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Ballistic Firearms Training Center

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[TERMINAL HANDGUN BALLISTICS]

Terminal handgun ballistics illustrating kinetic energy, momentum, recoil, and bullet energy for self-defense cartridges.

Terminal Handgun Ballistics

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When people talk about stopping power they are really talking about incapacitation; aka knockdown energy or knockdown potential. Knockdown power is thought to be the ability of a bullet to knock down a target; this is not true. Knockdown power is a misnomer; a better phrase to describe this process might be power to incapacitate. The following discussion will reveal how target incapacitation works along with discussions on variables.

Wounds that incapacitate are not necessarily fatal and a fatal wound does not necessarily incapacitate, an exception to this is a brain shot in (CNS –Central Nervous System) T-zone. Incapacitation is accomplished primarily through blood loss (exsanguation), CNS or a psychological response to be being shot. Blood loss and CNS are the primary area of study in this paper.

When close range shooting in a critical incident, the main desired outcome is incapacitation. Stopping the assailant's offensive behavior is the desired outcome. Wound fatality is secondary to incapacitation. Incapacitation is dependent on five factors:

1. **Shot Placement** – shot placement is critical to incapacitation. Shots to non-vital areas of the body are ineffective, with the exception that psychologically a non-vital shot may incapacitate. Shots to the T-zone are more likely to immediately incapacitate than shots into the vital areas of the torso. Fatal shots to vital organs do not necessarily.
2. **Penetration** – The bullet has to reach the CNS (Central Nervous System) or vital organs to accomplish incapacitation. It is estimated that the skin on the exit is equivalent to 4 inches of flesh. Bullets that mushroom early and have low energy may stop before reaching any vital structures. Shots to the body from the side have to travel further to reach vital areas. Bullets that over penetrate can be a danger to innocents. Defensive rounds that penetrate 12" to 15" may be optimal in most cases, but in the case of an obese person they may be totally ineffective. This is a variable that can't be controlled; who will know the size of their assailant or angle of entry?
3. **Wound Channel** – The path made by the bullet is the permanent wound channel. The larger the bullet and the flatter the bullet or mushrooming bullet leaves a larger wound channel; this facilitates greater blood loss providing the penetration has reached vital organs and/or major blood vessels.
4. **Bullet Energy** – The amount of energy a bullet has determines mushroom size and increases the wound channel size. The bullet may pass through a variety of tissue, bone, connective tissue, organs, etc. The elasticity of these tissues can result in additional wound channel damage if the elastic limit of one or more of these structures is exceeded. (e.g. the liver is not very elastic, the temporal cavity formed is inelastic, therefore greater damage occurs in the liver.) Temporal cavity expansion can stretch a structure like nerves causing a stun or deadening effect. Martial artists experience this with punches to nerves that leave an opponent's arm or leg temporarily paralyzed. Pistol rounds typically do not have the energy to cause temporal cavity damage like high powered rifles bullets possess, with the exception of tissues that are inelastic or nerves that are stunned. Temporal

cavity expansion at handgun velocities doesn't tend to damage elastic tissues. The expansion of these tissues is not exceeded and the temporal cavity collapses leaving the wound channel as the only damaged area.

5. **Psychology** – the mental state of the assailant may cause incapacitation immediately when shot even in a non-vital area, but on the other hand, an assailant on drugs may continue the fight with multiple vital hit areas and only stop only once blood loss/pressure dropped to a fatal level. The state of the assailant is difficult if not impossible to determine in the short duration of a critical incident.

Knockdown Power Myth

Good defensive rounds (cartridges) are designed to incapacitate an assailant better than cartridges not designed for self-defense. Many articles exist that discuss the knockdown power of various cartridges. These articles are often inaccurate and mislead readers about what cartridges are best for self-defense. It should be noted there are a multitude of variables that present during a critical incident shooting. Knowing this, the reader should understand that any table, calculation, or gelatin ballistic tests are only empirical data upon which one can base an understanding of terminal ballistics. There is however, some science based data on terminal ballistics that can be duplicated with correlating results by independent investigators.

To illustrate a scientific approach, a comparison can be made between a couple of common self-defensive rounds and the dropping of an equivalent heavy weight from a known height to prove knockdown power is a myth. This requires some basic physics and algebra to prove this point.

