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Hunting: Prehistoric Spear Velocity

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Abstract
In this paper we outline a series of equations that describe a spear's velocity profile, with respect to time, that is based on a simplified model of projectile launching techniques and drag forces.

Introduction
Hunting large game animals in prehistoric times was a dangerous task, especially when using hand driven spears [1]. Any technological advancement that allowed the hunters to place more distance between themselves and their prey (or aggressors) would have provided an evolutionary advantage. A variety of thrown weapons were developed [2] from simple 'unaided' projectiles (javelins and spears) to more complex 'mechanically aided' throwing systems such as atlatls [3, 4] (also known as spear throwers). The faster and therefore further these projectiles could be thrown and still penetrate an animal's hide the better for the hunter.

Throwing a spear-like object
The series of motions required to throw a hunting projectile is complex [5] involving a rotation of the torso in one plane and a rotation of the throwing arm in two planes at three separate locations: shoulder, elbow and wrist. Using an aid such as an atlatl results in a functionally similar full body launching motion [6, 7]. In both cases observations of modern practitioners show that: a) the projectile is held approximately horizontal throughout the throw and b) the motion predominantly responsible for launching the projectile is the rotation of the forearm from an angle of approximately -45^{o} to +45^{o} to the vertical (see fig 1). The only difference is that the atlatl appears to extend the functional length of the forearm. The importance of this will be explored using a simple physical model.

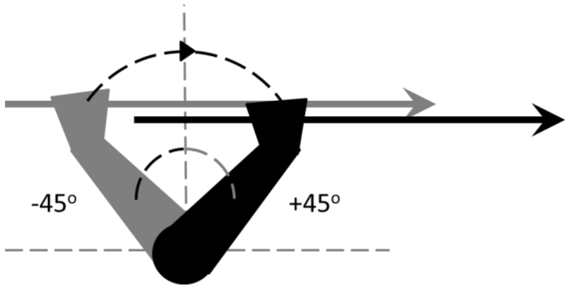

Fig 1) Diagram showing the rotation of the forearm during a spear throw.

Modelling the throwing action
Assuming the motion of the forearm in isolation the elbow joint can be considered as a fixed pivot point. Therefore the hand-projectile attachment point must move through a circular arc. The tangential velocity, v_t, at which the projectile leaves the hunter's hand is therefore related to the angular velocity, ω, by the following equation [8]:

$$v_t = r\omega, \qquad \ldots eqn\ 1$$

To a first order approximation we can assume that the contraction of the bicep [9] produces a uniform angular velocity, therefore $v_t \propto r$. Thus increasing the effective r by using an atlatl increases v_t.

We also know from projectile theory that the velocity in the x- and y-directions after the projectile leaves the hand are [8]:

$$v_x(t) = v_t - a_{drag}t, \qquad \ldots eqn\ 2$$
$$v_y(t) = 0 - gt, \qquad \ldots eqn\ 3$$

But we also know that the drag force acting on the spear as it travels through the air is [10]:

$$F_{drag} = \frac{1}{2} C_D \rho_{air} A v(t)^2, \qquad \dots eqn\ 4$$

Substituting equations 1 and 4 into equation 2 gives:

$$v_x(t) = r\omega - \frac{C_D \rho_{air} A v(t)^2 t}{2m}, \qquad \dots eqn\ 5$$

$$v_y(t) = -gt, \qquad \dots eqn\ 6$$

$$v(t) = \sqrt{v_x(t)^2 + v_y(t)^2}. \quad \dots eqn\ 7$$

Therefore we can see that the horizontal velocity of the projectile at any given time, $v_x(t)$, is dependant its total instantaneous velocity, $v(t)$. We will model this projectile motion using Excel in a later paper.

References

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