

Arrow Lethality Study Update - 2005

Part V

By

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Summary Overview: Trends, Tendencies, FAQ's and Comments.

Chart 8 is a summary of average penetration for all broadheads tested, by broadhead type: mechanical broadheads, modular (replaceable blade) broadheads, and rigid broadheads. Considering all 364 buffalo "test shots" (which excludes some of the "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.

The test shots with mechanical broadheads 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 shot data contains 9.5% scapular hits; modular broadheads 16.7%; and rigid broadheads 19.5%. In other words, the rigid broadheads penetrated significantly better despite having a higher percentage of use on more difficult shot impacts.

Graph 5 is for all shots impacting an entrance side rib, and shows the percentage of shots penetrating the rib; by broadhead type. The data excludes shots striking any other bone, such as the scapula, before encountering an entrance rib, but does include all angular impact rib shots.

In evaluating Graph 5, consider that all shots with mechanical broadheads (100%) are from broadside, and have a perpendicular angle of impact. Modular broadhead data includes 57.7% broadside shots and 43.3% shots quartering from the rear (qfr) at an impact angle of 20°. Rigid multiblade shots include 10.7% qfr at 45°; 7.1% qfr at 20°; and 82.2% broadside shots. Rigid single blade data includes 9.7% qfr shots impacting at 45°; 9.0% qfr at 20°; 3.2% qfr at 15°; and 78.1% broadside shots. The findings depicted in Chart 8 and Graph 5 are consistent with data from prior studies.

Graph 6 depicts the percentage of broadheads damaged; by broadhead type. Though no direct correlation can be drawn between the Asian Buffalo testing and earlier studies, except Cape Buffalo testing, the similarity to earlier findings is striking. Mechanical broadheads did not (commonly) exist when

the original Natal Study was conducted, but the current study's damage rate for modular broadheads is 60%, and was 64% during the Natal Study. The current study's damage rate for rigid broadheads is 16.5%. In the Natal Study, rigid broadheads were divided into single and multiblade broadheads, but rigid single blades showed a 15% damage rate, while rigid multiblade heads had a 50% damage rate. The rigid multiblade heads in the current buffalo testing are only those that have been at the top of their category in previous testing; the best of the multiblade broadheads tested; or new designs not previously tested, but highly recommended for inclusion in the study by many who have used them, such as the Wensel Woodsman.

The study continues to examine kinetic energy, momentum and arrow mass, and how they relate to outcome penetration in tissues. Though a highly complex subject, these, along with an understanding of the resistance forces involved, are the most important aspects of the study; the basic forces determining an arrow's ability to penetrate real tissues.

As has been the case with prior data, no correlation trend between arrow kinetic energy and penetration can be established. To clearly bring this lack of relationship to the reader, Graph 7 presents the 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 for the 364 shots were tried; from 5 ft.-lb. increments to 20 ft.-lb. increments. Graph 8 illustrates the averaging in 20 ft.-lb. increments, and compared to the average penetration. Neither this nor any other cluster groupings show a definable relationship between kinetic energy and penetration.

A 'penetration peak' shows in the 40 to 60 ft.-lb. impact kinetic energy range of Graph 8. The peak is a result of most heavy arrows falling within this group; with the balance falling below the 40 ft.-lb. level. A major goal of the buffalo 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-ft./second and average mass of 793.7 grains. The averages for the other groups are: 0.52 slug-ft./sec. and 799.8 grains for the 40-60 ft.-lb. group; 0.51 slug-ft./sec. and 483 grains for the 60-80 ft.-lb. group and; 0.57 slug-ft./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 only exceeds the less than 40 ft.-lb. group's penetration by 1.7%! This paradox results from the different 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 the resultant momentum is very 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 penetration in tissues. Arrow mass, through its contribution to the momentum, is the prime determiner of *how long* the force is applied to the tissues. The importance of the time factor in the applied impulse of force is clearly discernable.

Graph 9 illustrates the impact momentum for all 364 shots; grouped into .05 slug-ft./sec. 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 penetration in tissues.

Graphs 10 and 11 contain data on all 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. The sample size is small, especially in the less-than-750 grain grouping. Few arrows of less than 750 grains mass managed to traverse the thorax.

Graph 10 shows the characteristic positive correlation of momentum and penetration. In Graph 11, impact kinetic energy and penetration show, if anything, an inverse correlation tendency.

