Fundamentals of Rifle Shooting

The job of the shooter is to fire one perfectly executed shot!

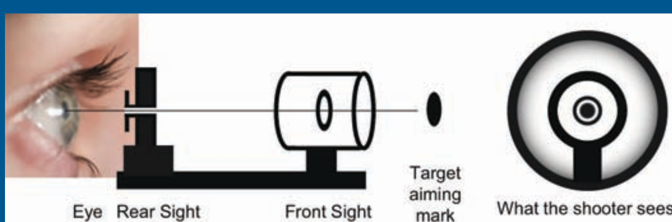
When one analyzes the general process of shooting in competition and what the athlete must do to be successful, it boils down to what we call the "job of the shooter" which is to fire one perfectly executed shot. Then analyze, reset and repeat. The job, as in every other, consists of tasks or skills accomplished in a specific way and general order. When we analyze these tasks, we can break them down to five essential components or fundamentals. Skip one or do it incorrectly and the result is very likely to be less than the acceptable standard.

A fundamental is an essential component of a system that, without it, the system fails or the structure falls. The five fundamentals of rifle shooting are: aiming, breath-control, hold-control, trigger-control and follow-through. For new shooters, learning the fundamental skills correctly provides a strong foundation to build upon, without which, the athlete will not progress as quickly or be able to reach his or her potential in the sport.

Aiming

We begin with the fundamental process of aiming. The most common type of sighting system used in rifle shooting is an aperture or peep rear sight affixed to the receiver, in conjunction with a front sight tunnel attached to the muzzle end of the barrel with changeable or adjustable front sight inserts. The most commonly used front-sight insert is an appropriately sized round aperture although a post insert may be used. Using this type of sighting system makes aiming much easier and more precise than using open sights like those found on pistols with a notch and post.

In order to hit the target consistently, the barrel must be pointed in the correct place. To do this the shooter must align their eye with the rear sight and front sight. The small opening of the rear sight should appear round with the front sight centered in the field of view. The target is not included in the definition of sight alignment.

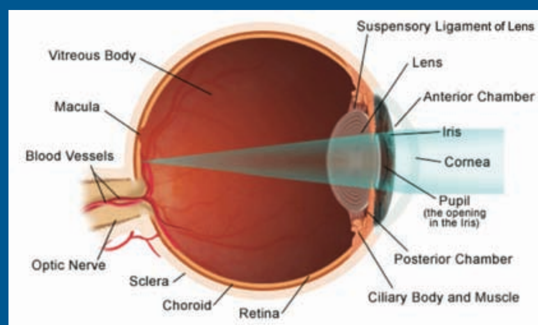


Sight Alignment

Sight picture, on the other hand, is the combination of aligned sights and the aiming point or target. The sight picture shown is an ideal image because the gun is continuously moving and so the aiming point does not stay perfectly still inside the round aperture insert ring. Aiming, then, is the dynamic process of aligning the eye, the rear sight, the front sight and the target. In theory, the aiming method described above seems quite simple and easy to understand. However, when the shooter tries to aim it can prove to be much more challenging as difficulties often arise from the peculiarities of the eye and its use during aiming.

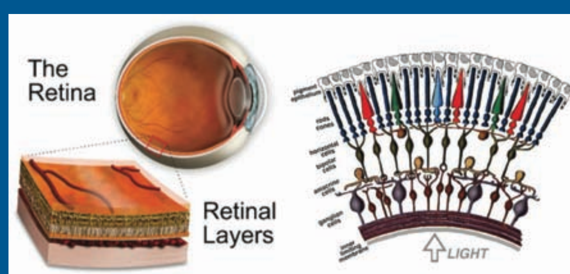
The Eye

Aiming places great demands on the shooter's visual capacity. Accuracy and consistency directly depend on visual acuity and the conditions that determine visual acuity. As the sensory organ, the human eye, coupled with the processing of the brain is capable of distinguishing millions of different colors, shapes, size, brightness and location of objects in the environment. We depend on this sense more than any other of the five senses, especially in the shooting sports, so it is important to know what we are dealing with as we aim.



Eye with Internal Structures

The eyeball is an optical device for focusing light. The front portion of the eye consists of several refractory tissues and surfaces, the cornea, aqueous humor, the iris, which has an opening called the pupil, the crystalline lens and the vitreous humor, through which light passes to stimulate a light sensitive membrane, the retina. The image formed on the retina, albeit smaller and upside down, is converted to nerve impulses by a photochemical reaction and transmitted to the visual cortex portion of the brain via the optic nerve that processes what we see.



Retina Detail with Rods & Cones

In order to see the world around us clearly, the image formed on the retina must be sharp. The normal eye at rest (or relaxed) is focused at infinity, so distant objects appear in focus, but nearby objects appear out of focus. To see closer objects clearly, the ciliary muscle contracts reflexively to change the shape of the crystalline lens to a more convex form increasing the refractive power and bring the near object into focus on the retina. This ability is called accommodation. Distant objects will now be out of focus. The eye cannot clearly focus on objects located at different distances at the same instant. While the reflex action of accommodation can take place quickly (especially in younger people when the crystalline lens is quite flexible) this puts a strain on the visual apparatus and must be avoided.

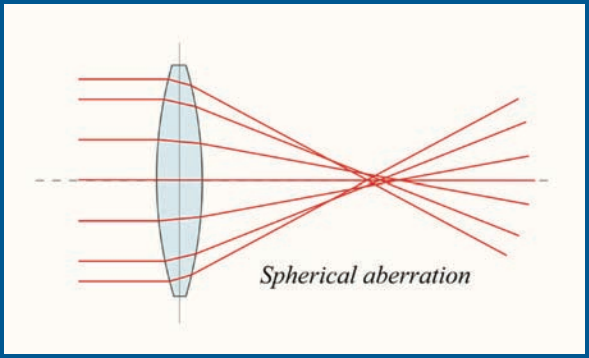
The eye also responds automatically to varying amounts of ambient light, by opening or closing the pupil via another reflexive action of the group of smooth muscles that controls the iris. This dilation or contraction of the pupil, called adaptation, regulates the amount of light entering the eye. The normal pupil opening ranges from a maximum of approximately eight millimeters to a minimum of two or three millimeters. As we age, the maximum opening decreases to six millimeters making it more difficult for older people to see at night. The pupil opening adapts much more quickly to increased illumination (a few seconds) than it does to a decrease in illumination (a few minutes). Therefore, it is critical to avoid looking at brightly illuminated objects before or during shooting, and a major reason flash photography is not permitted during shooting competitions.

The action of the pupil is similar to the f-stop in a camera. The depth of field or the range of distances that the camera (eye) sees as being in focus increases as the f-stop aperture (pupil) size becomes smaller. The artificial pupil of the fixed rear aperture, or an adjustable rear iris, takes advantage of this thereby allowing the shooter to increase the depth of field so all the elements of the sight picture are clearly seen in focus.

Imperfections of the Eye

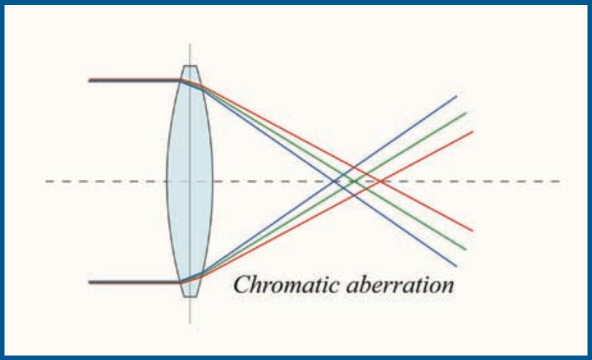
As a result of optical imperfections of the various components of the eye, the edges of the image produced on the retina are not always perfectly clear. This is the ultimate limit of the resolution of the eye or visual acuity. However, under differing conditions of ambient light and/or fatigue, visual acuity is not constant and can change.

There are several inherent phenomena that occur as a result of the eye being an optical instrument. The first is spherical aberration, which occurs when parallel rays of light passing through the crystalline lens are refracted differently and thus not focused at a single place on the retina. Light passing near the edge of the pupil, farther from the center of the opening, are refracted more than those passing through the center. This appears as a circle of diffused light rather than a sharp image. Spherical aberration is at a maximum when the pupil is open the most. Image clarity can be improved if one can eliminate the outer rays by either contracting the pupil or using an artificial pupil like that on the rear sight.



Spherical Aberration

A related problem is chromatic aberration. Visible light is made of all the colors of the spectrum. When visible light passes through a lens, light in the blue and violet region refracts more than that in the orange and red region of the spectrum focusing each color at a slightly different point, causing a fringe or margin of colors to appear around the edges of the image, especially around bright objects. This occurs because lenses have different refractive indexes for different wavelengths of light. Eliminating or reducing the amount of shorter wavelength (blue) light by a filter can improve image clarity.

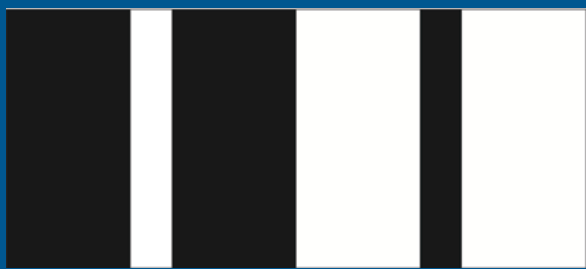


Chromatic Aberration

Another phenomenon occurs when light passes through small openings, like the pupil or rear aperture, the rays bend and produce an image on the retina that is not a single point, but a circle surrounded by a number of concentric light and dark rings of decreasing brightness. This is called light diffraction and is due to the wave nature of light. Diffraction rings are only noticeable when the pupil is very small and is the opposite of the cause of spherical aberration (large pupil). Diffraction effects are more noticeable when bright light is shining into the eyes causing the pupil to contract. Another demonstration of diffraction is found when looking through a small aperture. Looking carefully at the center of the opening, there seems to be a faint grey ring floating there, it is not dirt or fuzz, it is the diffraction pattern of the light.

Light can also be diffused as it passes through the various eye media, which are not absolutely transparent. Light diffusion manifests itself as a radiance or weakly luminous haze covering the field of vision, and is especially noticeable as a halo of light around brightly illuminated objects against a dark background or when bright light enters the eye directly.

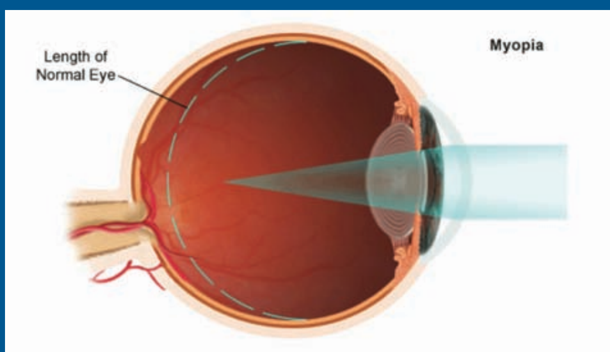
Light irradiation is probably more applicable to pistol shooting with open sights, but it is included here for those who may use a post insert to show the effect of optical over-estimation of sizes of objects set against a dark background. The widths of the black and white stripes are identical but the white stripes appear larger than the black ones do. The effect is related to the amount of light illuminating the surface. A change in the brightness of the target's white background will cause the eye to perceive the space between the front sight and the lower edge of the target as being different even though it is the same, resulting in high or low shots.



Light Irradiation

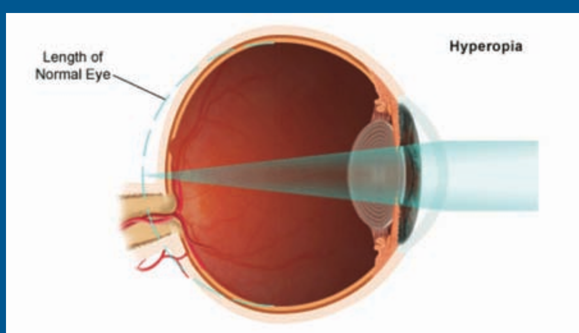
The eye is considered normal if the rays of light from a distant object entering the eye focus exactly on the retina without any effort at accommodation. However, other optical imperfections of the eye affect visual acuity including nearsightedness (myopia), farsightedness (hyperopia) and astigmatism.

