# Arrow Lethality Study Update – 2005
## Part V
**By**
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**Summary Overview: Trends, Tendencies, FAQ's and Comments.**

Chart 8 summarizes average penetration for all broadheads tested, by type: mechanical, modular (replaceable blade), and rigid; considering all 364 buffalo "test shots", but excluding "focal study" shots, such as: 'skin test'; skip angle testing; etcetera. Rigid broadheads averaged 24% more penetration than modular broadheads, and 56% more than mechanical broadheads.

Mechanical broadhead test-shots averaged 46% greater impact-kinetic-energy than the rigid broadheads, and modular broadheads averaged 30% more. Average impact-momentum between mechanical, modular, and rigid broadheads is near equal; 0.47, 0.46, and 0.49, respectively. Mechanical broadhead test data contains 9.5% scapular hits; modular broadheads 16.7%; and rigid broadheads 19.5%.

Graph 5 depicts all shots impacting an entrance-side rib, showing percentage of shots penetrating; by broadhead type. It excludes shots striking other bones, such as scapula, before encountering the rib, but includes angular impact rib shots.

In evaluating Graph 5, consider that all mechanical broadhead shots (100%) are broadside, with perpendicular impact angle. Modular broadhead data includes 57.7% broadside shots and 43.3% shots quartering from the rear (qfr) at an impact angle of $20^0$. Rigid multiblade shots include 10.7% qfr at $45^0$; 7.1% qfr at $20^0$; and 82.2% broadside shots. Rigid single blade data includes 9.7% qfr shots impacting at $45^0$; 9.0% qfr at $20^0$; 3.2% qfr at $15^0$; and 78.1% broadside. Findings are consistent with prior data.

Graph 6 depicts percentage of broadheads damaged; by type. No direct comparisons can be made between Asian Buffalo testing and earlier studies, except Cape Buffalo, but similarity to earlier findings is striking. Mechanical broadheads did not commonly exist when the Natal Study was conducted, but the current damage rate for modular broadheads is 60%, and was 64% in the Natal Study. Current damage rate for rigid broadheads is 16.5%. In the Natal Study, rigid broadheads were divided into single and multiblade categories. There, rigid single blades showed a 15% damage rate, while rigid multiblade heads had a 50% damage rate. Rigid multiblade heads in the current testing are those at the top of their category in previous testing, or new designs not previously tested, but highly recommended for inclusion by many who use them, such as the Wensel Woodsman.

Examination of kinetic energy, momentum and arrow mass, and their relationship to outcome tissue penetration continues. Though complex, these, along with understanding of resistance forces involved, are the most important study aspects; basic forces determining tissue penetration.

As in prior data, no correlation *trend* between impact-kinetic-energy and penetration can be established. To clearly bring the lack of relationship to the reader, Graph 7 presents raw impact-kinetic-energy and penetration data for the 364 buffalo shots. The range of impact-kinetic-energy is from 23 ft.-lbs. to 94 ft.-lbs. If anything is striking about the data it is the randomness.

Numerous differential clustering of impact-kinetic-energy were tried; from 5 ft.-lb. increments to 20 ft.-lb. increments. Graph 8 illustrates averaging in 20 ft.-lb. increments; compared to average penetration. Neither this nor any other clustering shows a definable relationship.

Graph 8 shows a 'penetration peak' shows in the 40 to 60 ft.-lb. impact-kinetic-energy range. It results from most heavy arrows falling into this group; the balance falling below the 40 ft.-lb. level. A major goal of testing is to find *minimum* impact-force levels giving reliable penetration. No testing with high mass arrows has been conducted above the 60 ft.-lb. level.

A relevant relationship exists between mass and momentum as 'predictors' of outcome penetration. The less than 40 ft.-lb. group has an average impact-momentum of 0.48 slug-feet/second and average mass of 793.7 grains. The averages for the other groups are: 0.52 slug-feet/second and 799.8 grains for the 40-60 ft.-lb. group; 0.51 slug-feet/sec. and 483 grains for the 60-80 ft.-lb. group and; 0.57 slug-feet/sec. and 431 grains for the 80-100 ft.-lb. group.

The 60-80 ft.-lb. group has higher impact-kinetic-energy and higher impact-momentum than the less-than-40 ft.-lb. group, yet averages 12% less penetration. With more than double the impact-kinetic-energy and 16% more impact-momentum, the 80-100 ft.-lb. group exceeds the less than 40 ft.-lb. group's penetration by only 1.7%! This paradox results from the differing contribution each group's arrow mass makes to the momentum.

Arrows in the highest kinetic energy group, 80-100 ft.-lbs., have the lowest mass arrow weight. The contribution of arrow mass to resultant momentum is low. Lower mass contribution to momentum means a shorter *time* of impulse. How long the force acts upon the tissues is a key component in outcome tissue penetration. Arrow mass, through its contribution to the momentum, is the prime determiner of *how long* the force is applied to the tissues; on any given shot. The importance of the time factor of applied impulse of force is clearly discernable.

