rigid Arctic harpoons are thrown, although we have no practical experience with them.

Perhaps dart flex does help increase dart velocity, not through releasing its potential energy, but rather by its effects on the throwing motion. Our slow motion footage shows that for some of the more flexible darts filmed, the point of atlatl/dart release is further along in the rotation than with the less flexible darts. The less flexible wooden darts from Bob Berg, which were used in the atlatl flex experiments, would be released almost perfectly straight above the throwing hand or at 90 degrees of rotation. The more flexible cane darts that Whittaker normally throws were sometimes released as far as at 105 degrees of rotation. This extra 15 degrees might increase the velocity of the dart by adding to the time that the atlatl is actually accelerating the dart, and therefore the more flexible darts may be more efficient than the less flexible darts.

Conclusions

Experimental studies using modern recording technology, coupled with mechanical modeling using well-known physical principles, allow a better assessment of what actually happens during spear throwing with an atlatl. The motion is very comparable to any other overhand throw, the difference being that the atlatl lengthens the lever arm at the wrist. The rotation of the atlatl thus provides most of the velocity attained by the dart. Contrary to the intuition of most atlatlists, a flexible atlatl appears to provide little advantage over an inflexible one. While it is true that a flexible atlatl can be modeled as a spring, the springing action provides no addition to the velocity of the dart.

This tells us that the enormous range of variation through space and time in the form and materials of atlatls is not dictated by the advantages of flexibility, although it is certainly possible that ancient atlatlists, like those of today, believed that a flexible atlatl propelled a dart more effectively. The flex of an atlatl is not, however, a logical step on an evolutionary path toward the bow and arrow.

References

Baugh, Richard A.
1998 Atlatl Dynamics. Lithic Technology 23(1):31-41.

2002 Atlatl Flexibility Analysis Via Computer Modeling. accessed 7/02 on http://www.primitiveways.com/pt-atlatlflex.html

2003 Dynamics of Spear Throwing. American Journal of Physics 71 (4): 345-350.

Cundy, B. J.
1989 Formal Variation in Australian Spear and Spearthrower Technology. BAR International Series 546, Oxford.

Cushing, Frank H.
1895 The Arrow. The American Anthropologist 8(4):307-349.

Farmer, Malcolm F.
1994 The Origins of Weapons Systems. Current Anthropology 35(5):679-681.

Howard, Calvin D.
1974 The Atlatl: Function and Performance. American Antiquity 39(1):102-104.

Perkins, William R.
1993 Atlatl Weights: Function and Classification. Bulletin of Primitive Technology 1(5):58-61. The Atlatl 15(2):10-11 (2002)

Perkins, William R.
1995 Effects of Stone Projectile Points as a Mass Within the Atlatl and Dart Mechanical System. Bulletin of Primitive Technology 10:69-72.

2000a Archeological, Experimental, and Mathematical Evidence Supporting the Use of the Atlatl as a Primary Big Game Procurement Weapon of Prehistoric Americans. Bulletin of Primitive Technology 20: 69-72.

2000b Effects of Stone Projectile Points as a Mass Within the Atlatl and Dart Mechanical System and its Relationship to the Bow and Arrow. Indian Artifact Magazine 19(2):8-9, 78-79.

2002 Atlatl Weights: Function and Classification. The Atlatl 15(2):10-11 (2002).

2004 Atlatl and Dart Mechanics. BPS Engineering webpage, URL http//:www.atlatl.com accessed 1/5/06.

Perkins, William R. and Paul Leininger
1989 The Weighted Atlatl and Dart: A Deceptively Complicated Mechanical System. The Atlatl 2(2):1-3; 2(3):1-4; 3(1):1-3.

VanderHoek, Richard.
1998 The Atlatl and Dart. Unpublished MA thesis, Anthropology Dept, University of Illinois at Urbana-Champaign.