Nearsightedness occurs when the parallel rays entering



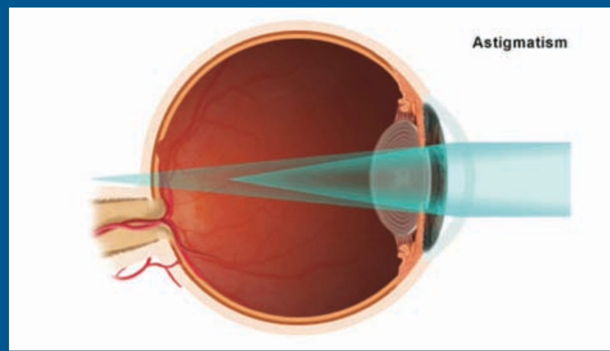
Myopia

the eye are focused in front of the retina. This is typically the result of an eyeball that is too long or a lens that has too much refracting power. Myopia is easily corrected with proper corrective lenses. Many top-level shooters are nearsighted and



Hyperopia

wearing glasses does not interfere with their performance. Farsightedness is the opposite condition from myopia. An eyeball that is too short and/or a lens that has too little refracting power causes light entering the eye to focus behind the retina. Shooters over the age of about 40, suffer from presbyopia, which is due to the gradual hardening with age of the crystalline lens so that it is no longer flexible enough for the ciliary muscles to change the shape sufficiently to focus on close objects. These conditions are a bit more challenging to correct but can be resolved by selecting appropriate corrective lenses. An eye where the cornea and the crystalline lens do not have a perfectly spherical shape is astigmatic. The light rays entering



Astigmatism

the eye do not form a single focused image on the retina, but rather several foci at various distances from the retina. This causes the image to be indistinct and erratic. Corrective lenses can also be used to fix astigmatism but it is important that the orientation of the lens in shooting glasses be maintained correctly. If the lens is rotated off the correct axis in relation to the eye, the shooter's vision will be affected. Even if the eye and its structures are perfectly normal, the tear layer on the outside of the cornea can cause slight astigmatism that can be transient. Dry weather can reduce the amount of tear layer present at various places on the cornea and this can influence clear vision until the tear layer refreshes by blinking the eyelids.

Every shooter should have their vision checked regularly with a thorough eye examination, and even small defects should be corrected. Over long courses of fire, the extra effort to accommodation will fatigue the eye with a deterioration of vision. It is also important that a corrective lens is placed so that the line of sight is perpendicular to the surface of the lens and through the center of the lens. This is because the center of the lens is ground more precisely to the prescription. Special shooting glass frames that can be adjusted to hold the lens in the correct orientation when the head is in the aiming position are essential once the shooter advances.

There is still more we need to know about the eyes and how they work including binocular vision and how to adjust and optimize the aiming aids available to the shooter. More on that in the next installment, until then, keep your eyes on the target.

▪ *Marcus Raab*

Fundamentals of Rifle Shooting: Aiming & the Eye Part II

The job of the shooter is to fire one perfectly executed shot!

There is one more peculiarity of the eyes and human vision that is important in the aiming process: binocular vision. With both eyes looking forward, our vision system developed so that both eyes normally work together as a pair, however, there is a tendency for the brain to prefer visual input from one eye over the other. This is

Olympic Training Center Pistol Resident Athlete, Anthony Lutz, demonstrates the beginning position of the arms during the eye dominance test. Notice the clear result of this test.

eye dominance. It is similar to handedness, which is the preference to perform fine motor skills with one hand or side of the body over the other. The non-dominant eye provides supplementary information that the brain uses to determine distance, speed and depth perception and can take over that role if the dominant eye is ever damaged or compromised.

The general population is about 90 percent right-handed, whereas approximately two-thirds is right-eye dominant. The remainder of the populations favors the left hand and left eye, and a small fraction of people prefer neither eye. A coach is able to see that there is a small but significant portion of new shooters who will be right handed but prefer visual information from the left eye. Much less frequent would be right-eye dominant left-handers. These shooters are termed "cross-dominant." Unfortunately, to complicate matters for coaches, there are also degrees of eye dominance with individuals ranging from strongly to weakly dominant and the fact that dominance can change due to fatigue.

To conduct an eye dominance test, have the shooters stand and with their arms fully extended in front of their body, crossing their hands to form a small opening with their thumbs. Next, with both eyes remaining open, have them look through the opening at a distant object (your nose is a good focal point). At this point, you can easily identify the dominant eye, which you can now see through the opening in the shooters hands. Have the shooters bring their hands slowly toward their face, keeping the selected object in view at all times. When their hands touch their face, the opening in the hands will be over the dominant eye. Repeat the exercise if necessary to clarify ambiguous results.

Shooters who have strong eye dominance on the same side as their preferred hand are a simple case. They shoot from the preferred shoulder. The next segment comprises those who are weakly dominant on the same side as their preferred hand. These shooters may be confused by a double vision of the front sight and need to block the extraneous information coming into that eye. The third group includes new shooters who are weakly cross-dominant and may be able to shoot from their preferred hand side but will definitely need to block the confusing visual image. You should also try shooting from the opposite shoulder to see if these shooters can perform better. If they are strongly cross-dominant it is probably best to shoot from the shoulder of the preferred eye. These cases are easy to spot because shooters will try to see through the sights with the opposite eye and forcing their head into an unnatural position.

The picture illustrates the final phase of the eye-dominance test. Please pay attention to how close his hands are to his eye. Throughout the entire test, the coach/tester should have a clear view of the shooter's dominant eye. As anticipated from the primary phase of the test, Lutz is a left-handed pistol shooter who is clearly left-eye dominant.

Occluders, Blinders, Hats and Visors

Squinting or closing of the non-aiming eye to eliminate the double image of the front sight can cause eye fatigue and muscle strain. Additionally, by closing the non-aiming eye, that pupil will dilate because it is not receiving the amount of light it normally would, and because of a sympathetic response, the aiming eye's pupil will open more than normal. This can cause a loss of focusing ability and increase eye fatigue. As coaches, we should strive to have our athletes utilize the body's natural tools in the performance of a task; therefore, both eyes should remain open. The solution for the double image is to use an occluder.

Often made of an opaque material like target paper or a translucent material like plastic milk carton, an occluder is an object that blocks some of the field of view reaching the non-shooting eye. Translucent material allows some diffused light to enter the non-shooting eye, allowing both eyes to receive similar amounts of light. Occluders are attached to the either the rear sight or the shooter's glasses. Avoid black color or covering the eye completely with an eye patch, as this will trigger the sympathetic pupil response.

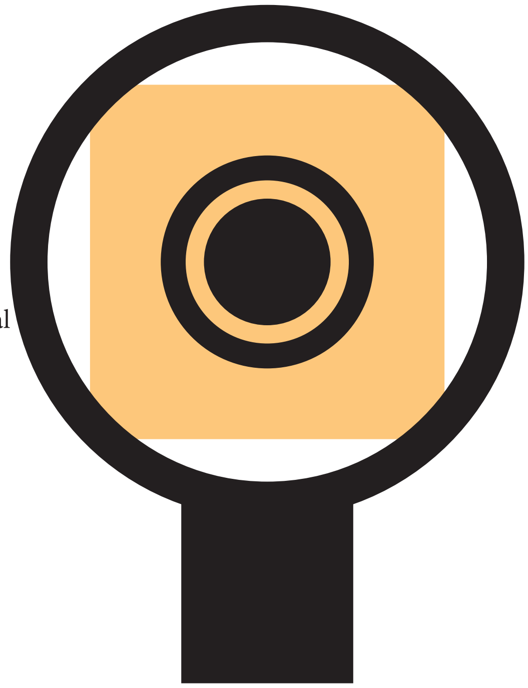


Figure 1

Blinders, like horse blinkers, are made of paper or other material and serve to stop light and distracting movements from entering the eyes from the left and right sides of the head. Check the competition rules for restrictions on the size and placement of blinders and occluders.

Hats or visors prevent overhead light or glare from interfering with obtaining a clear sight picture. Again, there may be limitations on hats and visors. The brim of the hat or visor should not touch the rear sight as this may be against the rules, but more importantly it may cause flinching or blinking of the eyes as a conditioned response in anticipation of the shot.

Practical Use of the Eyes for Shooting

No two sets of eyes are identical. Even between a shooter's set of eyes there are differences in acuity and light sensitivity. It is impossible, therefore, to formulate an exact missive concerning the aiming process and system that applies to all people; but some generalities apply to most, but not all, people. We will assume the shooter's eyes are in good health (or aided by corrective lenses), and that the sights and accessories are in good condition and the shooter knows how to use them. So with all of this knowledge, how do we use the visual faculty to the best advantage?

If the eye focuses intently on an object longer than eight to ten seconds the photochemical reaction associated with the rods and cones becomes overloaded and the regeneration that normally takes place slows down. The shooter can then experience a false or "burned image" on the eye's retina. This false image continues transmitting to the brain, which perceives a "correct" sight picture, when in reality the sight has drifted away from the center. The shooter swears the shot was good but it often lands in a very different place. You can try it yourself. Look intently at the sight picture (Figure 1) here for ten to twelve seconds then look at a blank wall. You will see a ghost image of the sight picture even though you are no longer looking at it.

Encourage shooters to look away from the sight picture between shots with an unfocused gaze into the distance at a neutral colored background, to allow the eyes to rest and recover between shots.

A common error in aiming, especially for beginners, is aiming too long as they try to hold the gun on the target. It should be fairly evident how important it is to not abuse the eye focusing muscle by shifting focus too frequently from one point to another, for example from the sights to the target and back to the sights. The shooter must also not aim for extended periods without resting the eye. Thus, eight to ten seconds of intense aiming is the limiting time for the entire shot process, as we shall see later. Over-aiming beyond 10 seconds causes premature eye fatigue and even one occurrence can compromise vision for subsequent shots unless time is given for the eyes to rest and recover.

Another common aiming error occurs when shooters pick up the rifle and immediately begin intense aiming. They are trying to obtain a good sight picture before they are really ready, which leads to over-aiming. Only allow aiming when every other aspect of preparing for the shot is complete.

- *Marcus Raab*

Fundamentals of Rifle Shooting: Aiming & the Eye Part III

Many beginning shooters use too small of an aperture in the mistaken belief that they can aim more precisely at the middle of the target.

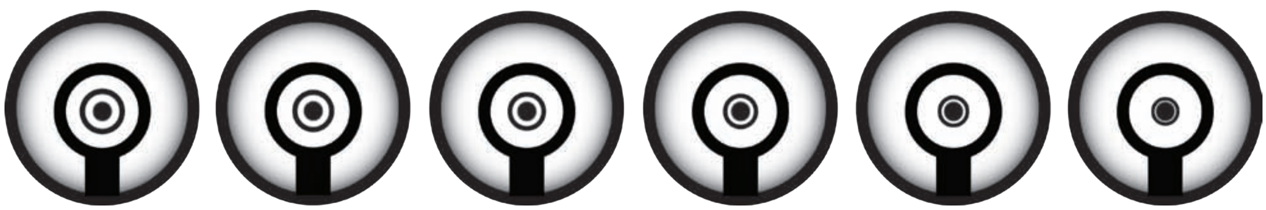
If you walk into a photography darkroom without benefit of a flashlight, you are unable to see due to the lack of light. Likewise, a person standing in a thick fog bank during the day cannot see anything; even though there is plenty of light, everything appears white. What is it that allows us to see objects? It is the difference in brightness or the amount and color of the light reflected from the surface of objects in the viewing area. We call this difference brightness contrast. Brightness contrast is one of the factors affecting perception. Under optimal conditions, the contrast of the black bull and the front sight ring (that absorb most of the light) and the white background (that reflects the majority of the light) results in a high level of brightness contrast. Thus, we are able to clearly see the target and the front sight ring. However, under certain conditions of brightness contrast, the target and/or front sight ring cannot be seen clearly when aiming. Rather, it may appear gray or as an indistinct blob.

The exact cause is not well understood and the amount of the effect varies per shooter; however, it appears to be related to the ratio of contrast to the total amount of light entering the eye. The practical solution is to alter the ratio by changing the amount of light entering the eye through one of four methods. First, the rear aperture opening may be changed. Second, reduce or enlarge the front aperture size to change the ratio of the amount of light in the ring of white around the target. The third option is to use filters or tinted shooting glasses. These work by reducing the amount of total light entering the eye. Be cautious of the filters used, as some remove portions of the spectrum that may make vision difficult, i.e., a yellow filter removes blue and violet light. Another option is to change eye relief slightly, which has a similar effect to changing the rear iris.