Graph 9 illustrates the impact-momentum for all 364 shots; grouped into .05 slug-feet/second increments, and compared to average penetration. Though the relationship between impact-momentum and penetration is not at a one-for-one level, it shows a positive correlation *trend* with outcome tissue penetration. Note that arrow mass is not considered in either Graph 8 or 9. These graphs are looking at whether kinetic energy or momentum, considered alone, shows a correlation with outcome tissue penetration.

Graphs 10 and 11 contain data for non-extreme FOC arrows *completely traversing the thorax*. They show averages by arrow mass weight groups, and compare penetration with impact-momentum and impact-kinetic-energy. Sample size is small, especially in the less-than-750 grain grouping. Few arrows of less than 750 grains mass fully traversed the thorax. Testing was conducted at impact-kinetic-energy levels up to 94 ft./lbs., but failure of virtually all high velocity, low mass arrows to completely traverse the thorax is reflected in the narrow range of impact-kinetic-energy shown in Graph 11.

Graph 10 shows the characteristic positive correlation of momentum and penetration. In Graph 11, impact-kinetic-energy and penetration shows no relational tendency.

In Graph 10, the 750-900 and greater-than-900 grain groupings contain a near equal number of shots. Comparing these two groups, an impact-momentum increase of 12.5% resulted in a 13.5% increase in penetration.

The less-than-750 grain grouping and the 750-900 grain grouping have the same impact-momentum; 0.49 slug-feet/second. If these two groupings are combined, their average penetration is 16.53 inches. Comparison of the greater-than-900 grain group with the combined groups shows a penetration increase of 11.1% for the 12.5% impact-momentum increase. In both cases, the correlation between impact-momentum and penetration is very close; nearing one-to-one. This is because virtually all arrows traversing the thorax had similar physical attributes: high mass weights; best quality broadheads; shaft diameters smaller than the broadhead’s ferrule diameter; and good flight characteristics.

As Graph 9 (all shots) showed, positive correlation between momentum and penetration holds even when multiple variables are introduced: all broadheads; shaft materials and profiles; shaft-diameter-to-ferrule-diameter ratios; levels of impact-kinetic-energy; and even the drastic variation caused by bent and/or broken broadheads. With sufficient record numbers, variances are ‘smoothed out’ in averaging. The *direction* of correlation between impact-momentum and outcome-tissue-penetration remains positive, with only the *degree* of correlation changing. When external arrow dimensions are equivalent; as in Graph 10; the degree of correlation between momentum and outcome-penetration is a function of the time component of the impulse of force which, at given force and resistance levels, is dependent upon arrow mass contribution.

Graph 12 and 13 display impact-kinetic-energy, impact-momentum, and penetration for Extreme FOC arrows. Though both the range and number of shots is small they demonstrate the same relational tendency as normal and high FOC arrows: impact-kinetic-energy shows no correlation with penetration; impact-momentum shows a positive correlation.

A positive kinetic-energy to penetration correlation appears only when a single arrow setup is considered; with average penetration increasing as impact-kinetic-energy goes up. However, the increased velocity required to yield higher kinetic-energy also increases the "given arrow's" momentum. The penetration-increase to kinetic-energy-increase relationship is not *proportional*; it shows marked *decrement*. Mathematically, "proportional" means "having the same or a constant ratio". "Decrement" means the *rate of penetration increase* decreases as the impact-kinetic-energy increases. In other words, the *gain* in penetration becomes smaller each time impact-kinetic-energy is increased by a set amount.

## Frequently Asked Questions

**How is the Study funded; who is "backing' the Arrow Lethality Study?** The study is entirely self-funded and, to date, over $300,000 dollars of personal expense has been incurred conducting the studies. I have no personal involvement with the archery industry. I neither manufacture nor sell any archery equipment. I receive neither compensation nor sponsorship from any company producing either archery or outdoor equipment. There is no 'industry influence' upon the studies.

All equipment tested is personally purchased or donated by other interested bowhunters. A very few 'one off' test-broadheads; prototypes, if one prefers; were made by manufacturers upon my request. In a few such instances the makers refused payment. Some fletching materials were purchased and donated by the Australian Bowhunter's Association. All other expenses have been personally absorbed.

**Why is so much time and effort spent on determining the relationships between impact-kinetic-energy and impact-momentum on terminal arrow performance?** The information not only helps bowhunters understand how these factors influence arrow lethality, but also those not familiar with bowhunting, but in a position to greatly impact bowhunting; such as Government regulatory bodies.

Though data for terminal performance of hunting arrows on real animals is substantial compared to that available a few years ago, it is miniscule compared to that available for firearms. One thing is clear; kinetic energy, as commonly used, has no validity as a "predictor" of an arrow's ability to penetrate tissues, or deliver a lethal hit. Neither does the type of bow, or its draw weight.

Bow efficiency differs widely. Recent testing with an ACS-CX longbow drawing 55# gave a higher velocity; ergo higher impact-momentum; with a 782 grain arrow than did a modern, 70#, reflexed, deflexed, Tonkin Cane cored, longbow. In light of such information, is a law requiring a minimum draw weight of 60# for hunting moose, or big bears, logical? No. How about 55#? A 45# ACS-CX out-performs most 55# "traditional" bows using arrows of like mass; and I suspect a 40# version would equal many, and exceed some.