First, let's discuss basic kinetic energy and momentum to understand the meaning and use in terminal ballistics. During this discussion the following self-defense cartridges will be used along with a 30-06 hunting cartridge to make comparisons.

Self-defense cartridges used in this discussion:

9MM, 115 grain TMJ bullet, ballistic coefficient (B.C.) 0.177, bullet velocity at 21 feet from muzzle at 1088 fps

45 Auto, 230 grain TMJ bullet, ballistic coefficient (B.C.) 0.195, bullet velocity at 21 feet from muzzle at 856 fps

Kinetic Energy

Let's first calculate kinetic energy for the bullet at 21 feet.

Kinetic Energy (ft-lbs) = $(w \times v^2)/2g$ 'w=weight in lbs, v=velocity, g=32 ft/sec^2

since the bullet weight is in grains, it is first converted to lbs by:

w= (bullet in grains)/7000 '7000 grains per pound

Substituting our out data for the 9 MM data: 115 gr., 1088 fps results in:

w=115/7000

w=0.01643 ‘Remember w=115/7000

K.E. = $(0.01643 \times 1088^2)/64$

K.E. =304 ft-lbs of kinetic energy‘Kinetic Energy

Theoretically, this implies that a bullet striking an object weighing 304 pounds would be moved 1 foot. This assumption is incorrect as K.E. is a scalar quantity that has magnitude but no direction. Additionally, this implies total conversion of energy from the bullet to the object, this would not happen as bullets deform, split, mushroom and/or splatter expending energy, etc.

To illustrate this point more clearly lets calculate the K.E. for a 30-06, 30 caliber, 180 grain bullet at 2700 fps.

w=180/7000

K.E. = $(0.02571 \times 2700^2)/64$

K.E. = 2929 ft-lbs of kinetic energy

So, if a 300 lb deer is shot by a 180 grain bullet at 2700 fps the bullet would have 2929 ft-lbs of K.E. The paper calculation below indicates the deer would be moved 9.8 ft. This simply doesn’t happen.

9.8 ft. = 2929 ft-lbs/300 lb deer ‘Paper calculation (remember K.E. is a scalar unit)

If you hunt, you obviously know this is not true. The deer simply flinches when hit in the vital area and runs for a short distance. The amount an object moves is determined by momentum not kinetic energy. So, calculating momentum for this hunting round the follow equation is used:

$mv_1 = mv_2$ ‘$mass_{bullet} \times velocity_{bullet} = mass_{deer} \times velocity_{deer}$

To convert lbs to mass the following equation is used:

m= w x v ‘weight in lbs times velocity equals mass

solving for a 180 gr. bullet at 2700 fps

m= (180 gr./7000 gr./lb) x 2700 fps

m = 69.4 ft-lb/sec

The deer = 300 lbs so using our first equation

69.4 ft-lb/sec = 300 lbs x v 'Using our first equation

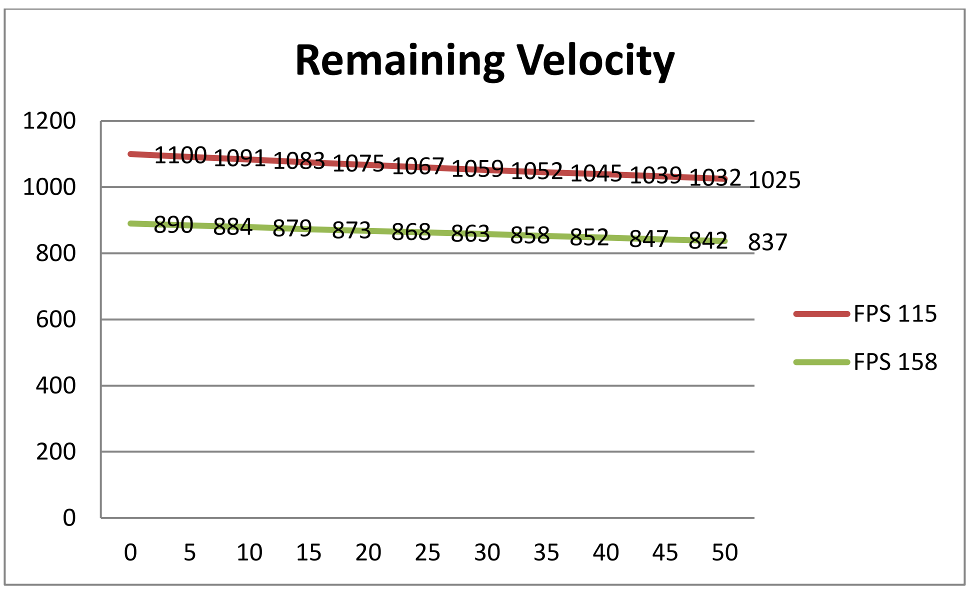
Solving for v = 69.4 ft-lb/sec/300 lbs

v=0.23 fps or 2.8 inches per second, (multiply 12” x 0.23 feet per sec to convert to inches/sec)

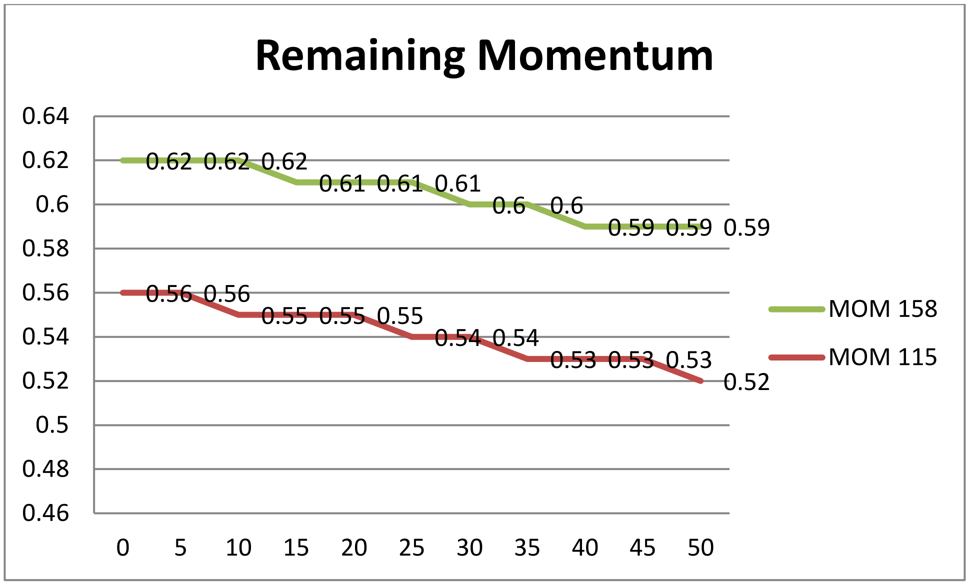
The deer is moved with a velocity of 2.8 inches per second

So, based on this calculation of momentum, 2.8 inches per second correlates with what most hunters see when a deer is shot; not a deer being moved 9+ feet! Momentum is the unit that must be used to understand target movement as it has magnitude and direction. If you have ever seen a steel plate competition or bowling pin pistol match, this is readily understood.