Adjustable Rear Iris

The artificial pupil of the rear sight aperture already takes advantage of the spherical aberration problem by allowing only those light rays that will pass close to the center of the lens. However, ambient conditions are not always ideal for vision. For greater control, an adjustable rear iris can compensate for different light conditions to make the front sight ring and the target (the contrast between the sight picture elements) as clear and sharp as possible for the current light conditions. The artificial pupil (aperture of the rear sight) is smaller than the pupil of the eye, so adjusting the iris diameter results in a barely perceptible difference.

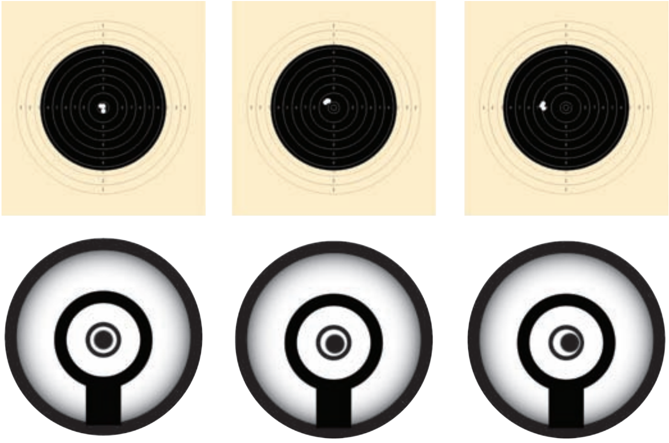
Image clarity is controlled by opening or closing the rear iris. A reasonable rear iris setting method is to close the iris down (slowly, to give the pupil time to adjust) until the sight picture perceptibly darkens and then open it up until maximum contrast is seen between the black and white areas of the sight picture. The result should be the clearest sight picture possible. Assuming no other filters and "normal" eyes, the crossover between too dim an image and sharp image to grayed-out image often occurs around 1.0-1.2 millimeters or so. This is why all fixed size metal irises provided with sights are 1.1 millimeters.



Selecting the proper aperature size is crucial for success.

Flattening

Sometimes, one side of the target or aperture ring will disappear or grey out. A brightness contrast problem or astigmatism may aggravate this flattening, but the more likely cause is the shooter looking through the edge of their pupil. The light passing through the edge of the pupil refracts more than light passing through the center of the opening. The more radically bent light rays strike the retina at a sharper angle and may not stimulate clear vision. This is the same spherical aberration problem discussed previously. The solution is to adjust the cheek piece to ensure the shooter is looking directly through the center of the rear aperture iris. Using an accessory parabolic mirror mounted on the rear aperture can help the



shooter see if they are indeed lining up the center of their pupil with the center of the rear aperture opening.

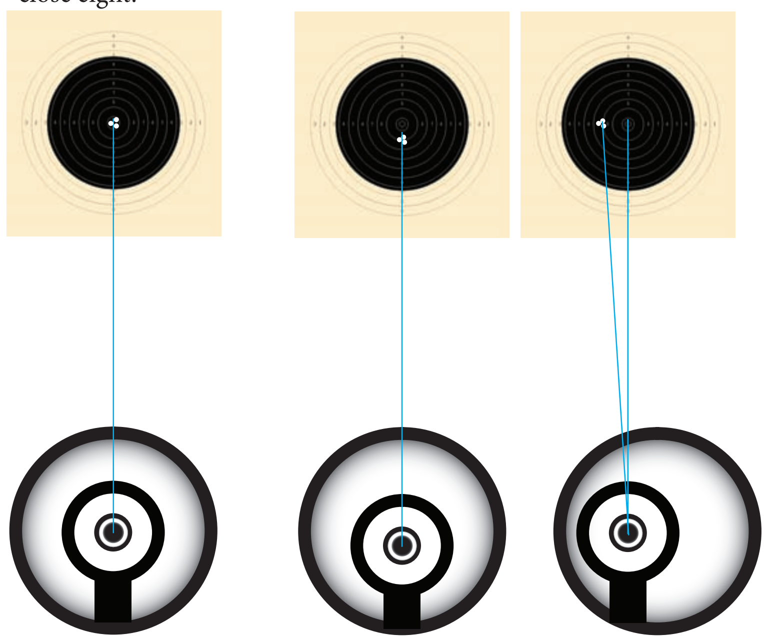
Front Aperature

Selecting the proper front aperture size depends mostly upon the athlete's ability to hold the rifle still, but also on each individual's eye and available light. Select an aperture size that allows the apparent movement of the entire target to remain inside the aperture during the best part of the hold. Using an aperture that is too small often leads to poor trigger control habits like "snap shooting" or jerking the trigger as the sights zoom across the bull. On the other hand, if the aperture is too large the shooter will have a difficult time determining if it is sufficiently centered on the target, though trigger control can be smoother. The optimal size front ring will allow the shooter to recognize instinctively that it is centered on the target and yet contains all the hold movements during the best portion of the hold.

Many beginning shooters use too small of an aperture in the mistaken belief that they can aim more precisely at the middle of the target. In some extreme cases, the shooter uses such a small aperture that it covers the edge of the target. The line of white that they see is actually a diffraction pattern from around the inside edge of the front aperture! Almost everything they see while aiming looks centered but they cannot really tell if the sight picture is centered or not. The athlete's eye will also fatigue more quickly using the smaller aperture than with the larger aperture as they attempt to discern the very thin white line between the ring and the target. This is especially problematic with longer courses of fire.

In any case, the apparent size of the front ring should be approximately two times the apparent width of the aiming black. Only those shooters who have excellent holding skill should consider anything smaller than one-and-a-half times the width. Just like adjustable rear sight irises, replacing the fixed-size front sight ring with an adjustable front sight iris insert is useful for quickly and conveniently changing size between positions or adapting to variable light conditions.

The interesting thing about aiming a rifle is that it does not need to look perfect for the shooter to fire a 10. This is due to the finite size of the 10-ring itself and the size of the bullet or pellet. The center of the air rifle pellet hole can be as much as 2.5 mm (8.0 mm for small-bore) away from the exact center of the target and still score 10 points. This amount of error can actually look quite bad, but as long as the trigger is pulled smoothly the shot will still be a 10. In fact, as long as the edge of the target does not appear to touch the inner edge of a correctly sized front sight ring, and the trigger is pulled smoothly the worst value one should expect is a wide nine or a close eight!

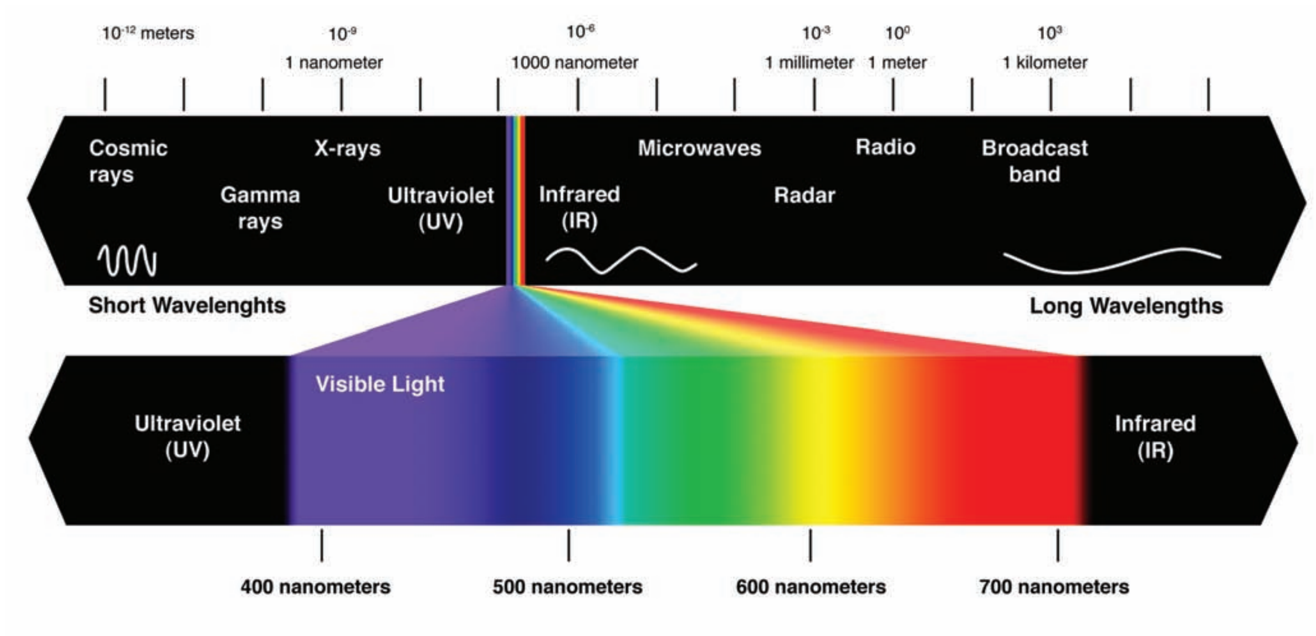


Of course, if the sights are not aligned correctly, then the error can be much greater. Even with the aiming black perfectly centered in the front aperture the shots strike the target farther away from the center because of the angular error. Even a small error in alignment has a large influence on the location of the shot. The place to look for the solution is in consistent head position and cheek piece adjustment.

The table is a "Rule of Thumb;" start beginners with the largest size and as they improve move down in small steps. Actual sizes will, of course, depend upon the distance between the rear sight (actually, the shooters eye) and the front sight. This distance is the sight radius. Short sight radius rifles need smaller apertures, while rifles with long sight radius need larger apertures to achieve the same sight picture. Smallbore targets at 50 meters and 50 feet appear smaller than air rifle targets, and therefore need smaller apertures.

Aperature Sizes for Beginners and Intermediate Rifle Shooters

	Air Rifle	*Smallbore*
Prone	3.8 to 4.0 mm	3.6 to 4.0 mm
Standing	4.0 to 4.3 mm	3.8 to 4.2 mm
Kneeling	3.9 to 4.1 mm	3.7 to 4.1 mm

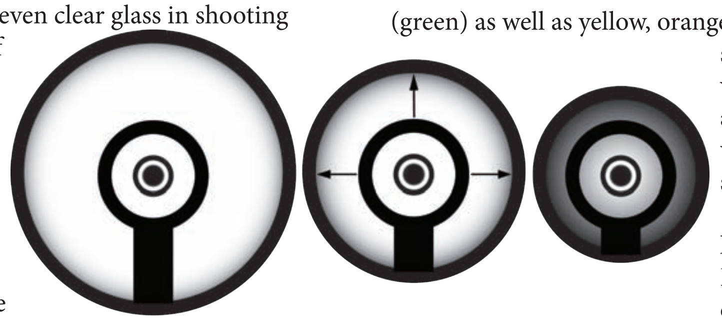


With smallbore rifles, shooters can extend the sight radius using an extension tube attached to the end of the barrel, often called a “Bloop Tube,” because of the sound they make on firing. The idea originated as a way to improve vision for older shooters who had trouble seeing the sight picture clearly. Adding a tube requires a larger aperture in relation to the added length of the sight radius (i.e., a 20 centimeter tube will require about a 10-15% larger aperture). These tubes also change the relationship of the number of adjustment clicks needed to move the strike of the bullet on the target. The longer the tube, the more clicks it will take to move the shot the same distance on the target compared to the original sight radius.

Filters

Often found as an integral part of the adjustable rear iris assembly, different color filters can compensate for different light conditions. When used in conjunction with rear iris adjustments, filters provide greater control over the amount and color of the light reaching the eye. The advantage is that they are relatively inexpensive compared to individual filters that attach to shooting glasses. Moreover, it is also easier to change the filters by simply turning a ring on the assembly while in position. An important concept to understand is all filters, regardless of color, even clear glass in shooting glasses, reduce the amount of transmitted light, some more than others.

Gray filters absorb light over the entire spectrum, reducing intensities but not removing any particular wavelength. These are useful on very bright days where the sun is behind the shooter and the targets are brightly illuminated. Filter sets usually include two or three of these gray filters in varying density—light, medium and dark.



Shorter eye relief

Longer eye relief

As they reduce the amount of all light colors transmitted to the eye, dark gray filters can reduce visual acuity. By decreasing the total amount of light entering the eye on very bright days, the brightness contrast can be fine-tuned with the adjustable iris to give a clearer sight picture. This can help reduce strain on the eye under extremely bright conditions and compensate for any loss in visual activity (as compared to not using a filter).