It is impossible to influence those not familiar with bowhunting without *hard data*. It is difficult to get a law changed once it is in place. Ill founded legislation can restrict highly effective bowhunting equipment from the field, while promoting use of less effective equipment; thus precluding hunting-access to some, for no justifiable reason.

Hard evidence may indicate a need to re-define "adequate". A great example is data emerging from Extreme FOC testing. Early finding are *extremely suggestive* that their use *may* allow light draw-weight bows to give terminal arrow performance equaling, or exceeding, normal to high FOC arrows from the heavier draw-weight/arrow-force bows now required in some localities, even for fairly sizable game. Only time and further testing will tell how the Extreme FOC arrow parameters will develop.

**Why the opposition to replaceable blade broadheads, multiblade broadheads and wide cut broadheads?** There is no opposition. Some individuals are "sharpening challenged". It is better they use a sharp, replaceable blade broadhead than a dull "best quality" broadhead. Those preferring multiblade broadheads also need to know the performance characteristics and limitations each design exhibits. Each need to know that: (1) not all such broadhead/arrow combinations are created equal, and (2) what limitations the broadhead/arrow they use implies for minimum impact-force and shooting angles.

With whatever bow generated impact-force I will using on any given hunt, if penetration is adequate on all *potential* hits, for the largest game that *might* be encountered, I like wide cut broadheads. The Deadhead is a favorite for lighter built game, however it is clearly not *"the best choice"* when a very large animal, like a buffalo or scrub bull, is on the *potentially* encountered game list (or a really big pig, for that mater).

**How does the study benefit "the average bowhunter"?** Arrow design factors affecting tissue penetration are the same, regardless of all else. Some feel the studies contain no information pertinent for those hunting only lesser species; deer-size game. This is far from true. Measure the thickness of a deer's scapular ridge; scapular head; or head of the humerus. These can be very heavy bone, especially on larger-bodied specimens. Thicker portions of the scapular flat on many species qualify as “heavy bone”; elk, moose, big bear, big pigs, etcetera.

Often one hears, “Just shoot them in the right place and great penetration is not needed.” I have yet to meet a highly experienced bowhunter who claims to have *never* hit an animal “in the wrong place”. In hunting, both target and environment are dynamic. Because of this mutability, no bowhunter has absolute control over all aspects of the shot. Bad hits do, and will, happen. Using equipment maximizing arrow “penetration potential” often converts such hits from a lost-animal situation one having a happy ending.

**Can any arrow be relied upon to break heavier bone?** Some hold the view that no arrow is a ‘bone breaker’. This is not true; especially on lighter-built big game species. Will any ‘usable’ arrow *always* break *every* heavy bone it hits? No. There are too many variables; impact force; given-bone mass; impact angle; arrow skip; and a host of other factors. Will any rifle bullet? Solid (non-expanding) rifle bullets; from calibers fully capable of penetrating through an elephant; will glance off light bone when impact angle is too acute. Because such a bullet; or arrow; fails to penetrate every bone under every possible condition, does it mean that they are not ‘bone breakers’, or that no advantage is gained by using one that penetrates bone with the highest possible frequency? Of course not.

It must be made perfectly clear that I am <u>*not*</u> advocating one deliberately take shoulder shots. However, an arrow with high-penetration-potential *increases the probability* of lethal penetration, should such a hit result. Though the setups I hunt with are ‘heavier’ than average, in accidental hits of this nature when hunting I’ve had no failure of a high-penetration-potential arrow to give lethal penetration on a scapular flat hit, even on sizable animals: elk; moose; wildebeest; eland; bigger bears and pigs.

**What then is the minimum impact-force required for an arrow to be a “bone-breaker” on deer-size game?** At this point I have absolutely no idea. I do know the combination I commonly hunt with is well above threshold. Heavy-bone hits on deer-size game has, thus far, given a 100% kill-rate; generally with an exit wound, and frequently a pass-through; regardless of the bones hit. It is hoped future testing will provide a clearer indication of where the threshold lies.

Arrow penetration-potential will be a major factor at any given impact force. In testing, there are broadheads that the setup I use *will not consistently* push through the shoulder bones of large bodied deer. It is their *occasional failure* which precludes my use of higher-resistance broadheads for serious hunting, and I've lost no animal, thus far, through their non-use.

**Who benefits most from using arrows designed for maximum penetration?** Defining factors maximizing arrow penetration is of greatest benefit to those at extreme ends of the spectrum: (1) ones using relatively light equipment on 'standard' big game; and (2) those hunting the larger species. But it also benefits average bowhunters, using average equipment. Arrows maximizing penetration expands the capabilities of their equipment. It gives more pass-through shots and an increased "safety margin" of penetration for those times when Mr. Murphy takes a hand, resulting in a 'worse case scenario'; impacting heavy bone, or requiring extreme penetration to reach vital organs.