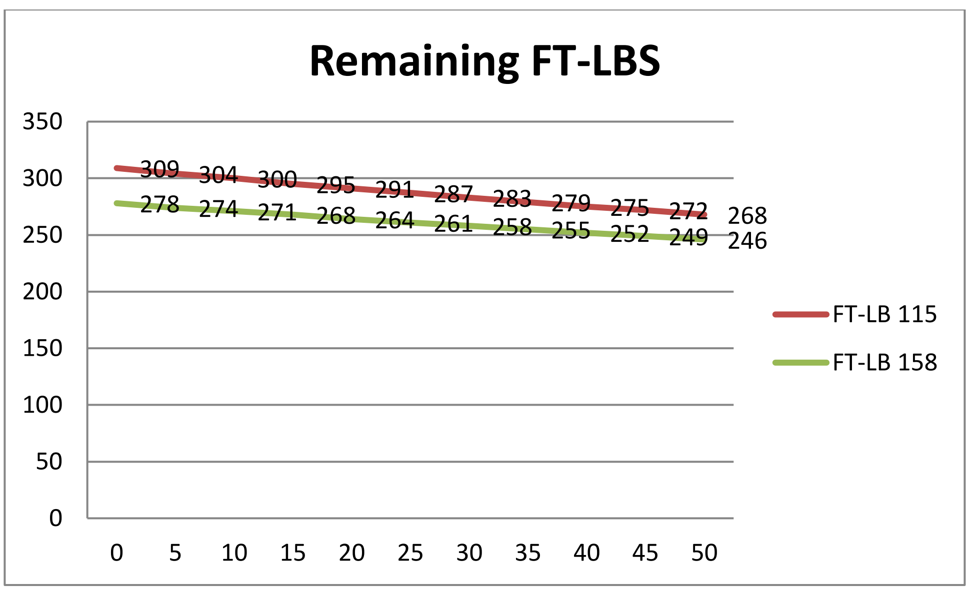
The following examples illustrate the importance of bullet momentum, velocity, and force. In these examples a comparison of two 9 MM bullets is made; a 115 gr.; and 158 gr. bullet.



The graph of remaining velocity illustrates the little difference within 50 yards.



Remaining momentum is significantly higher in the 158 grain bullet versus the 115 grain bullet. The momentum is higher at a lower velocity so the bullet travels through the target the same distance but at a slower velocity.



The remaining ft-lbs/sec of kinetic force is higher for the 115 grain bullet but as discussed earlier it is the momentum that has magnitude and direction.

In actual tests with ballistic gelatin, both 9MM bullets traveled the same distance. However, as seen in this data the 158 grain bullet has a slight advantage in that the bullet takes longer to travel the same distance. Actual shootings (empirical data) have shown the 158 grain bullet to be superior to the 115 grain bullet.

Comparison of a 1 LB Weight with Equivalent Momentum to a 9MM 115 Grain Bullet at 1080 FPS
In the following discussion, a comparison will be made to illustrate two mass having the same momentum but different weights and velocities. The calculations are shown for those who may be interested in how the height of the 1 lb weight was determined to have the same equivalent momentum of the 115 grain bullet at 1080 fps.

Let's determine the mass of a 115 grain bullet and a 1 Lb weight.

Given: 9 MM 115 grain bullet with a velocity of 1080 fps

$mass_{115}$ = (115 gr. /7000 gr.)/32 ft/sec^2

$mass_{115}$ = 0.000513 ***'Mass of a 115 grain bullet***

$mass_{1lb}$ = 1 lb/32 ft/sec^2

$mass_{1lb}$ = 0.031250 ***'Mass of a 1 lb weight***

To find velocity of 1 lb weight using momentum equation and 9MM data

$m_1 \times v_1 = m_2 \times v_2$ **'momentum equation**

$momentum_{115}$ = 0.000513 x 1088 fps ***'Momentum of a 115 grain bullet at 1080 fps***

$momentum_{115}$ = 0.558571 fps ***'Momentum of a 115 grain bullet at 1080 fps***

0.558751 =0.31250 x v_2 **'Finding the velocity of the 1 Lb weight**

or

v_2 = 0.558751/0.31250

v_2 = 17.87 fps ***'velocity of 1 lb weight equivalent to 9 MM 115 grain bullet at 1080 fps***

To find the drop height of a 1 lb weight to equal 17.87 fps the time of the drop is calculated.

$t_{sec} = (v_1 - v_0)$/32 ft/sec_2 **'v_1 the final velocity, v_0 the initial velocity is zero**

t_{sec} = (17.87 ft/sec – 0 ft/sec)/32 ft/sec_2

t_{sec} = 0.558438 ***'total time of drop based on velocity of 1 lb weight from $m_1 \times v_1 = m_2 \times v_2$ equation***

Now the average velocity is found (initial velocity is 0 fps as the weight is not moving at the start of the drop)

$v_{ave} = (v_1 + v_0)/2$ **'v_1 the final velocity, v_0 the initial velocity is zero**

v_{ave} = (17.87 ft/sec + 0 ft/sec)/2

v_{ave} = 8.935 fps **'Average velocity**

Distance traveled is determined by:

$s_{dis} = v_{ave} \times t_{sec}$

s_{dis} = 8.935 fps x 0.558438

S_{dis} = 4.98 ft. **'The height a 1 lb weight would have to be dropped to be the equivalent momentum of 9 MM 115 grain bullet traveling at 1080 fps.**

Final Comparison

So, a 1 lb weight traveling at an average velocity of 8.9 feet per second is the equivalent of a 115 grain bullet traveling at 1080 feet per second. Since this is the equivalent momentum, one can see the bullet based on these calculations would not knock over a 180 lb man. The K.E. of the 1 lb weight at a final velocity of 17.9 fps is 5 ft-lbs. This also illustrates that K.E. of the bullet 115 grains at 1080 fps is not the same as a 1 lb weight at 17.9 fps. The momentum is equal but the K. E. is not! The K.E. is not equivalent because the relationship is non-linear due to the squaring of the velocity in the calculation.

Comparison of a 1 LB Weight with Equivalent Momentum to a 45 Caliber 230 Grain Bullet at 856 FPS

In the following discussion, a comparison will be made to illustrate two mass having the same momentum but different weights and velocities. The calculations are shown for those who may be interested in how the height of the 1 lb weight was determined to have the same equivalent momentum of the 230 grain bullet at 856 fps.

The following calculation determine the height a 1 lb weight would have to be dropped to be the equivalent momentum of 45 auto 230 grain bullet traveling at 856 fps

Given: 45 auto 230 grain bullet with a velocity of 856 fps

$Mass_{230}$ = (230 gr. /7000 gr.)/32 ft/sec^2

$Mass_{230}$ = 0.001027 ***'Mass of a 230 grain bullet***

$Momentum_{230}$ = 0.001027 x 856 fps

$Momentum_{230}$ = 0.878929 fps ***'Momentum of a 230 grain bullet at 856 fps***

$mass_{1lb}$ = 1 lb/32 ft/sec^2

$mass_{1lb}$ = 0.031250 ***'Mass of a 1 lb weight***

To find velocity of 1 lb weight using momentum equation and 9MM data

$m_1 \times v_1 = m_2 \times v_2$

0.878929 =0.031250 x v_2

or

v_2 = 0.878920/0.031250

v_2 = 28.13 fps ***'velocity of 1 lb weight equivalent to 45 auto 230 grain bullet at 856 fps***

To find the drop height of a 1 lb weight to equal 17.87 fps the time of the drop is calculated.

$t_{sec} = (v_1 - v_0)$/32 ft/sec$_2$ **'v_1 the final velocity, v_0 the initial velocity is zero**

t_{sec} = (28.13 ft/sec – 0 ft/sec)/32 ft/sec$_2$

t_{sec} = 0. 878929 ***'total time of drop based on velocity of 1 lb weight from $m_1 \times v_1 = m_2 \times v_2$ equation***

Now the average velocity is found (initial velocity is 0 fps as the weight is not moving at the start of the drop)

$v_{ave} = (v_1 + v_0)/2$ **'v_1 the final velocity, v_0 the initial velocity is zero**

v_{ave} = (28.13 ft/sec + 0 ft/sec)/2

v_{ave} = 14.065 fps

Distance traveled is determined by:

$s_{dis} = v_{ave} \times t_{sec}$

s_{dis} = 14.065 fps x 0.878929

s_{dis} = 12.3377 ft. **'The height a 1 lb weight would have to be dropped to be the equivalent momentum of a 45 auto 230 grain bullet traveling at 856 fps.**

Final Comparison

So, a 1 lb weight traveling at an average velocity of 14.1 feet per second is the equivalent of a 230 grain bullet traveling at 856 feet per second. Since this is the equivalent momentum, one can see the bullet based on these calculations would not knock over a 180 lb man. The K.E. of the 1 lb weight at a final velocity of 28.1 fps is 12.3 ft-lbs. This also illustrates that K.E. of the bullet 230 grains at 856 fps is not the same as a 1 lb weight at 28.1 fps. The momentum is equal but the K. E. is not! The K.E. is not equivalent because the relationship is non-linear due to the squaring of the velocity in the calculation.