Yellow filters absorb wavelengths in the blue, violet and ultraviolet regions. Short wavelength light is easily scattered and these rays refract more when passing through the lens of the eye and decrease visual acuity. During days of moderate visibility due to fog or haze there are plenty of tiny water droplets or dust/pollution particles in the air to scatter the blue light even more. As the blue region of the spectrum does not help visual acuity, removing this portion of the spectrum is advisable. In dull, hazy or foggy conditions, the yellow filter can provide better contrast between light colored and black objects allowing clearer aiming. Yellow filters reduce the amount of light entering the eye by approximately 17–20%, so on days of heavy fog or darkness, it may not be advisable to use any filter. Ranges illuminated mainly with fluorescent lights also have more scattered blue light, so yellow filters may improve sight pictures.

Green filters transmit wavelengths of around 500 nm (green) as well as yellow, orange and red while absorbing some, but not all, of the blue violet region. The green filter is a good intermediate filter to use when gray or yellow does not seem right.

Reflected or scattered light has random orientations. Polarizers are a special category of filter that transmits light to remove the dazzle or glare reflected off shiny surfaces. They are gray filters that do not remove any particular portion of the spectrum. If two polarizers are used in tandem and their planes are parallel,

Adapting to Changing Light Conditions	
Situation	**Potential Solution(s)**
Bright light conditions	Reduce the size of the front aperture, reduce the size of the rear aperture and insert filters.
Poor light conditions	Remove all filters, open up the rear aperture and try a larger front aperture.
Bright to Dark	A starting place for the shooter when the change is from bright to darker light conditions is to try a larger rear aperture, reduce the density of filter if used or remove completely and change to a larger front aperture in that order.
Dark to Bright	Try a smaller rear aperture, increase the density of filter, and reduce the front aperture in that order.

then the maximum amount of plane polarized light is allowed to pass. As the polarizers are crossed, less light can pass through until no light is transmitted when they are turned 90 degrees relative to each other.

There are many other filter options with some of the new rear sight iris/filter accessories available. In some cases, two or more filters can be used in combination. Each filter removes a specific region or regions of the spectrum. The best way to learn how each will affect (improve or degrade) sight picture clarity is to experiment systematically in a wide variety of lighting conditions and keeping accurate notes as to their effectiveness.

Eye Relief

Rarely thought of as a way of influencing sight picture quality, proper positioning of the rear sight can improve sighting efficiency. Eye relief is the distance between the pupil of the aiming eye and the rear sight aperture. Shooting reference books commonly list one to four inches as the proper amount of eye relief, yet this also includes other variables.

The further the eye is from the rear iris opening, the smaller the amount of outside world the shooter sees around the front sight tunnel. This positioning makes it easier to keep the sights aligned properly, but produces a darker image as the amount of light reaching the eye is reduced. The closer the eye is to the rear iris, the more light reaches the eye and more things can be seen around the front sight, like wind flags and number boards, but, it is harder to keep the sights aligned. The position of the head on the stock, and thus the location of the eye, must be consistent and on the same point to maintain sight alignment from shot to shot. Key considerations are consistency in the placement of the cheek against the stock, both vertically and horizontally, as well as the distance to the sight. Errors in placement of the head are a prime source of many unexplained shots.

Since significant changes to the sights alter the location of the eye (subsequently the head also), it is important to zero the rifle, find the proper head position and adjust the check piece as needed to set eye relief. Then move the rear sight on its mounting dovetail until the shooter sees the appropriate amount of view around the front sight. For top performance, a shooter must negotiate the position of the rear sight to permit alignment of the sights.

A common error is setting the sight so close that it rests against the shooter's forehead or glasses. This can cause reflexive flinching, blinking or anticipation of the shot caused by bumping the shooter on recoil. None of which are good for accurate shooting.

Changing eye relief by moving the rear sight will change the center of the shot group on the target. This should not occur during the course of fire unless the shooter can take additional sighting shots. Assuming the mounting dovetail is machined parallel to the bore, moving the sight forward will cause the shots to strike the target higher; whereas moving the sight rearward will results in lowers shots.

Guidelines for Adapting

Utilizing all the various tools available to enhance the sight picture quality, the following are some general guides for the shooter and coach. Again, each shooter is an individual and must ultimately decide for alterations for different conditions. The objective is to find the combination that yields the best possible sight picture.

Though it may seem that having adjustable everything is essential to for success, it is not true. From a coaching perspective, stay away from tubes, gadgets or similar accessories when working with beginners and intermediate level rifle shooters. The extra complexity of detaching, cleaning and re-attaching the tube, for example, can create more problems than improvements. Teach beginners how to shoot and earn points through training, rather than attempting to buy points through gadgets. In many cases, gadgets get in the way or may become a crutch with shooters learning bad habits instead of how to shoot properly. Wait to introduce accessories until there is a valid need and after they have a thorough understanding of their function and use.

Successful rifle shooting depends on the efficient use of the shooters visual apparatus. With the basic understanding of how vision and aiming work, a shooter can negate the effects of unpredictable lighting. Handling those effects during competition is a tactical skill that can only be acquired through training. It would behoove a shooter and/or coach to have not only detailed records of ranges and conditions previously encountered, but also solutions that helped achieve an optimum sight picture.

- *Marcus Raab*

Where Are You Looking?

Fifty-second in a series

10th Anniversary Article

"But I Must Have a Precise Reference!"

Visual skills are very important in the target shooting sports. A great deal of time, money and effort are invested in attempting to optimize the athlete's visual environment. Special lenses, glasses and apertures or other devices are often put to use. In some cases visual training activities and routines are utilized. As with many aspects of the sport, the visual fundamentals often become overlooked once an athlete passes the learning stage and moves to the "advanced" aspects.

Unlike shotgun athletes, target pistol shooters look at the front sight. No, not at the target! While looking at the front sight is fairly universally understood and accepted, there are subtleties that are generally overlooked. Where? Just as with the pistol shooter in the previous article, we strive to look at the front sight, yet often end up with our focus on the target and the front sight becomes blurry. Why is this? There are at least two primary reasons: eye physiology and outcome concern.

"While looking at the front sight is fairly universally understood and accepted, there are subtleties that are generally overlooked."

Our eyes, regardless of the use of corrective lenses, naturally focus at a great distance when relaxed. Bringing the plane of focus back from the distant target to the much closer front sight requires muscular effort. We may see a sharply focused front sight at first, only to see it eventually become less distinct and then fairly blurred as our eye rapidly fatigues. This situation worsens as the match progresses as the eye muscles fatigue, along with the rest of the mind and body.

For most people, adjusting their normal lens correction by +0.50 diopter sphere results in the front sight being so sharp that it almost seems to snap out of the picture. The eye is at rest and the front sight is crisp. For those who need no everyday eyewear correction, just wear a +0.50 diopter sphere lens.

At this point, many people notice the target is no longer sharply defined. See Figure 1 and notice the target is not crisp or deep black. (In practice, the target is not as grey as shown here, though it is still very indistinct.) Athletes either reject the lens or add an adjustable iris to their shooting glasses in an effort to re-sharpen the target. Although adjustable apertures are useful in some situations, this is not one of those cases.

It is a mistake to believe that the target must be sharp in order to shoot with precision. This has been proven by many, especially those who train on a special target with a black center that fades to white at the edge of the target card. There are no rings, center black or boundaries –just a continuous fade from black to white. Despite the lack of clear aiming reference, it is easier for most advanced athletes to shoot very tight groups on this training target than on a regulation target.

Outcome concern is the other major reason our eye ends up out on the target. After all, we are looking at what we think is our "goal." The target is not the goal. It is a mental and visual distraction—especially when worried about a poor shot. The target is only required for an aiming reference and scoring. This principle applies universally in all target shooting disciplines. Make sure to separate outcome from doing.

We now turn our attention to the topic of where to look when actually on aim. Though it seems obvious, pistol shooters often hear: "Look at the front sight!" Does that mean at the middle of the top edge, across the top edge or checking the white gaps on both sides?

When on aim, the eye should rest quietly on the center of mass of the part of the front sight that is visible through the rear sight. Figure 1 clearly shows a white dot on the spot where the eye must sit during the aiming process. When an athlete builds a solid physical and technical routine, he/she finds that when resting his/her eye on the white dot he/she is able to perceive whether or not the sights are aligned without "looking around" at the sight picture. With the eye resting in one spot, and the brain having less processing to perform, the hold area is dramatically reduced. Remember, active visual processing, or merely thinking, opens up the hold. Nothing raises confidence like steadiness!

Having determined where to look with respect to the front sight, now we must determine where to hold. Pistol shooters have a lot of choices: 1) center of the target, 2) bottom edge of the black, 3) very thin line of white between the front sight and the edge of the black, 4) measured white space between the front sight and the bottom of the black that equals the white space on either side of the front sight, 5) deep down in the white and possibly others. All have their proponents and detractors.

Center hold is very popular in standard pistol because of the mix of time limits for the 5 shot strings. It is essentially universal in the rapid stages of sport/center and in the rapid fire pistol event due to the design of the target. Some air and free shooters also choose this method.

Bottom edge of the black hold and thin line of white hold are two common aiming techniques, especially for the precision events and stages. Many athletes dislike the black-white-black-white "flicker" above the front sight as their area of hold takes the sight above and below the bottom edge of the black. This aiming technique is distracting as it magnifies the perception of movement, thus reducing athlete confidence.

Measured white hold reduces or eliminates the flicker problem (if the gap is large enough), while still providing an aiming reference that feeds the perceived "need" of many shooters to have a "precise" aiming reference; however, measuring is a very active visual and cognitive process and is counterproductive.

Deep down in the white, interesting things happen. First, the athlete notices a lack of distinct aiming reference, which is frightening. Those who are willing to experiment, learn that, if they let their eye rest on the front sight – yes, the white dot spot – the aiming area is "sensed" and the target is so far above the front sight that its move-ment is no longer a distraction. Note that the apparent movement is now the target's because the eye is gently following the front sight as if "locked on" and the perception of movement is diminished. Despite the target seeming to "float" well above the front sight, the brain is quite easily capable of finding the same "spot" for shot release. Of course, the aiming "spot" must be thought of as an area of hold and accepted without reservation. This hold method is conducive to deeper shot process techniques that result in shot delivery that is more consistent, confident and decisive.

This technique is especially powerful in air and free events. Decreased distraction of the target movement and a "quiet eye" allow an athlete to instinctively know where to hold. Yes, this takes guts and time to develop, but it is a rewarding and powerful technique that results in small, confidently delivered groups. A quick "try" will give a false result and the technique will be prematurely and erroneously rejected. Now you know why the bull is so high above the front sight in Figure 1.

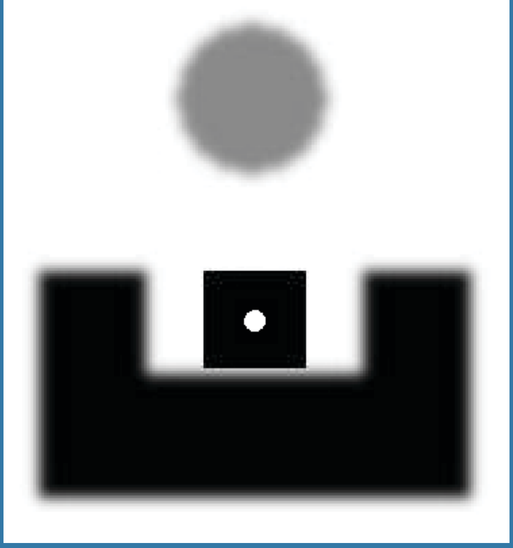


Figure 1

Finally, we must explain why the gaps on either side of the front sight are so wide. Many pistol shooters, especially in the precision events of air and free, prefer very thin gaps and adjust their rear sight accordingly. Taken to an extreme, this is counterproductive, as will be seen in the discussion in the next article about rifle front aperture sizes. The same principles apply. This, and other related topics of interest to both rifle and pistol shooters, will be discussed in more detail in the next article.

▪ *JP O'Connor*

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Where Are You Looking?

Fifty-third in a series

Part II

"I have a team full of shooters with a world class hold; And almost none of them can deliver the shot!"

In the previous article, we explored two important aspects of the sight picture for target pistol shooters, both resulting in seemingly large white spaces instead of what are mistakenly thought to be "precise" references. We now take this theme to rifle, with surprising results. Pistol shooters should carefully read this article just as rifle shooters should have carefully read the previous article. Both articles hold insights for both disciplines. The quote at the beginning of this article is from a national team rifle coach a few years ago. He was commenting to me on the inability of many of his athletes to confidently, decisively and consistently deliver quality performances under pressure. Each athlete had his or her own challenges and reasons.