The 750-900 and greater-than-900 grain groupings of Graph 10 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 per second. If these two groupings are combined the 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. The correlation between impact momentum and penetration shown in

Graph 10 is very close; near one-to-one; 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 very good flight characteristics.

As Graph 9, for all shots, showed, the positive correlation trend between momentum and penetration holds even when a multitude of variables are introduced, such as: all broadheads; all shaft materials and profiles; all shaft-diameter-to-ferrule-diameter ratios; all levels of impact kinetic energy; and even the drastic variation caused by bent and broken broadheads. When record numbers are sufficient, the variances are 'smoothed out' in the averaging. All that changes is the *degree* of correlation between impact momentum and outcome penetration. The degree of correlation is a function of the time component of the impulse of force; and arrow mass is the prime determiner of the impulse's time component.

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 only appears when a single arrow setup is considered. In this situation the average penetration does increase with an increase in impact kinetic energy, but the increased velocity required to yield higher kinetic energy has also increased the arrow's momentum.

The penetration increase with a given arrow does not show a proportional relationship (mathematically, this means "having the same or a constant ratio") with the increased impact kinetic energy. Rather, it shows *decrement*; the rate of penetration increase decreases as the impact kinetic energy increases. In other words, the *amount of gain* in penetration becomes smaller each time the impact kinetic energy is increased by a set percentage. In our 'given arrow' example, the penetration increase correlates closely with the arrow's increased impact momentum; as was the situation shown in Graph 10, where all arrows have very similar characteristics.

Frequently Asked Questions

How is the Study funded; who is "backing" the Arrow Lethality Study? The study is entirely self-funded, and over \$300,000 dollars of personal expense has been incurred conducting the

studies, *thus far*. 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.

Virtually all equipment tested is either personally purchased or donated to the study by other interested bowhunters. A very few 'one off'; prototype, if one prefers; broadheads tested 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. Other than those exceptions, all expenses are 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.

Some African countries have laws requiring specific levels of output kinetic energy, as well as draw force, in order for a particular bow/arrow combination to be legal for specific classes (sizes) of game. Such laws ignore other, much more relevant factors influencing terminal arrow performance. Might the same thing happen elsewhere?

Requests for input have been received from game councils seeking criteria for setting minimum equipment requirements for bowhunting. The last request was very specific. The firearms law required a rifle of at least .243 caliber, generating at least 1500 ft.-lbs. of muzzle energy, for deer. They were seeking similar, easy to legislate, specifications for bowhunting equipment.

The reply was long and, hopefully, educational. Included were copies of pertinent information from study reports. The mechanisms by which arrows kill are different. The bow is the least important part of the arrow lethality question. Though data for terminal performance of hunting arrows on real animals is substantial; compared to what was available only a few years ago; it is miniscule compared to that available for firearms. One thing is clear; arrow kinetic energy has no validity as a "predictor" of the ability of an arrow to penetrate tissues, or to 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 a higher level of impact momentum; with a 782 grain arrow than did a modern, 70#, reflexed, deflexed, Tonkin Cane cored, longbow. In light of such information, would a law requiring a minimum draw weight of 60# for hunting moose, or the big bears, be logical? No. How about 55#? A 45# ACS-CX out-performs most 55# "traditional" bows using arrows of like mass; and I suspect that a 40# version would equal most.

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 conceived and founded legislation restricts highly effective bowhunting equipment from the field, while often promoting use of equipment shown to be less effective. Such laws prevent some individuals from qualifying to hunt; those without the physical abilities to use equipment legislated as 'minimums'.

A great example is the data emerging from the Extreme FOC arrow testing. Early findings are *extremely suggestive* that their use *may* allow very light draw weight bows to give terminal arrow performance equaling, or exceeding, some of the 'heavier' equipment requirements currently in place, 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 truly "sharpening challenged". It is far better for them to use a sharp, replaceable blade broadhead than a "best quality" broadhead that is not sharp. Those preferring to use 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 the bow generated impact-force I plan to be using on any given hunt, where their penetration is adequate on all *potential* hits, for the largest game that *might* be encountered on a hunt, I like to use wide cut single blade broadheads. The Deadhead is a favorite broadhead for the lighter built big 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. The same applies for multiblade broadheads.

