SILHOUETTE AND BALLISTICS

Here are some generalities about ballistics.

1°) Internal ballistics:
Should the bullets we are using today be shot through a smooth bore, they would adopt an erratic trajectory and would finally tumble. To be stabilized, an elongated projectile must have a minimum rotational speed by length unit, specific to its diameter and length.
For a given diameter, the more the bullet is long, the more the rotational speed with regard to the displacement must be high to stabilize it.
It is the rifle twist which determines this rotational speed. The more the twist is "elongated" (slow), the more the rotational speed is low. Long bullets (heavy for a given caliber) need a short twist (fast).
A mathematician of the 19th century designed a formula which bears his name (the Greenhill formula). It gives the maximal length of a bullet stabilized by a given twist. A bullet longer than this value will tumble somewhere on its trajectory. It is one of the reasons why a handload accurate at 50 meters is not necessarily accurate at 200 meters. The Greenhill formula was designed for lead bullets but its results are valid for the current jacketed bullets we use. On the other hand, it does not apply to bullets made of materials having a density very different of the lead density like copper, bronze, aluminum, zinc, impoverished uranium, gold …

$$\text{Greenhill formula: } Bl = \frac{150 \times C^2}{T}$$

Bl = Bullet length C = Bullet diameter T = Twist

All the measurements must be in the same unit.

Example:
Maximum length of a bullet stabilized in a .308" barrel (7.82 mm) with a twist of 1 turn in 10 inches (254 mm):

$$\text{In imperial: } Lb = \frac{150 \times 0.308 \times 0.308}{10} = 1.423 \text{ inch (36.1 mm)}$$

$$\text{In metrics: } Lb = \frac{150 \times 7{,}82 \times 7{,}82}{254} = 36.1 \text{ mm}$$

Some comments about recoil.
Recoil is a physical phenomenon which can be computed. But it is also a subjective sensation felt differently by everyone.
Some people are recoil sensitive, some others are less. The shape of the stock is important too. If the stock is a perfect fit to the shooter, a heavy recoil will not be painful and vice versa.

The recoil begins as soon as the bullet moves. When the bullet exits the muzzle, the firearm has already recoiled.

Recoil is quantified through the momentum equality formula:

Mg x Vg (gun) = (Mb x Vb (bullet)) + (Mp x Sp (powder)) where M are the masses and V the velocities.

The gases mass exiting at high speed behind the bullet must be considered. It was established that the average velocity of the gases is 1430 m/s (4692 fps). The formula becomes:

$$Vg = \frac{(Mb \times Vb) + (1430 \times Mp)}{Mg}$$

Vg = recoiling velocity of the firearm in m/s.
Mb = mass of the bullet in kg.
Mp = mass of the powder in kg.
Vb = bullet velocity in m/s.
Mg = mass of the firearm in kg.

2°) External ballistics:

The more a bullet is elongated (heavy) for a given caliber, the more its ballistic coefficient is high (with the same shape).

For silhouette shooting, select the heavier possible bullets, according to the twist, the case capacity and the recoil. A recoil manageable in Creedmoor position can be painful when shooting standing.

Here is an example with two Sierra bullets commonly used in 357 Magnum:

	Weight	Bal. Coeff.	MV	V 200 m	M 200 m
Sierra 8340	158 grains	0,175	460 m/s	317 m/s	3.25
Sierra 8350	170 grains	0,284	400 m/s	323 m/s	3.56

These values speak by themselves. the heavier bullet, with the lowest muzzle velocity, is the fastest at 200 meters and delivers almost 10% more momentum.

3°) Terminal ballistics:

It is not kinetic energy ($E = ½ M V^2$) which tumbles the silhouettes. It the momentum (Q=MV, M mass of the bullet in kg, V muzzle velocity in m/s, Q momentum in kg m/s) imparted by the bullet.

In theory, about 3 kgm/s of potential momentum is enough to tumble the ram in big bore pistol. Practically, more is needed because the imparted momentum (inferior to the potential momentum) varies with the location of the impact, the quality of the metal sheet the silhouettes are made, the roughness of the metal sheet, the material of the stands (wood, metal, …), etc. And the stands are not always level and the feet of the ram not always perpendicular to the body so the ram is more difficult to tumble.

With a potential momentum over 4 kgm/s, ringers are almost nil. To get this, you don't need a portable howitzer. A 30-20 cartridge loaded with a 150 grains bullet exiting at 520 m/s (1706 fps) is enough.

JPB