Comparison:

A 9 MM 115 grain bullet at 1080 fps is equivalent to a 1 lb weight at 8.9 fps or dropped from 5.0 ft.

compared to:

A 45 caliber 230 grain bullet at 856 fps is equivalent to a 1 lb weight at 14.1 fps or dropped from 12.4 ft.

The 45 caliber 230 grain bullet at 856 fps has greater momentum even though it is traveling slower than the 9 MM bullet. The 45 caliber bullet also loses less momentum over distance traveled. As expected the 45 caliber bullet is more effective self defense round because of these attributes, but also because of its size. The wound channel created by a 45 caliber bullet is larger making it more effective. The bullet also travels slower through the target but retains more energy during the time of travel.

The final comparison of 1 lb weights dropped from heights equivalent to the momentum for each respective cartridge illustrates that the momentum NOT the kinetic energy is what is important. If we compared the K.E. for the 45 auto 230 grain bullet is 376 ft-lbs at 856 fps and the 9 MM 115 grain bullet is 299 ft-lbs at 1080 fps.

Think about the recoil of each handgun and then think about the momentum of the 1 lb weights. Would recoil of 17.8 fps or 28.1 fps seem reasonable? Can you imagine trying to hang onto a handgun with 376 ft-lbs of energy? This is why kinetic energy is so misleading. Again, K.E. is a scalar unit with no direction, but momentum does have direction.

Variables:

Choosing an effective self defense round is not a black and white, right or wrong, choice. There can be a multitude of variables during a critical incident and no one can predict what variables will present. Here are some variables that do need to be considered:

1. Shot place is always the primary key to incapacitation; even a 22 LR can be effective if proper placed but is not recommended as a good self defense round.
2. Proper penetration is necessary to achieve incapacitation; critical incident shootings happen extremely fast, targets move, shot placement may not be optimal (e.g. shots from the side or angular to the body)

3. Larger bullet calibers and hollow point bullets make a larger wound channel. The larger channel facilitates greater blood loss thus, incapacitation in a shorter time. It should be understood that handgun bullet velocities may not provide sufficient velocity to mushroom hollow point ammunition. In fact, varying tissues, cartilage, and bone may interfere with the process.
4. Larger bullets retain momentum and are more effective than lighter bullets which lose momentum more quickly.
5. The target has to be engaged as it is seen with little time for target assessment. Body types vary, thin, obese, muscular, etc.
6. Weather changes during the year can present issues. Is the weather extremely cold, do people wear heavy coats and layers of clothing? Summer months are the opposite; very light clothing. How does this effect penetration or over penetration?

Conclusion:

When it comes to bullet selection for self-defense there are too many variables to definitively determine the best caliber and ammunition for all situations. At best, caliber and ammunition selection is based on the aforementioned primary variables. Some key points are:

Shot placement is critical to incapacitation. Large caliber hollow point bullets with heavier grain weight at higher velocities are better suited to self-defense. The bullet retains momentum and creates a larger wound channel. The bullet velocity should be high enough to provide 12” to 15“ of reliable penetration. This can be tested on ballistic gelatin for an empirical evaluation. This test is empirical in the sense that it doesn’t replicate varying tissue densities, connective tissues, cartilage, and bone structures.

The selection of self-defense ammunition should be tempered by the constraints to shoot a large caliber cartridge effectively (shot placement). Hollow points should be selected on the basis of construction and use for self defense usage. Manufacturers have improved hollow point ammunition (however, don’t count on expansion, but, if it does expand it is an advantage) to facilitate passing through clothing before expanding the body.

Self-defense ammunition and/or gun selection may change due to environmental factors that affect self defense carry and penetration. Heavy clothing versus lighter clothing during changing seasons may require changes in guns and ammunition alternatives to effectively carry concealed.

While there is much focus on ammunition, there should be more on emphasis on training under stress. Given all the information above, none of it alone is a substitute for poor performance (shot placement) under stress. Also, given the fact that most self-defense situations by their nature are a reactionary requires effective training to make up the time deficient for effective defense.

Gun selection, ammunition selection, and the type of training taken; reinforced through regular practice make an effective self-defense regiment. What is put into training come out in self-defense; nothing more, nothing less.