How does the study benefit "the average bowhunter"? The arrow design factors affecting outcome penetration are the same,

regardless of the size of the big game animal one hunts. Some individuals feel that the Arrow Lethality Studies, thus far, contain no information pertinent for those who only hunt lesser species; such as deer sized game. This is far from true. Measure the thickness of the *scapular ridge* of a deer, or the head of the humerus bone. These are heavy bones. Even the scapular flat of many commonly hunted species qualifies as "heavy bone"; elk, moose, big bear, etcetera.

Often one hears, "Just shoot them in the right place and one does not need great penetration." I have never met a highly experienced bowhunter who claims he/she has never hit an animal "in the wrong place". In a hunting situation, both the target and the environment are dynamic. Because of the mutability of a hunting shot, no bowhunter has absolute control over all aspects of the shot. Bad hits do, and will, happen. Using equipment that maximizes the arrow's "penetration potential" often converts such hits from a 'lost animal' situation one having a 'happy ending'.

Some hold the view that no arrow is a 'bone breaker'. This also is not true; especially on the lighter-built big game species. Will any 'usable' arrow always break every heavy bone it hits? No. There are too many variables; impact angle; arrow skip; and a host of other possible influencing factors. Will any rifle bullet? I've seen solid (non-expanding) rifle bullets; fired from calibers fully capable of penetrating through an elephant; glance off *relatively* light bone when the impact angle was too acute. Because such a rifle bullet; or arrow; fails to penetrate heavy bone under every possible condition, does it mean that they are not 'bone breakers'; or that it is of no importance to use one that penetrates heavy bone with the highest possible frequency? Of course not.

Who benefits most from using arrows designed for maximum penetration? Defining the factors which maximize arrow penetration is of greatest benefit to bowhunters at the extreme ends of the spectrum:

- 1) Those using relatively light equipment on the 'standard' big game animals.
- 2) Those who hunt the larger game species.

But there are also benefits for the average bowhunter, using average equipment. The use of arrows which maximize 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 "worse case" shot/hit scenarios; a shot impacting

a heavy shoulder bone, or a shot requiring an extreme degree of penetration in order to reach the vital organs.

What good does it do to have so much penetration that 'normal hits' end up with the arrow sticking in the dirt after passing through the 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 increase is so vital that first-responders are advised to *never* attempt removal of the shaft from such 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? A great many factors affect the degree of blood-trail left by an arrow wound. The degree of blood trail has been tracked in previous studies. A concerted effort is underway to develop an extensive tracking/reporting system to uniformly quantify the degree of blood trail left by different types of arrow wounds (as well as a number of other factors which may influence the recovery/loss rate for arrow-shot animals, such as: 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). A number of individuals, using a wide verity of equipment/arrows/broadheads are involved in collection of data for this extensive 'focal study'.

Data from the previous studies is *strongly suggestive* that the degree of blood-trail (relative to existing environmental conditions) is dependent only upon: (1) where the entrance wound is located; (2) the presence or absence of an exit wound; (3) the location of any such 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 need to be added to this list. (The effect retained arrow shafts may have on blood-trail outcomes is also being looked at in the new blood-trail study.) In the initial studies no correlation could be found between cut area, cut volume or number of cutting blades and the resultant degree of blood-trail. With a vastly increased amount of data perhaps some clearly defined answers can be found.

Comments on arrow penetration

When guiding rifle clients in Africa, one of our requirements was that the rifle they had 'in hand' must, at all times, be *fully adequate* for the largest game "on the ticket". One never knew when a stalk on an impala or warthog would suddenly turn into a chance to take a Cape Buffalo. If the opportunity was to be capitalized upon, the rifle 'in hand' had to be adequate to take the shot; by both common sense and the law!

At that instant in time it mattered not that the client had brought along a .458 or .500 double rifle to use on their buffalo (elephant; hippo; lion; substitute what you like); which was now in the hands of a tracker, some hundred yards behind. It was often a 'now-or-never' situation. I apply the same rule to bowhunting; have equipment 'in hand' adequate for *anything* I *might* be asking of it.

One study goal is to determine performance parameters of various arrow components. Such information expands our understanding of how different arrows function during tissue penetration. This provides a foundation for the bowhunter to make an informed decision on what arrow components to use, 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 having "too little" can be heartbreaking when a shot goes awry. Robert Ruark's book immortalized the phrase, "Use Enough Gun". "Use enough" applies equally to every hunting weapon.