One challenge that many of them shared, and that almost none of them or their coaches understood, was that their front apertures were too small. The vast majority of shooters have selected a size that is too small for them, especially if they have a great hold. On the contrary, a small percentage of shooters use what appears to others to be huge front apertures. What is going on here, and why do we make the assertion that most have their aperture too small?

First, we must explore why smaller apertures, consistent with one's ability to hold the rifle steady, are thought to be best. As an athlete improves his or her ability to hold the rifle steady, he or she may choose to reduce the front aperture size. In all cases, the size is generally recommended to be large enough to contain the hold so that the bull is not disappearing outside the front aperture ring. As a result of this advice, once an athlete develops a tight hold, he or she may choose an extremely tight aperture.

The reason for small apertures is visual precision. Without a doubt the smallbore ten-ring and ten-dot for air rifle are very small and consistently hitting them demands a high degree of repetitive precision. The "engineers" among us want measureable precision; they choose the bottom of the black or thin line of white pistol holds and tight front apertures on rifles. The good news is this provides an opportunity for improved visual precision. The bad news is this causes lots of eye movement and it increases the sensation of movement of the hold. These themes should be familiar from the previous article.

With tight front apertures, one is tempted to "check" all around the white ring between the bull and the front aperture ring to ensure it is even. This is done by following the ring in a circle or by bouncing around in sort of a star pattern. Additionally, the athlete is constantly trying to discern the very small white ring to evaluate the aim causing eye strain.

A few years ago, triangular apertures were made available on the market. An "engineer" had the bright idea that a triangle provided only three places to check, instead of the entire ring. While that was true, it involved eye movement. The apertures were a failure because holds opened up and results were worse than before. This was no surprise to athletes and coaches who understand the need for, and power of, the quiet eye.

When the eye is moving, the gun is moving. When the mind is thinking, the gun is moving. Both subtle eye movements and increased brain activity cause the hold to open up. The tight front aperture magnifies the apparent movement of the gun. This erodes the athlete's confidence and destroys the ability to follow a high performance style of shot process. Trigger jerking and/or flutter finger become quite common in this situation. Many a triggering problem has been solved with a large front aperture. The result of tight apertures is the perception of increased hold motion, eroded confidence, added eye strain, increased brain processing (visual and otherwise), significant and debilitating triggering issues and a greatly increased difficulty in shooting. When the hold looks bad to the athlete, it may as well be horrid.

A penny's worth of gain through perceived aiming "precision" comes at the cost of a dollar's worth of performance degradation in several other critical areas. Ten years ago, in the third article in this series, we explored the challenges an Olympian and very dominant rifle shooter was having in decisively delivering shots. The primary technical issue for that athlete was a front aperture that was too small.

The appropriate size front aperture is not very tight. See Figure 1 of a typical front sight with a generously sized front aperture and a target bull. (The rear sight is not shown.) This diagram does not represent a specific target with a specific front aperture, meaning that it is not necessarily to scale. It does clearly illustrate two important factors: 1) a wide ring of white between the bull and the front aperture ring (which could be even wider than shown here), and 2) a very thin front aperture ring.

When introduced to an aperture of appropriate size, many a rifle athlete has been stunned at the almost immediate transformation in their shooting. Others have taken a short time to warm up to the sometimes dramatically changed sight picture, but ultimately are very pleased with how it feels to deliver the shot and with the results.

Observant readers will notice that no actual aperture sizes have been given thus far. "What size apertures do I need for air rifle and for smallbore rifle?" There is no single correct answer! …except this answer: "It depends." One must know the value of several variables in order to determine the correct answer. What size is the aiming bull? How far away is the target? How far is it from the surface of the athlete's eyeball to the front sight aperture inside the globe? Even knowing these variables, what is optimal? How do we know? We must answer this question first, in order to determining actual sizes.

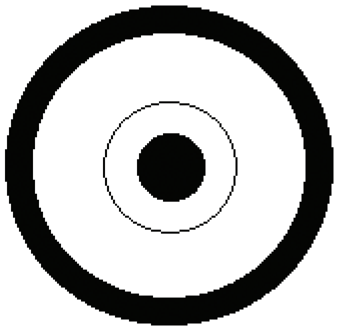


Figure 1: Note the very thin front aperture ring and the wide white ring between the aperture ring and the aiming black. Ideally, the front aperture should be floating as shown (no crossbars) and should usually be a very light salmon (pink) color. This diagram is not to scale, and the inner white ring is often even wider.

Many years ago, *Precision Shooting*, in one of their magazines or annuals, published an article that discussed research on front aperture size. It turned out that the width of the white ring between the front aperture ring and the aiming black must cover at least three minutes of angle (MOA) from the shooter's point of view. Angles are often measured in degrees, with 360 degrees in a circle. A degree may be further divided into 60 "minutes". Thus, 60 minutes of angle (60 MOA) make up one degree of angle.

About 50 to 60 years ago, the Soviets studied many aspects of rifle sights and sighting systems, among other things, in great detail. Front aperture size, aperture ring thickness, and interestingly, front aperture insert color, were among the numerous factors studied. For shooting outdoors, they found light pink apertures to be most effective. Now you know why Anschutz sells that color! They also found that very thin front aperture rings were the most effective. Air events were not studied as they were not part of Olympic shooting at that time. Sadly, the paper(s) with the results of the research activities cannot be found; however, references to the studies shed some light. Taking the published statements and translating them in terms of MOA, one gets identical results to the above article.

It was interesting to discover that these two different resources came to the same conclusion. Unfortunately, there are no other known studies or resources on this topic. Therefore, a number of empirical observations and informal studies were performed with athletes at all levels to explore this topic. In some exercises, athletes used aperture sizes that were changed randomly for each shot, ranging in size from very tiny, with almost no white ring between the bull and the front aperture, all the way to so large the bull seemed to be floating on its own.

In all cases, when the front aperture size was chosen to show the athletes a white ring width of 3 MOA or more (often much more), the athletes felt confident about their shot delivery, were decisive, had smooth triggering, and shorter holds. Sometimes the difference was so profound that the athletes would comment on how much easier it was to shoot and that the results were better and more predictable than normal. It was discovered that front aperture sizes could be larger than the 3 MOA size by as much as 0.5 mm or more with identical and sometimes even better effects.

When the aperture size was such that the athlete was presented with a white ring width that was less than 3 MOA, even by the tiniest amount, profound changes took place: confidence took a dive, hold times increased, triggering became rough, and overall shot delivery was less decisive. If the aperture size was only 0.1 mm too small, the negative effects were observed by both coach and athlete.

Remember the minority of coaches and athletes, and those few elite athletes, with the really big apertures? Now you know one of their "secret" keys to success. What about the common advice to change aperture sizes between positions? What about the advice to try a smaller aperture in order to decrease the hold area? Be careful! In the case of an elite athlete with an extremely small hold area in the sling positions, one might consider a slightly smaller aperture. The hold area must be considerably smaller than in the standing position and the athlete must not already have any issues with decisiveness or clean triggering. Even then, careful experimentation is required.

In the standing position, some athletes have developed extremely small holds. (E.g. hold area contained well inside the diameter of a pellet on the air rifle target.) Again, very careful experimentation is required.

In both of the above cases, more often than not, the athlete and coach, even at the elite level, in search of what they believe is good visual precision, talk themselves into using an aperture that is too small, rather than obeying all the signs to the contrary.

However, an increase in size for a shooter with a looser hold (e.g. a newly beginning shooter's standing position) is certainly appropriate. One is well advised in almost every case to stick with the three MOA rule as the bare minimum size. One may use an even larger aperture, 0.5 millimeters or more, with no problem. To go smaller, even by the tenth of a millimeter, is fraught with serious peril. There are exceptions, but regardless, it is very rarely safe to assume you are one of those exceptions. Refer again to the Olympic athlete in the third article in this series; only a handful of current athletes in this country shoot as well as that athlete and a three MOA or larger aperture was needed even in that case.

Why must the white space be three MOA or more? If the band of white between the front aperture ring and the aiming black is too thin, there is so much “flicker” that it overwhelms the perception of the ring of white, making it more difficult for the mind to center the sights and increasing the visual processing load in the brain. There are likely additional visual processing factors also involved.

Tight front apertures encourage “checking” with eye movement. The tighter the ring, the more the perception of movement is magnified, eroding the athlete’s confidence. The wider the front aperture ring, the smaller the aiming mark appears. Thin front aperture rings and unobstructed apertures (no cross bars) help reduce the perception of “grey bull” some shooters experience.

In pistol, using a wide rear notch in order to have wide gaps of white on either side of the front sight is very beneficial, especially when one is looking at the right spot. This is imperative in the rapid fire events and stages, and is very important in the precision events and stages. All the same theories apply.

Theory is of limited value without practical application. Let us now finally translate the three MOA rule into actual rifle front aperture sizes. The question may be reduced to a single answer chart requiring one simple measurement, shown in Table 1. Measure the distance in inches from the surface of the athlete’s eyeball to the aperture inside the front sight globe (please measure off to the side of the eye). The chart uses eye distance in inches since that is the most commonly available measuring unit in the U.S., and the apertures are listed in millimeters since that is the most common sizing unit used in most target rifle apertures. In some cases, two sizes are shown for a given distance. In those cases, it is best to choose the larger size of the two, especially if the eye distance is “…and a half” inch.

Rifle Front Aperture Size - Millimeters

Eye Dist. Inches	ISSF Air 10m	ISSF SB 50m	USAS SB 50ft	USNRA SB A-36 50ft	USNRA SB A-17 50ft	USNRA SB A-7 50ft
28	3.5	2.9	2.8	2.7	3.0	3.1
29	3.6	3.0	2.9	2.8	3.1	3.2
30	3.7	3.1	3.0	2.9	3.2	3.3
31	3.8	3.2	3.1	3.0	3.3	3.4
32	3.9	3.3	3.2	3.1	3.4	3.5
33	4.0	3.4	3.3	3.2	3.5	3.6/3.7
34	4.1/4.2	3.5	3.4	3.3	3.6/3.7	3.7/3.8
35	4.3	3.6	3.5	3.4	3.7/3.8	3.9
36	4.4	3.7	3.6	3.5	3.9	4.0
37	4.5	3.8	3.7	3.6	4.0	4.1
38	4.6/4.7	3.9	3.8	3.7	4.1	4.2
39	4.7/4.8	4.0	3.9	3.8	4.2	4.3
40	4.9	4.1	4.0	3.9	4.3	4.4
41	5.0	4.2	4.1	4.0	4.4	4.5
42		4.3	4.2	4.1	4.5	4.6/4.7
43		4.4	4.3	4.2	4.6	4.7/4.8
44		4.5	4.4	4.3	4.7	4.9
45		4.6	4.5	4.4	4.8	5.0
46		4.7	4.6	4.5	4.9	
47		4.8	4.7	4.6	5.0	
48		4.9	4.8	4.7		

Table 1 – Minimum Rifle Front Aperture Size – Millimeters – Use of apertures smaller than listed, even by only 0.1 mm, cause numerous triggering, confidence, and shot process problems.

Remember to always re-measure and adjust the front aperture size if you move the front sight forward or back as you refine your rifle setup and position to assure that you still have the correct size aperture.

As with many of the articles and ideas in this series, one’s perception and beliefs are tested by some of the ideas in this and the previous article and one is asked to consider ideas that seem counter-intuitive or are even thought to be wrong by some. The best athletes are the ones who work the hardest and have the most open minds. Results are results. Enjoy! ▪ *J.P O’Connor*

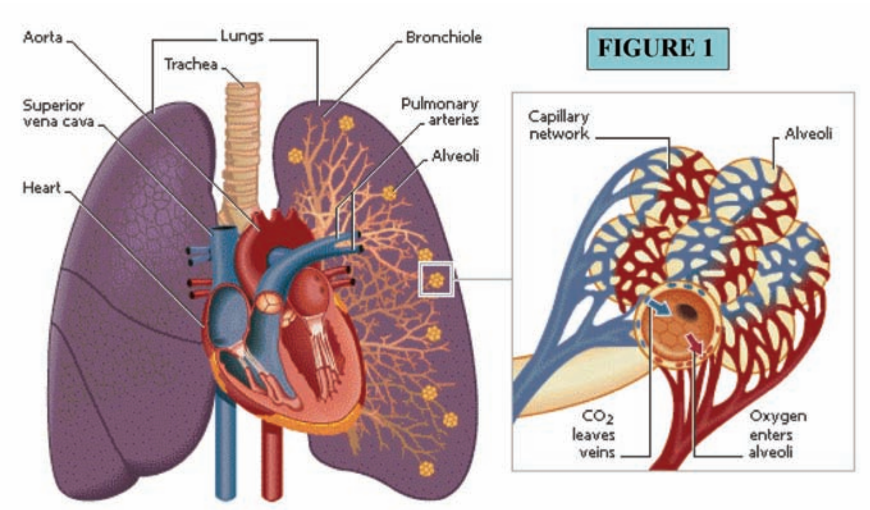
Based in the Atlanta, Ga., area, JP O’Connor (jpoc@acm.org and http://www.america.net/~jpoc/) is involved in shooting as a competitor, is a former Assistant National Coach – USA Paralympics Shooting Team, serves on the National Coach Development Staff in both rifle & pistol, coaches the rifle and pistol teams at North Georgia College & State University, and coaches a junior club. He enjoys working with a number of pistol and rifle athletes from around the country, ranging from beginners to the highly advanced, in clinics and one-on-one private coaching. Previous installments of this series may be found at www.pilkguns.com.