**What good does it do to have the arrow sticking in the dirt after passing through an animal? Isn't it better to have a larger wound channel with penetration stopping at the off-side of the animal?** Medical studies from human arrow wounds confirm that hemorrhaging as a result of a broadhead-tipped arrow wound occurs *significantly* more quickly when the arrow/shaft does not remain in the wound; applying direct pressure upon the tissues. The hemorrhage differential is so great that first-responders are advised to *never* remove the shaft from a wound until adequate facilities are available to deal with the increased hemorrhaging which results[1]. Additionally, it has been suggested that, in a moving animal, the tissues exert additional lateral pressure upon the shaft, further slowing hemorrhaging[2]. Based on those findings, it would appear that a complete pass-through is the desired shot outcome on game.

**What about blood-trails?** Many factors affect the degree of blood-trail left by an arrow wound. Degree of blood trail has been tracked in previous studies, and continues to be tracked. An extensive tracking/reporting system to uniformly quantify the blood trail left by different arrow wounds has been implemented. Several individuals, using a verity of equipment, are involved in data collection for a 'blood-trail focal study'. This new system also tracks other factors which may influence recovery/loss rates, such as: management after the shot; the experience level of the individual(s) following the blood-trail; environmental conditions existing at the time; techniques used during recovery of the animal; and species-specific influences upon the degree of blood trail.

Previous study data is *strongly suggestive* that degree of blood-trial is dependent upon: (1) location of entrance wound; (2) presence or absence of exit wound; (3) location of any exit wound, and; (4) what organs were hit during the arrow's passage. In light of the medical information noted above, whether or not the arrow (shaft) remained in the wound channel might well need adding to this list, and is being looked at in the new blood-trail focal study. Initial studies were not *suggestive* of any correlation between blood-trail and broadhead cut area, cut volume, or number of cutting blades. With a vastly increased amount of data perhaps more clearly defined answers will be found.

## Comments on arrow penetration

When guiding rifle clients in Africa, one requirement was that the rifle 'in hand' must, at all times, be *fully adequate* for the largest game "on ticket". One never knew when a warthog stalk might unexpectedly become a buffalo hunt (elephant; lion; substitute what you like). If the opportunity was to be capitalized upon, the client had to have 'in hand' an *adequate* rifle, by both law and logic. It mattered not that the client brought a .458 to use on buffalo if it was now back at the hunting car, or in the hands of a tracker some hundred yards behind. Often it was a 'now-or-never' opportunity. That same rule I apply to bowhunting: have equipment 'in hand' adequate for *anything* one *might* be asking of it.

One study goal is to provide a foundation for the bowhunter to make an informed decision on what arrow components to select, based on game hunted, bow efficiency and hunt conditions. Advance knowledge of the *likely outcome* of a specific shot, on a specific size of game, also helps the bowhunter decide what shots he should, or should not take with his particular setup.

There is no penalty for having "too much" penetration, but the consequences of "too little" can be heartbreaking. Robert Ruark's book immortalized the phrase, "Use Enough Gun". "Use enough" applies to every hunting weapon. It is becoming ever clearer that the arrow one uses is far more important in outcome penetration than the bow one uses. Unlike many other variables influencing the hunting shot's outcome: unseen obstacles; misjudged ranges; shooting position; 'nerves'; animal reaction and speed; etcetera, the hunting arrow chosen is a factor over which every bowhunter has *absolute* control.

Though the above may sound like the 'wrap-up' for this year's updates, it is not. One article remains. Though mentioned, its topic has not been presented previously. Data *suggesting* its existence has been present since the first Natal Study. The data is now substantial enough to corroborate its existence and warrant its presentation.

## References

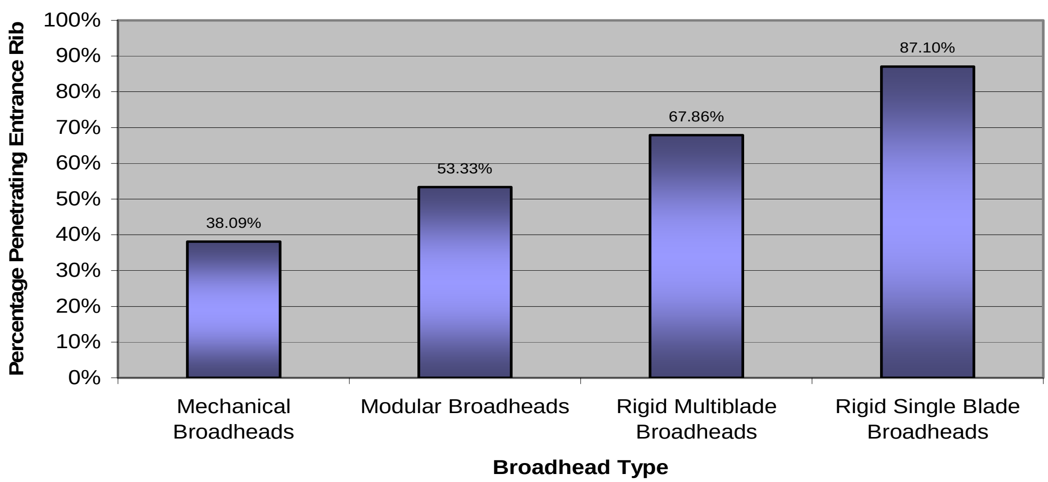
[1] Hain JR, 1989 "Fatal Arrow Wounds", *Journal of Forensic Science*