As more is learned about the terminal performance of hunting arrows it is becoming ever clearer that the arrow one uses is a far more important factor in outcome penetration than the bow one uses. Unlike 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 as if it is the 'wrap-up' for this year's updates, it is not. There is one more update article in the series. Though it has been mentioned, its topic has not been presented previously, though data *suggesting* its existence has been present since the first Natal Study. Data is now substantial enough to corroborate its existence and warrant its presentation.

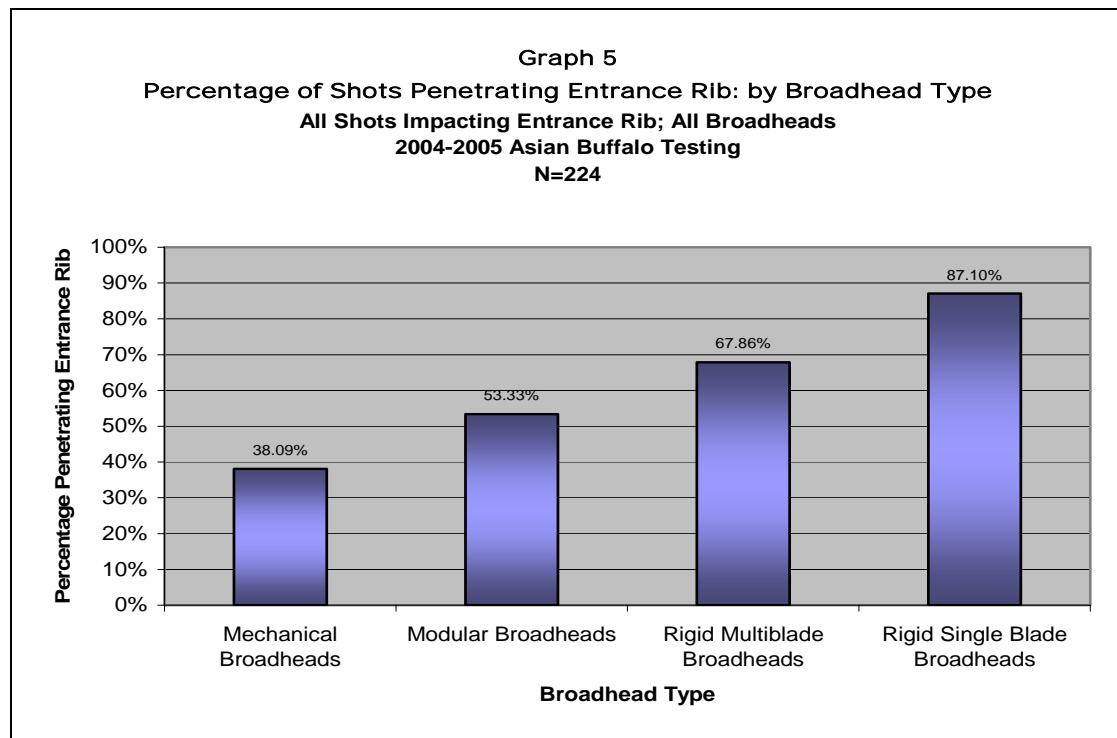
References

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

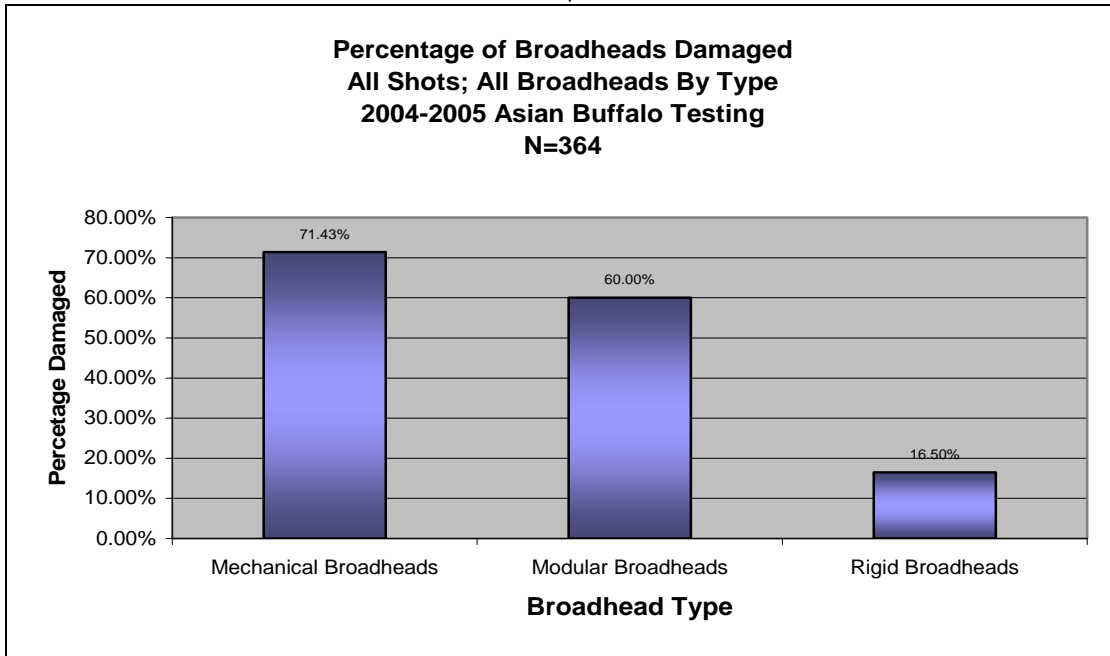
² Gregory NG, 2005 "Bowhunting Deer", *Animal Welfare, Universities Federation for Animal Welfare, The Biotechnical and Biological Sciences Research Council and The Royal Veterinary College*