BREATH CONTROL

By Marcus Raab

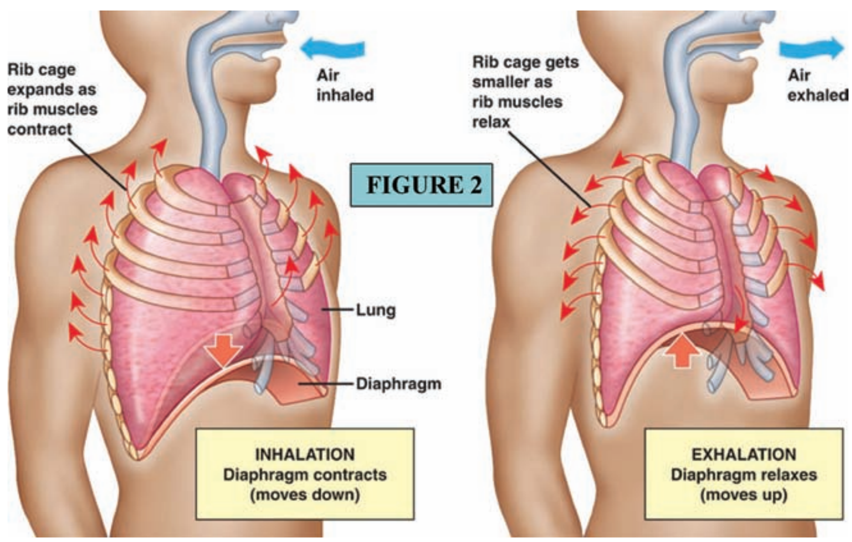
Our bodies must continually take in oxygen through the breathing process to continue functioning efficiently. The primary purpose of the respiratory system is to supply the blood with oxygen (O_2) for delivery to all parts of the body and to remove metabolic waste in the form of carbon dioxide (CO_2). The respiratory system does this through breathing.

The composition of inhaled or inspired air remains relatively constant. Air is primarily nitrogen (N_2) and several other inert gases, comprising 79.04 percent. Oxygen content is 20.93 percent and CO_2 comprises three-hundredths of a percent. Exhaled or expired air, excluding the excess water (H_2O) vapor, always contains more CO_2 (usually between two and five percent), less O_2 (usually 15 to 18 percent) depending on the individual and activity level, and slightly more N_2 (usually 79.04 to 79.6 percent) than the inhaled air. The slight increase in expired N_2 comes from the fact that the number of O_2 molecules taken in by the body are not replaced by the same number of CO_2 molecules produced through metabolic processes.



Air enters the respiratory system through the nose and the mouth. The sinus cavities and throat then warm the air. It then passes through a tube, the trachea, which enters the chest cavity. In the chest cavity, the trachea splits into two smaller tubes called the bronchi. Each bronchus then divides again forming the bronchial tubes. The bronchial tubes lead directly into the lungs where they further divide into many smaller tubes, which ultimately connect to tiny sacs called alveoli. The average adult's lungs contain about 300 million of these spongy, air-filled sacs surrounded by capillaries, providing a surface area of some 160 square meters (see Figure 1).

The blood arriving in the lungs from the rest of the body has a relatively high concentration of CO_2 and a relatively low concentration of O_2, compared to the inhaled air in the alveoli. Both gases diffuse in opposite directions along their concentration gradients, equalizing the concentrations between the blood and the air. The blood releases CO_2 into the alveoli. Meanwhile, the inhaled O_2 molecules in the alveoli diffuse through the capillaries into the arterial blood. The exchanged carbon dioxide follows the reverse path out of the lungs when we exhale (see Figure 2).



The lungs do not expand by themselves. Instead, they connect to the inside of the thorax via the inner and outer pleural membranes and comply with the movement of the chest. The physical process of inhaling occurs when the diaphragm, a dome shaped muscle sheet separating the thorax from the abdomen, contracts, pulling downwards, increasing the thoracic volume. Additionally, the external intercostal muscles connected to the rib cage, lift and expand the chest cavity, further increasing the thoracic volume. The increased volume of the lungs decreases the pressure inside. Atmospheric pressure air outside the body follows this low-pressure gradient to fill the lungs with fresh air.

Exhalation, on the other hand, is a relatively passive process. When the intercostal muscles and the diaphragm simultaneously relax, the tissues of the lungs and thorax stretched during inhalation naturally recoil. This in turn, reduces the thoracic volume and compresses the lungs thereby increasing the pressure inside the lungs. The increased pressure forces air out of the lungs through the mouth or nose.

The volume of air breathed in or out of the lungs during each breath is about one-half of a liter. This

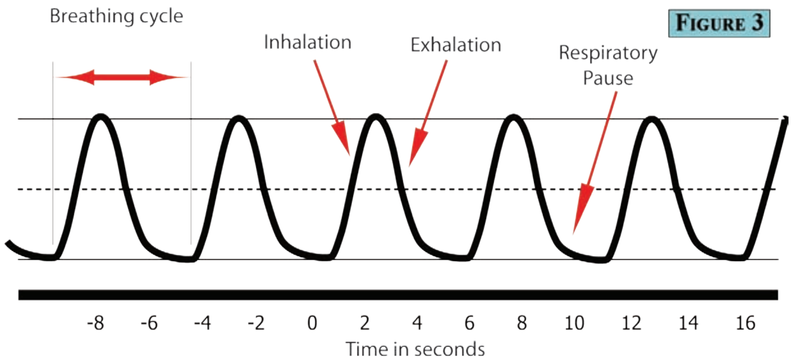


FIGURE 3

amount varies by individual and increases during exercise. The amount of residual air remaining in the lungs even after maximal forced exhalation is about one-and-a-half liters.

UNCONSCIOUS CONTROL MECHANISM

The act of breathing is unconsciously regulated by specialized centers in the brainstem, which automatically regulate the rate and depth of breathing depending on the body's needs. It is a rising concentration of CO_2—not a declining concentration of O_2—that plays the major role in regulating the ventilation of the lungs.

Reacting reversibly with the water in blood, carbon dioxide released from cellular metabolism produces carbonic acid, lowering the pH.

$CO_2 + H_2O \longrightarrow HCO_3^- + H^+$

This drop in the blood's pH stimulates chemoreceptors in the carotid and aortic bodies in the blood system to send nerve impulses via the vagus nerve to the respiration center in the medulla oblongata and pons in the brainstem. Nerve impulses sent through the phrenic and thoracic nerves control the action of the diaphragm and intercostal muscles. As the lungs expand, the ends of the centripetal fibers of the vagus nerve are stimulated, leading to a retardation of the actions of the respiratory center, allowing the intercostal muscles and the diaphragm to relax, causing exhalation.

The rate of cellular respiration, and hence O_2 consumption and CO_2 production varies with level of activity. Vigorous exercise can increase the demand for oxygen by over twenty times. Lactic acid produced by anaerobic exercise can also lower blood pH. The respiratory center responds by increasing the number and rate of nerve impulses. This causes an increase in the rate and depth of breathing which soon brings the CO_2 concentration of the alveolar air, and then of the blood, back to normal levels.

The carotid body in the carotid artery does have receptors that respond to a drop in oxygen concentration. Their activation is important in certain situations, e.g., at high altitude, where oxygen supply is inadequate, even though there may have been no increase in the production of CO_2.

CONSCIOUS CONTROL

Breathing is one of the few bodily functions that (within limits) is controlled both consciously and unconsciously.

Normally, the rate of respiration at rest is between 12 to 15 breaths per minute. The inhalation phase takes about one second followed almost immediately with exhalation, which takes slightly longer. A pause of a second or two between the end of exhalation and the beginning of the next inhalation occurs as the CO_2 content of the blood increases to the point where it triggers the next cycle to start. Controlling and extending this respiratory pause occurs in many activities. For example, in swimming, cardio fitness or vocal training, one learns to discipline their breathing. Even human speech is dependent on breath control.

It should be obvious that the shooter must not breathe while aiming, as the movement of the abdomen, chest and shoulders causes the gun to move significantly making an accurate shot almost impossible. Therefore, the shooter must interrupt their normal breathing cycle in some way for a short period, long enough to settle the hold, aim and shoot the shot.

Figure 3 shows a hypothetical pneumograph of the normal breathing cycle. The lowest point on the graph is the natural respiratory pause. This is the point where the chest muscles are relaxed and the air pressure inside the lungs is essentially equal to that surrounding the outside of the body. At this point, there is no need to exhale further as the CO_2 level in the blood has not reached the concentration necessary to initiate the signal to inhale. In a healthy person, this pause can extended for 12 to 15 seconds without difficulty or experiencing an unpleasant urge to breathe. Ventilating the lungs with deeper inhalations and exhalations before interrupting the breathing cycle can further extend this time.

Figure 4 shows the typical breathing cycle for rifle shooting. Normal breathing should continue until the athlete begins to aim and the sights settle on the bull's-eye. The breathing cycle is intentionally interrupted for six to eight seconds during which time the shooter will either fire the shot or reject that attempt and start the process again. Though the shooter may be able to hold their breath longer than eight to ten seconds, this causes problems with maintaining clear vision as the blood O_2 level is depleted. Additionally, the urgent feeling of the need to breathe due to the buildup of CO_2 in the blood ultimately becomes a distraction from the precise aiming task.

While attempting to fire a shot, a beginner will often take a deep breath and hold it in with his or her lungs fully inflated. Though he or she received instruction to avoid breathing during a shot, this is incorrect. Because the intercostal muscles are under tension holding the rib cage in its expanded position, the shooter will quickly feel uncomfortable, negatively influencing the stillness of the rifle.

Some experienced shooters pause their breathing after

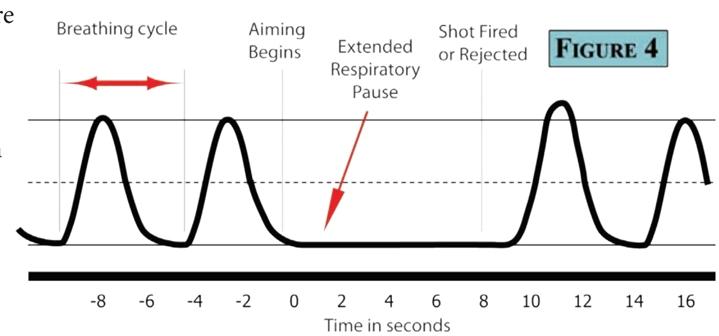


FIGURE 4

several respiratory cycles of decreasing depth, starting with a deep breath and shallower inhale and exhale sequences until obtaining hold refinement (see Figure 5). This technique variation provides some fresh air to the lungs without inducing the major disturbance to the aiming position that a normal breath would.

A few shooters have experimented with inhaling partially after the normal pause (see Figure 6) or stopping their breathing prematurely before the natural pause (see Figure 7). These techniques, however, are potentially problematic as the amount of breath inhaled or held from shot to shot may not be consistent, leading to vertical alignment deviations. This often results in holding too long as they attempt to adjust their point of aim onto the target.

Another pitfall of purposely holding air in the lungs is that of air leakage. As the shooter aims, especially in a sling position, the air is able to escape slowly from the lungs through the nose or mouth. Thus, the position's natural point of aim will gradually drift higher. In the standing position, it would sink lower. Add to this an over-aiming situation with declining visual acuity and the shooter can easily miss the center. It is much more consistent to exhale to the natural respiratory pause, which is the recommended method.