[2] Gregory NG, 2005 "Bowhunting Deer", *Animal Welfare*, *Universities Federation for Animal Welfare*, The Biotechnical and Biological Sciences Research Council and The Royal Veterinary College

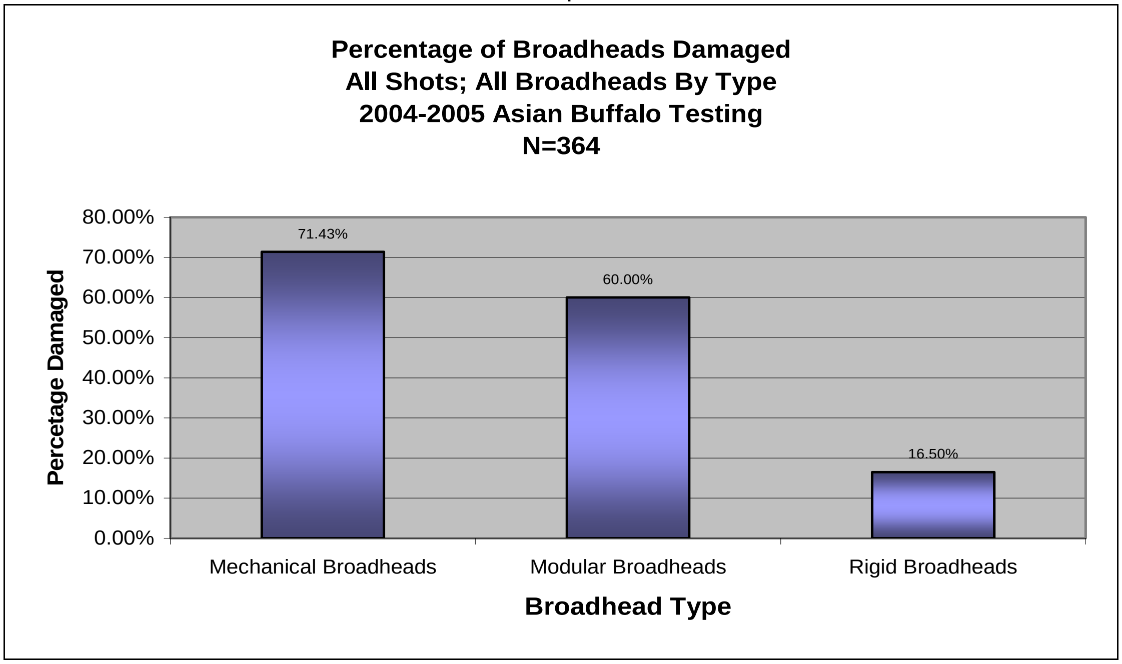
Chart 8
Average Penetration, Impact-kinetic-energy and Impact-momentum
All Shots
2004-2005 Asian Buffalo Testing
N = 364

| Broadhead Type | Avg. Penetration | Avg. Impact KE | Avg. Impact-momentum |
|---|---|---|---|
| Mechanical Broadheads | 7.32" | 50.74 | 0.47 |
| Modular Broadheads | 9.23" | 45.25 | 0.46 |
| Rigid Broadheads | 11.41" | 34.76 | 0.49 |

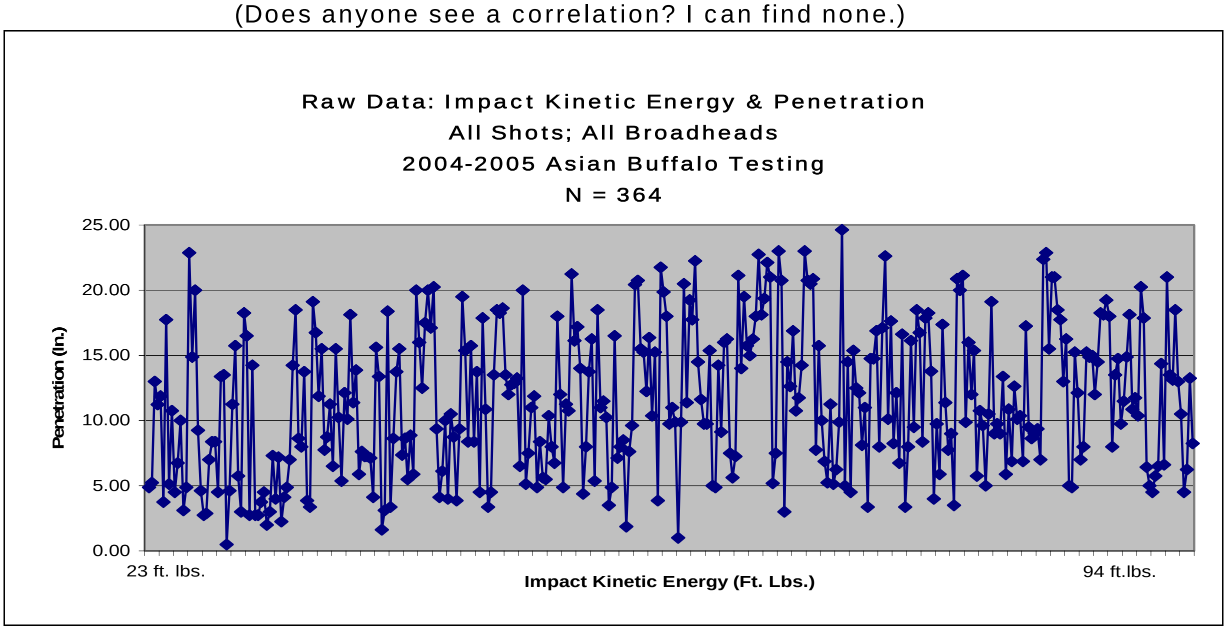
Graph 5
Percentage of Shots Penetrating Entrance Rib: by Broadhead Type
**All Shots Impacting Entrance Rib; All Broadheads**
**2004-2005 Asian Buffalo Testing**
**N=224**