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

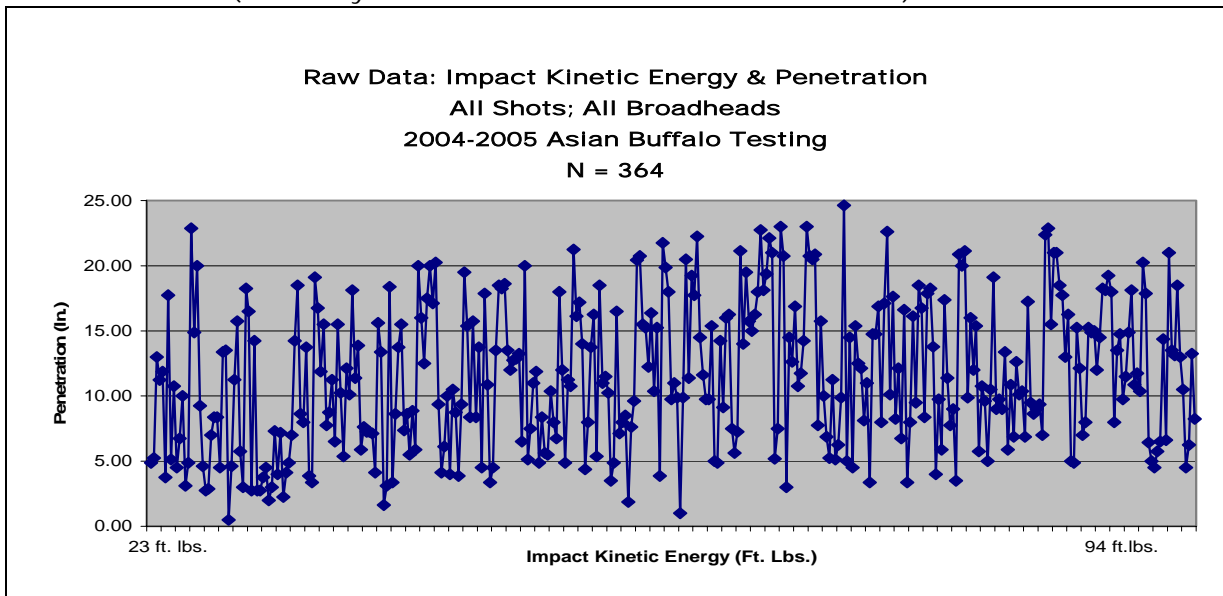


Graph 6



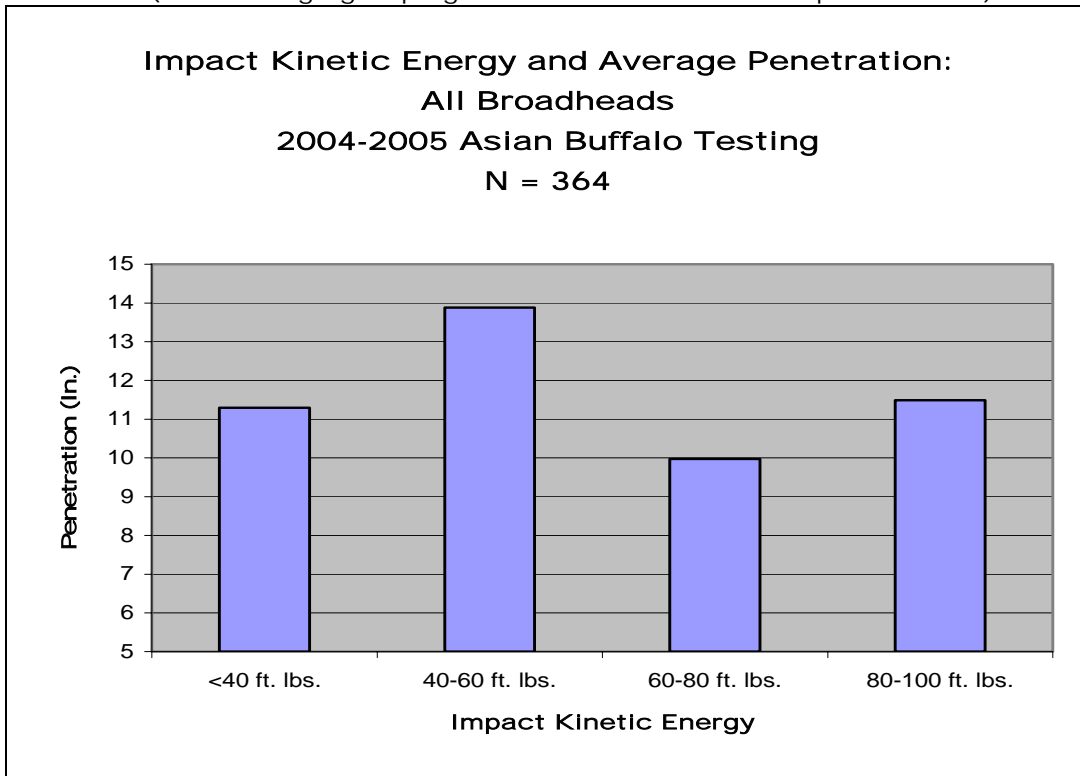