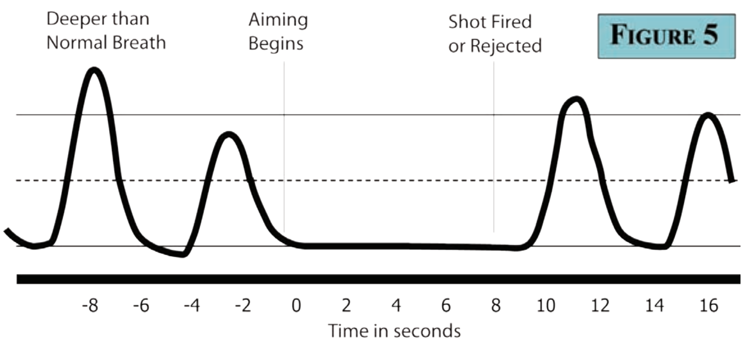


FIGURE 5

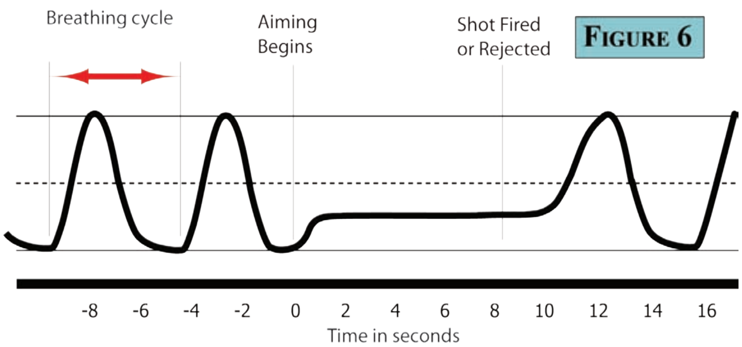


FIGURE 6

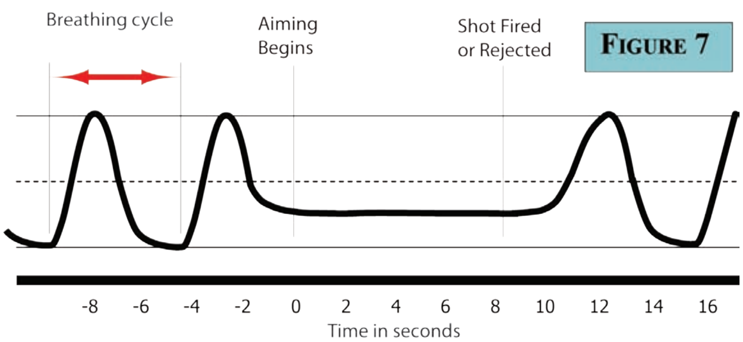


FIGURE 7

ABDOMINAL BREATHING VS. CHEST BREATHING

Under stress, breathing usually becomes shallow and rapid, and occurs high in the chest as the body goes into the "fight or flight" response. Shallow, chest-level breathing, when rapid, leads to hyperventilation. Hyperventilation, in turn, can cause physical symptoms associated with anxiety, such as light-headedness, dizziness, heart palpitations, or tingling sensations.

When relaxed and calm, you breathe more fully, more deeply and from your abdomen. Moreover, when you breathe from your abdomen, you inhale about one-half of a liter of air. When you breathe from your chest, you inhale about half of that amount. The more air you inhale translates directly into increased oxygen supply to the brain and musculature.

Additionally, abdominal breathing by itself can trigger a relaxation response, improve concentration and reduce anxiety by stimulating the parasympathetic nervous system. This branch of the autonomic nervous system promotes a state of calmness and quiescence. It works in a fashion exactly opposite to the sympathetic branch of the nervous system, which stimulates a state of arousal and the physiological reactions underlying panic or anxiety. If a shooter's mind is racing, it is difficult to focus his or her attention. Abdominal breathing helps to quiet the mind.

Some people do not even realize that they are breathing from the chest rather than the stomach. By changing their breathing pattern from their chest to their abdomen (stomach area), they can reverse the cycle and transform their breathing into a built-in tool for anxiety control.

You can see for yourself if you are stomach breathing by lying on your back and placing your hands on your stomach. Your stomach should rise and fall as opposed to your chest rising and falling. In order to practice this, picture your stomach filling up as a balloon would. Every time you breathe in, your stomach fills up and the balloon and rises, and every time you breathe out, your stomach flattens. During this time, your chest should stay mostly still.

Chest breathing is not always a negative. It may also be a useful tool for the shooter. While we want to be relaxed and calm when firing a shot, a chest breath or two immediately after the shot can reenergize the shooter especially during long courses of fire. Coaches should suggest that athletes employ chest breathing immediately after the shot to invigorate and begin replenishing the blood oxygen level. Additionally, athletes should switch to stomach breathing to relax into the position prior to a shot. This procedure helps prevent premature fatigue over long courses of fire and provide the basis for a solid shot plan.

Hold & Hold Control

By Marcus Raab, Assistant National Rifle Coach

Hold is a deceptively simple fundamental to describe. It is easy to say a good hold is one that has a small movement area oriented at the reference point (i.e., center of the target) and is stable and durable enough to allow smooth trigger control. It is much more difficult to fully define hold since it is so interrelated to all the other fundamentals and aspects of position, physical conditioning and mental skills. And it is even more challenging to actually develop and maintain a high quality hold for the shooter to execute the shot.

Shown below in Figure 1 are hypothetical holds for prone and standing. While some people can hold a sight picture that appears motionless, there is always some movement even in the prone position. It is often quite difficult to see this movement without some kind of aid. A telescopic sight which magnifies the target, for example, can show how much movement there really is in the shooters position. Athletes must learn to accept this movement and execute correct trigger control without disturbing or negatively influencing the sight picture. Even the shooter has trouble seeing the entirety of the movements, perhaps remembering only the last few instants before the shot is fired. This, of course, is enough to know where the shot should have hit the target, but insufficient to really analyze the holding ability.

Previously the only tool the coach had to evaluate the holding ability of shooters was his or her own eyes. You can still do that by standing behind the athlete and lining up the edge of the barrel or front sight tunnel with an object (e.g., another target) downrange. The challenging part is for the observer to stay still enough so that the only movement seen is that of the rifle muzzle. Recoil of the rifle also masks some aspects of the hold, especially follow-through.

Though expensive, computer training systems are available on the market; notably the Scatt, Rika, Noptel and others that can record the precise orientation of the rifle in relation to the target. What is so eye opening about these systems is that they allow the coach (and shooter) to actually see what is happening throughout the whole shot process. You can not only see the result of a shot after it has been taken but also what happened while aiming at the target, both before and after. Graphs produced from the mathematical analysis of the series of shots can help identify problems and lead to the best course of action to take regarding improvement. These systems work in either a dry fire mode or may be used live fire with pellets at 10 meters and even longer ranges depending on features.

The use of these training systems is almost essential for top-level performance as they can show such fine detail and the tiny mistakes that elude detection other than showing up as nines on the target. Even for the developing shooter, a visual depiction of how it should be done (with the opportunity to emulate the top shooters around the world) can significantly shorten the learning curve.

On the next page, there are Scatt traces (Figures 2, 3 and 4) of three different air rifle shooters showing the approach and hold up to the moment of the shot. The intermediate-level shooter has little control of his or her alignment with the target, forcing the rifle toward the center as well as a larger hold area. The advanced athlete shows better control over alignment and a smaller hold area, but the trace also indicates

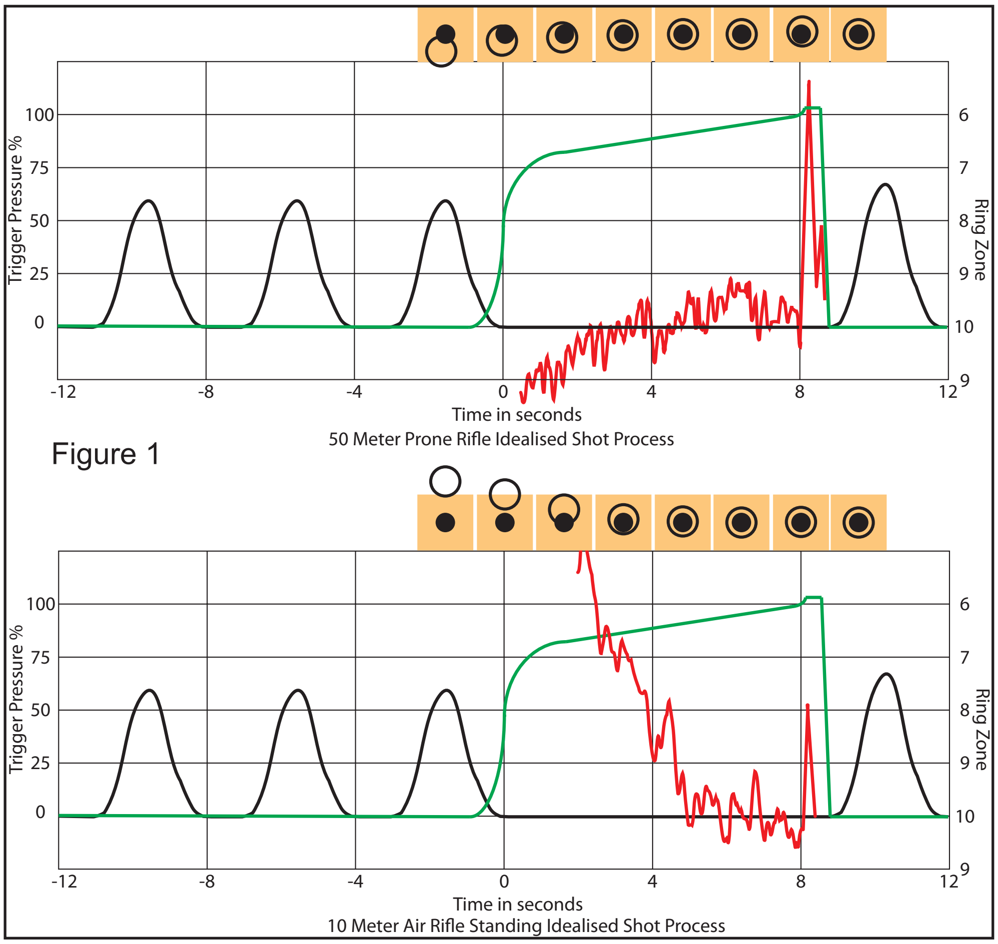


Figure 1

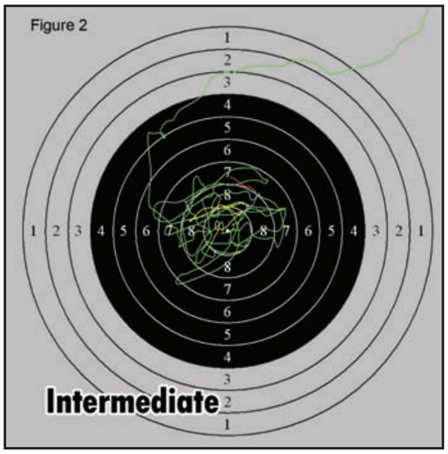


Figure 2

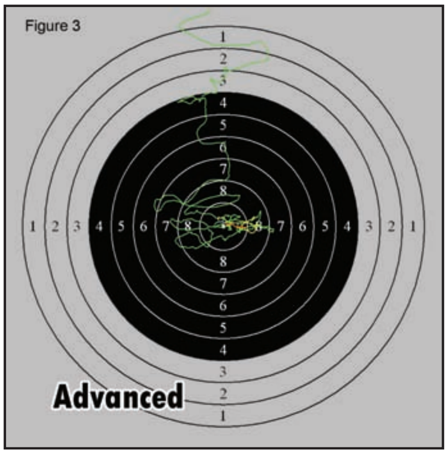


Figure 3

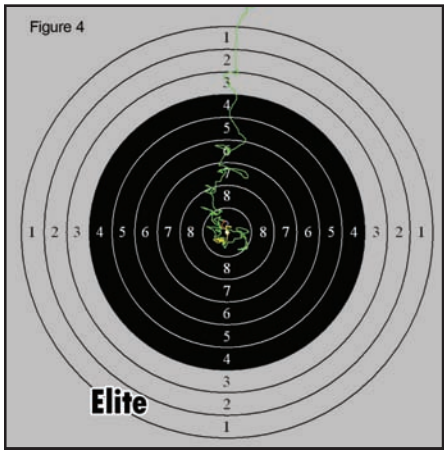


Figure 4

the possibility of tensed muscles. Notice the sharp changes in direction that overcompensate to the other side—this occurs when the shooter sees that the sights are not quite centered and nudges the rifle toward the center. Results: Intermediate = 8; Advanced = 9.