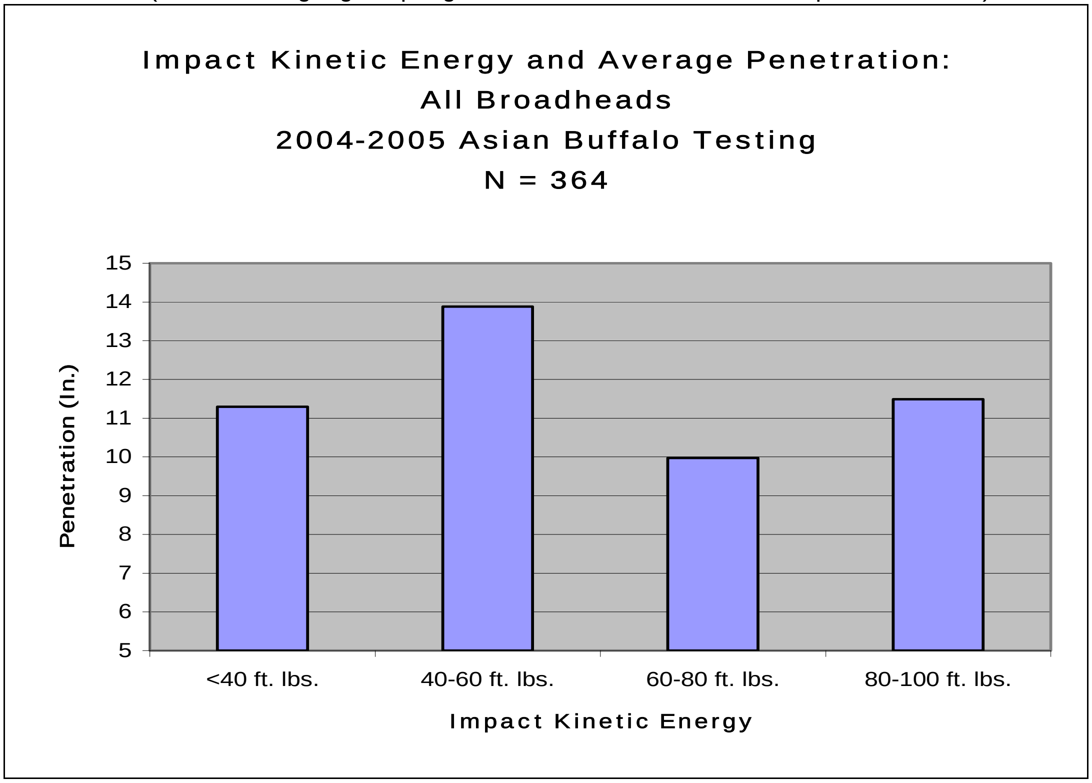
Graph 6



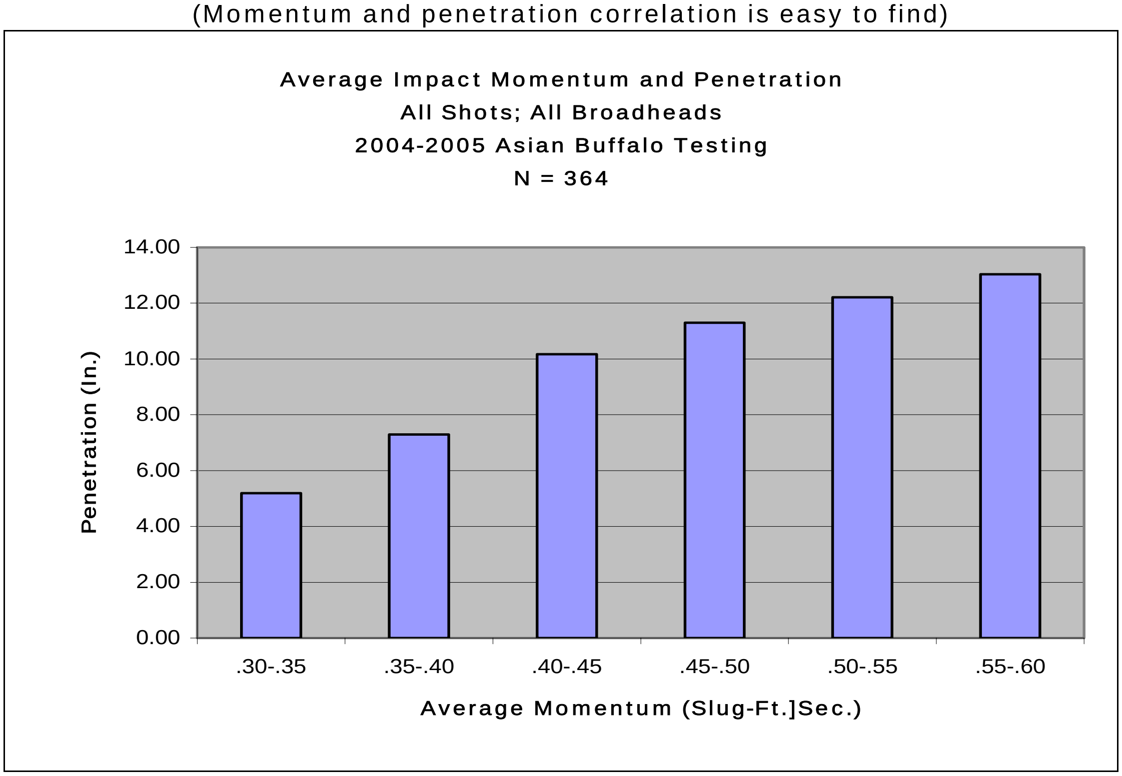

Graph 7
(Does anyone see a correlation? I