Graph 7

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



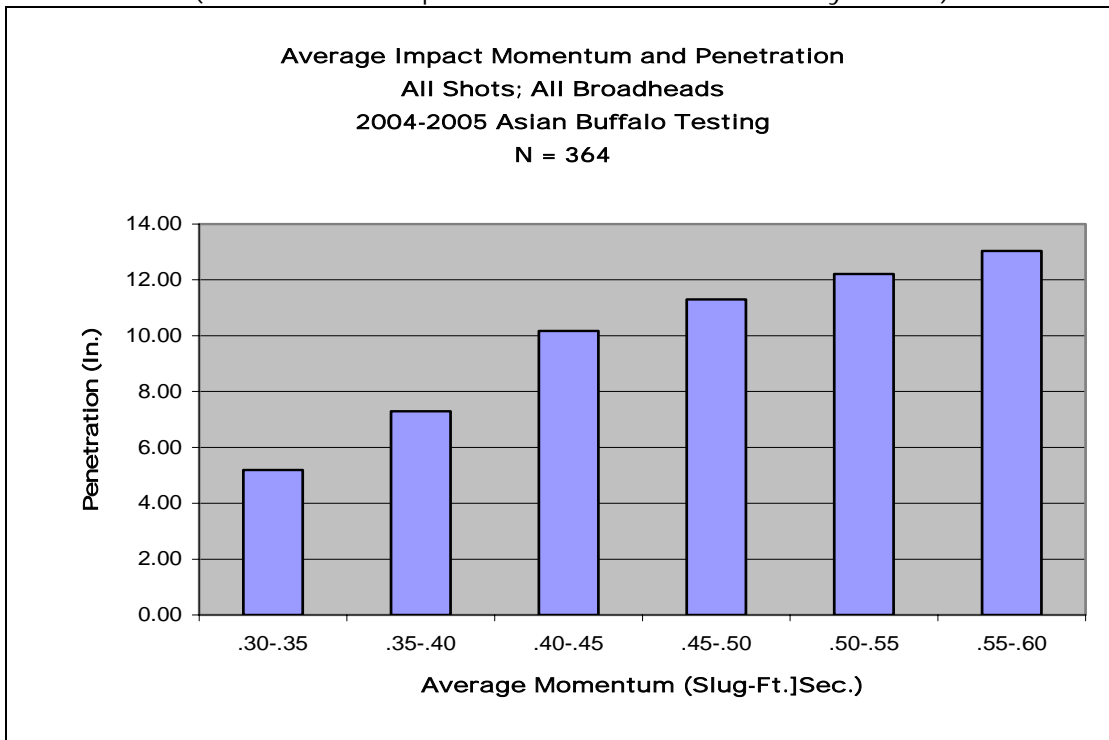
Graph 8