can find none.)



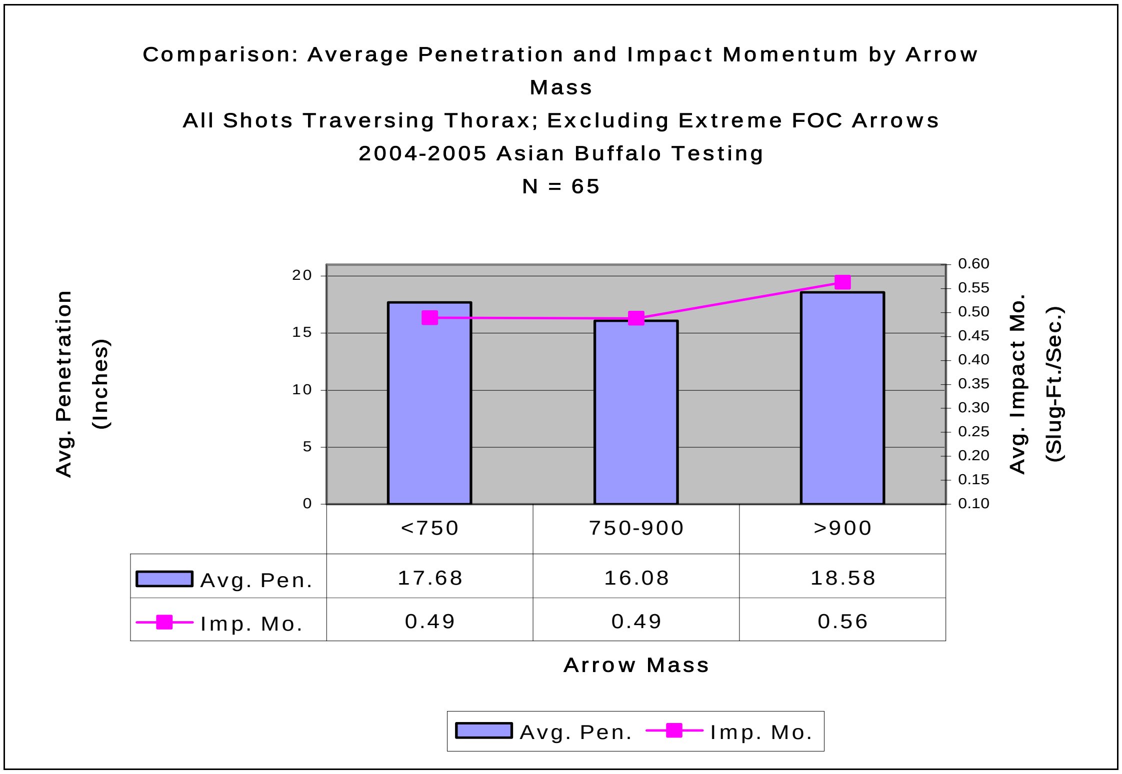
Graph 8
(No KE range grouping shows a correlation with penetration.)