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

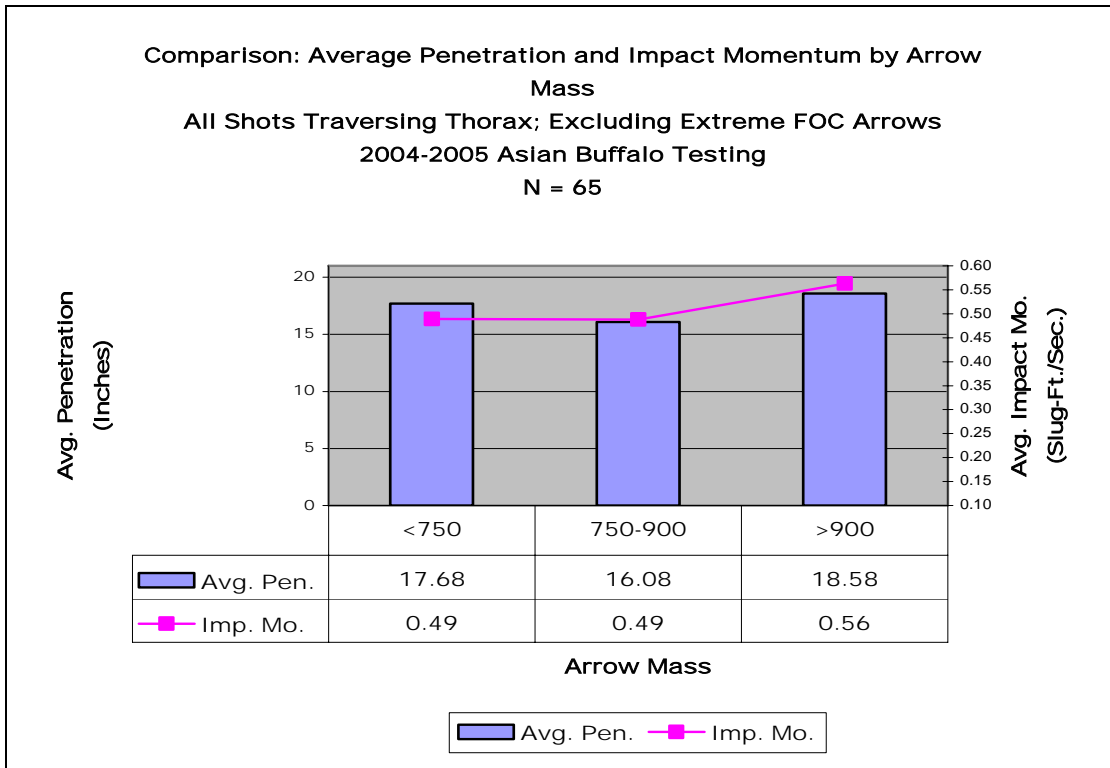


Graph 9

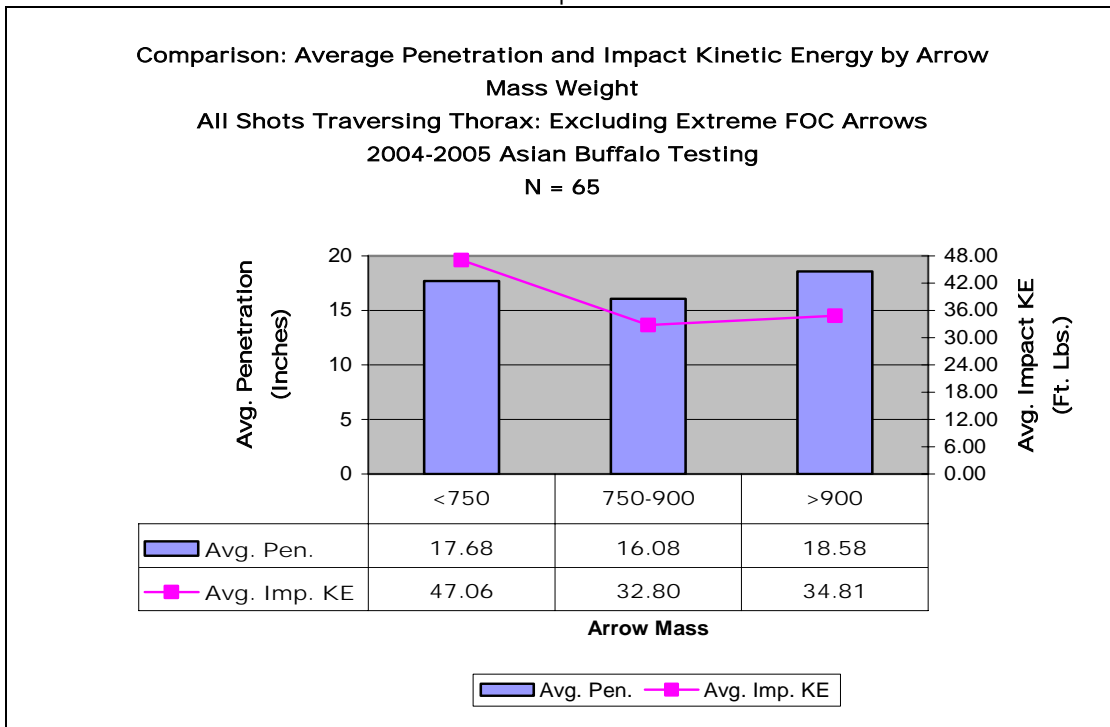
(Momentum and penetration correlation is easy to find)



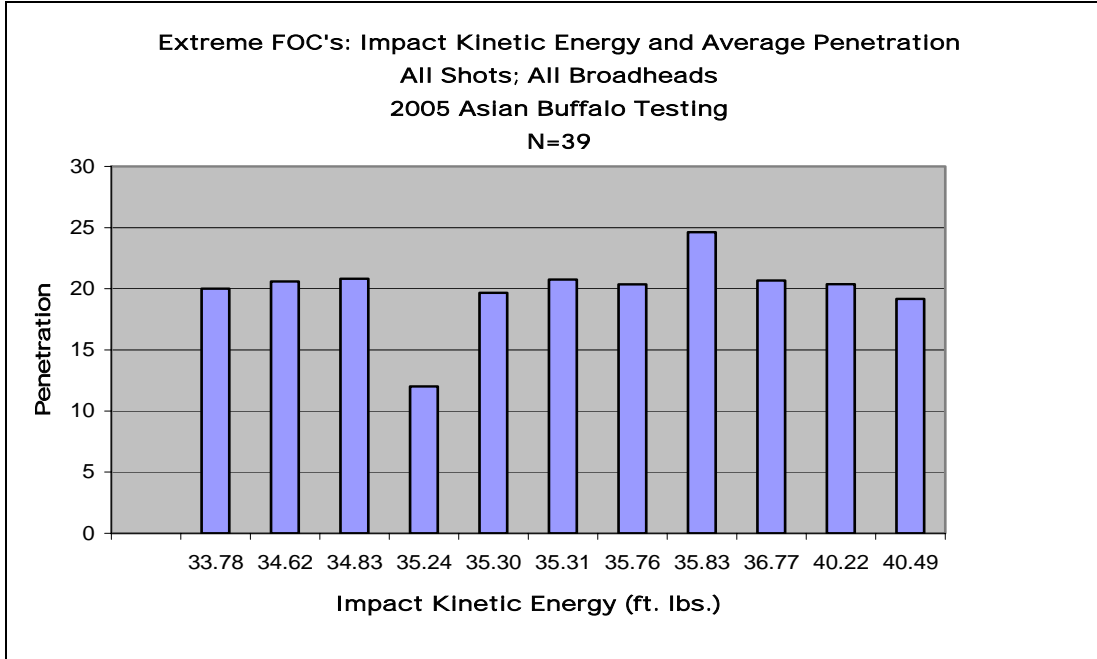
Graph 10



Graph 11



Graph 12



Graph 13