Graph 9
(Momentum and penetration correlation is easy to find)

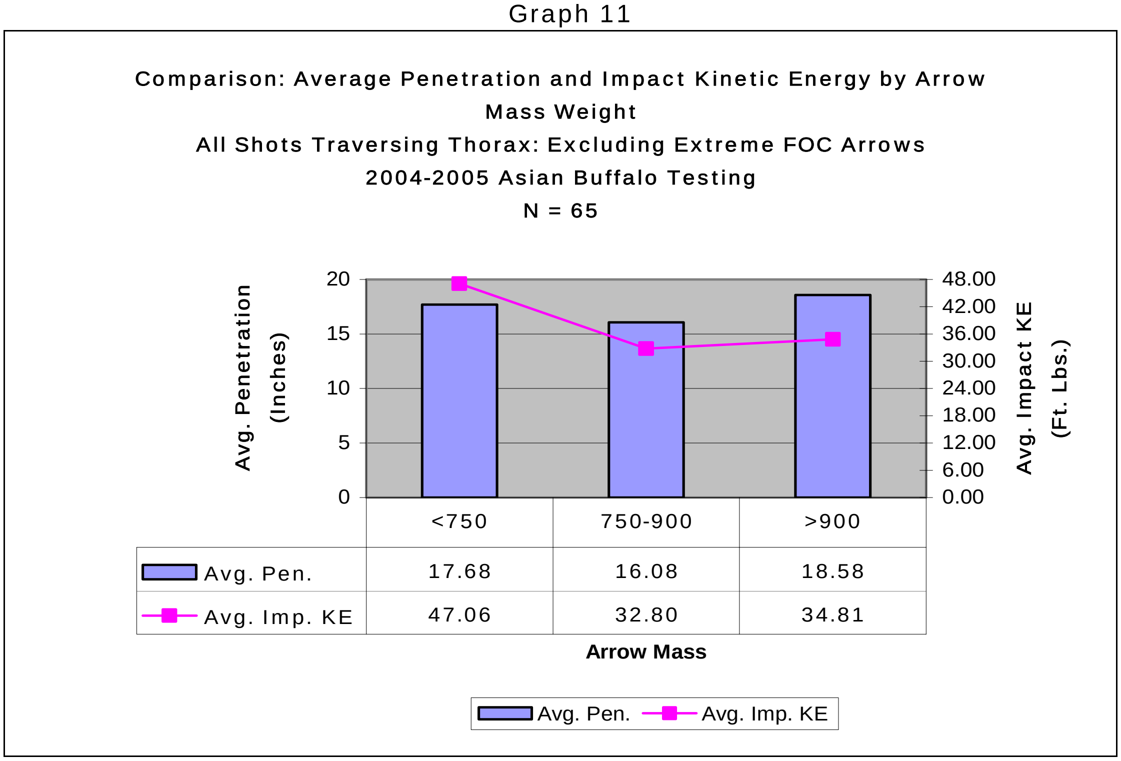


Graph 10




| | <750 | 750-900 | >900 |
|---|---|---|---|
| Avg. Pen. | 17.68 | 16.08 | 18.58 |
| Imp. Mo. | 0.49 | 0.49 | 0.56 |

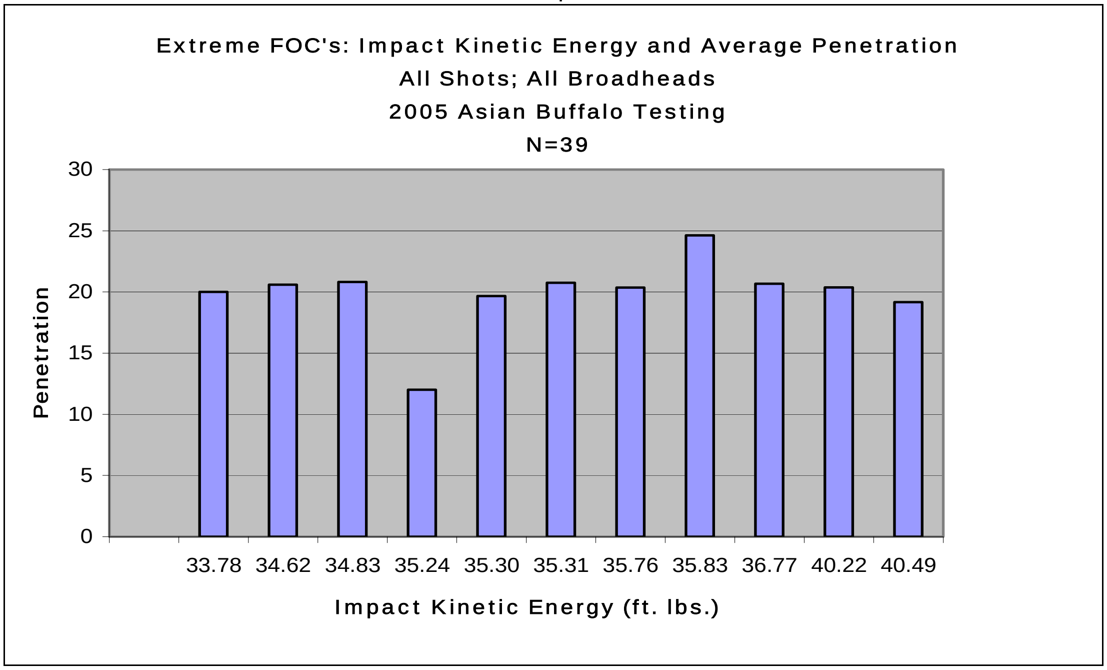
Graph 11




| | <750 | 750-900 | >900 |
|---|---|---|---|
| Avg. Pen. | 17.68 | 16.08 | 18.58 |
| Avg. Imp. KE | 47.06 | 32.80 | 34.81 |

Graph 12




Graph 13