As a comparison, this Scatt trace shows the hold of an elite air rifle shooter up to the moment of the shot. This athlete has excellent control of his or her positional alignment, which allows the hold to settle directly into the center and stop in the middle of the target. The small hold area illustrates relaxed muscles with no need to force the rifle toward the center (it is already there!). This hold looks almost motionless to the shooter. The result? A deep 10! This is what we all would love to see, but again it requires lots of training and practice.

Biomechanics

Biomechanics is the sport science field that applies the laws of mechanics and physics to that of human performance. It is used to gain a greater understanding of athletic performance through modeling, simulation and measurement. It is necessary to have a good understanding of the application of physics to sport, as physical principles such as motion, resistance, momentum and friction all play a part in rifle shooting.

What factors contribute to hold?

So how does a shooter progress to an elite quality hold; one that is small, centered, stable and durable? The most critical component of holding ability is a biomechanically sound position. The movement will vary in size and predominant movement pattern with each position, with supported or sling positions being relatively stable and durable, while standing is less stable. Each position presents its own challenges. Nevertheless, there are some principles that apply to all positions. It is how well these principles are applied that determines success in each position. The elements of a sound position and its development are:

- Bone Support
- Balance
- Natural Point of Aim & Alignment
- Comfort
- Consistency
- Legality

Skeletal Structure and Bone Support

The human skeleton consists of both fused and individual bones connected, supported and supplemented by ligaments, tendons, muscles and cartilage. It serves as the framework that supports organs, anchors muscles and protects critical organs such as the brain, lungs and heart. An array of differing joint types allows the muscles to move the body to perform tasks.

You have, no doubt, tried to hold something still at arms length. You were probably successful at first, but at some point you could no longer hold the object still and eventually your arm would finally reach the point where it could not remain in position no matter how hard you tried. Muscles, even strong muscles, will fatigue and not respond in the predictable way needed for the ultra-fine motor control necessary to execute the shot precisely. Whereas the bones of the skeleton do not suffer the same problem of fatigue and may be used almost indefinitely as the structural elements of the shooting position. In rifle shooting, with heavy guns and long courses of fire, maximizing bone support is an important aspect of developing a good position and hold. Without some minimal amount of muscle tension, however, we would be unable to maintain the skeleton in the same orientation.

Statics and Stability

When building a shooting position coaches must take into consideration the bones, muscles and other body structures and organs. Additionally, the proportions of the shooter's body, long or short arms, long or short legs, long or short torso and neck and the flexibility of the joints play a role in determining the best position for a specific shooter.

We seek to position the body to maximize the support of the bone structure while also minimizing the use of muscle force. This is best accomplished by placing the body parts that support the rifle position into vertical planes. For example, when a carpenter is creating a strong structure, he or she installs the walls in a vertical fashion to best resist the forces of gravity. If the walls were built at an angle and there is a large snowfall that weighs down the roof, it is likely that the building would either collapse or require additional support (the use of muscles) to remain standing.

The same is true for shooting positions. For the body to remain stable in the shooting position, the legs and arms that support the rifle must form vertical planes. This transmits the weight of both the rifle and body directly into the ground without the need to use muscle. While the sling plays a major structural role in helping support the prone and kneeling positions, shooters still need the bones in the proper orientation to maximize support. A coach must thoroughly understand this concept and be able to identify and correct positional errors when observed. The areas that you need to pay attention to are specific for each of the positions.

Balance

From a biomechanics perspective, human balance refers to the body's ability to maintain an upright posture by keeping the center of mass (gravity) positioned over the base of support with minimal postural sway. This may involve a fixed base (for standing) or a moving base of support (for walking or regaining balance after a slip). Balancing ability can be studied using ground reactions (force patterns at the foot-floor interface), body segment kinematics (motion of upper/lower extremities) and electromyography (electrical signature of muscles when contracting).

When discussing balance, we will only address a fixed base (in addition to the weight of the rifle and accessories) of support since shooting is a static sport.

Standing, for example, is a human position in which the body is held upright and supported only by the feet, referred to as an orthostatic state as shown in Figure 5. In the case of an individual standing upright quietly, the limit of stability is defined as the amount of postural sway when balance is lost and corrective action is required. The limit of stability may be described by an irregular conical envelope above the support base. This limit of stability far exceeds what is acceptable balance for the shooting position.

Although standing per se is not dangerous, there are a few pathologies associated with it. One short-term condition is orthostatic hypotension, or low blood pressure when standing, which is caused by gravity pulling the blood into the lower part of the body. Because the brain does not get sufficient blood supply, it can result in dizziness, lightheadedness, headache, blurred or dimmed vision and even fainting. Longer-term conditions are sore feet, stiff legs and low back pain.

While we have been focusing on standing, both kneeling and prone require balancing as well. Kneeling has a larger base of support than standing but less than prone. Even then, the kneeling position is balanced between the right foot, the kneeling roll and left foot. In prone the rifle is balanced on the left arm.

Figure 5

Figure 5 shows the support area and center of gravity. The man on the right shows a loss of balance when the center of gravity moves outside the support base.

Nervous system

The human center of mass is in front of the ankle, with a narrow base of support, consisting of only two feet. A truly static pose would cause a human to fall forward onto his or her face. In addition, there are constant external stresses (such as breezes) and internal stresses (respiration, digestion, excess water temporarily stored in the bladder, etc.).

Maintaining an erect posture relies on dynamic rather than static balance, which requires constant adjustment and correction. The nervous system continually and unconsciously monitors our movement direction and velocity as the body's vertical axis alternates between tilting forward and backward and side to side. Before each tilt reaches the tip-over point, the nervous system counters the imbalance with a signal to reverse direction. The muscle exertion required to maintain an aligned standing posture is generally minimal but crucial, with the muscles of the feet and ankles are intimately involved in balancing. The muscles of the calves, hips and low back also play a small role. However, recent attention has been devoted to the core muscles, as they are critical in maintaining stability. The transverse abdominals, or the internal core muscles that lie close to the spine, function as a compression corset and provide structural support and control. Dysfunction or imbalance of the core muscles is also associated with back pain. With rifle shooting positions being one-sided, the risk of developing an imbalance in strength and/or flexibility is increased. It makes sense, therefore, to improve overall core muscular strength, along with the legs, to help stabilize the standing and kneeling positions.

Balance control

Controlling this dynamic balancing process requires simultaneous processing of inputs from multiple senses. This includes equilibrioception (from the vestibular system located in the inner ear), vision and proprioception (the body's sense of where it is in space). The senses detect changes of body position with respect to the base while the motor system controls muscle actions to maintain balance.

The vestibule is the region of the inner ear where the semicircular canals converge, close to the cochlea (the hearing organ). Each semicircular canal has a bulbed end, or enlarged portion, that contains hair cells. Rotation or tilting of the head causes a flow of fluid, which in turn causes displacement of the top portion of the hair cells that are embedded in the jelly-like cupula. Two other organs that are part of the vestibular system are the utricle and saccule. These are called the otolithic organs and are responsible for detecting movement in a straight line. The hair cells of the otolithic organs are blanketed with a jelly-like layer studded with tiny calcium stones called otoconia. When the head is tilted or the body position is changed with respect to gravity, the displacement of the stones causes the hair cells to bend, which in turn sends signals to the brain.

The balance control system also utilizes visual input to maintain orientation and balance. For example, visual signals are sent to the brain about the body's position in relation to its surroundings. These signals are processed by the brain and the information is compared to reports from the vestibular and the skeletal systems. An erect head position is the key to maintaining balance. Not just for the balance apparatus in the inner ear, but also for the eyes and vision. The importance of visual input for balance is illustrated by the fact that it is harder to stand on one foot with eyes closed rather than eyes open. Another example is a swaying spotting scope or rifle rest stand, seen in a shooter's peripheral vision, creating rhythmic swaying of the shooter.

The third component of balance control is proprioception. It is the third distinct sensory mode that provides feedback and indicates whether the body is moving with the required effort. Additionally, proprioception detects where the various parts of the body are located in relation to each other. Proprioceptors on the bottom of the feet, for example, sense the pressure as it changes from the shift in the center of gravity.

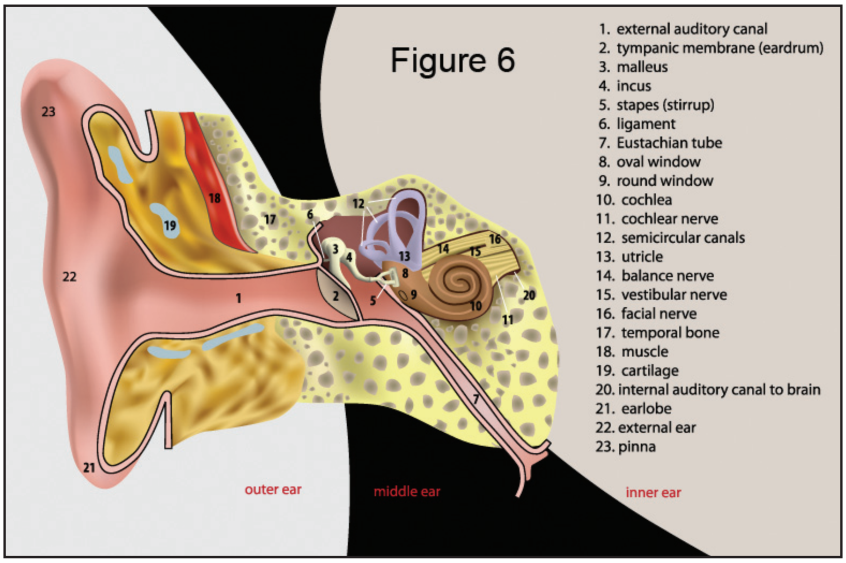


Figure 6 illustrates the inner elements of the ear that contribute to balance.

The sense of balance usually deteriorates in the aging process. However, it can be improved considerably with the help of specialized training.

Natural Point of Aim and Alignment

Often a confusing point for beginners and experienced shooters alike, Natural Point of Aim (NPA) has nothing to do with the target. It is where the rifle naturally points when the body is relaxed. The objective is to adjust the position so that the rifle points naturally at the target center when the body is relaxed. Alignment to the target is correct when the body is in a relaxed position supported by bone structure (with minimal muscle tension) and the rifle naturally points exactly at the center of the specific target. Alignment is not just left and right, but up and down as well.

"How do we check NPA?" (Note: There are several methods to check NPA. The suggestion below is only one such method.)

- Relax with head on the stock
- Close the eyes or glance away
- Check balance & muscle tension
- Open eyes & see where rifle is pointing
- Make needed adjustments & test again

Check-adjust, Check-adjust, Check-adjust, Check until it is perfect. Adjustment mechanics are different for each position but the goal is the same.

NPA should be checked every shot as an integral part of the whole shot process. If the NPA is aligned correctly, the shooter will see the rifle sights approach the target from exactly the same direction, and then slow and stop exactly on the center of the target. The shot can then be fired with confidence.

When alignment is not correct, the temptation is to engage the muscles to push the sights to the center. This results in poor shots as the rifle will move away from the center as the shot is fired. Consider, for a moment, if the NPA is exactly centered and the shot is released on the outside of the hold area, the rifle will tend to move toward the center. A better shot is the result. This is the reason for checking alignment until it is perfect.

Comfort

All shooting positions should be reasonably comfortable. Some discomfort is inevitable, especially during beginner training or after a long layoff from shooting, but within a few minutes of getting out of position the discomfort should disappear. Early training sessions should be intentionally short so that the shooter can build up a tolerance to the pressures of the sling and kneeling roll. Pain, however, is never a good sign and may indicate an injury or other problem. If the shooter is in pain, stop immediately and apply appropriate first-aid. Before allowing the shooter to continue, make certain that any issue has been resolved.

A good position allows normal flow of blood between the heart, head, arms and legs while shooting. Some restriction of blood flow and impinging on the nerves of the arm may occur when using a sling, but that can be somewhat alleviated by wearing thick sweatshirts or undergarments and a shooting jacket with a properly adjusted sling.

The kneeling position can also restrict blood flow to the leg and also impinge on the nerves that pass behind the knee. Comfort can be improved in the kneeling position by spending time in position on the kneeling roll while engaged in some other activity like reading or watching television. Building up the time that the shooter can comfortably stay in position will make it easier to stay focused on shooting instead of thinking how bad their foot and ankle feels. Stretching and flexibility exercises can also help improve overall comfort.

Consistency

In rifle shooting, we are trying to place one shot on top of the other in the center of the target. The only way to accomplish that task is by having a solid position that allows the shooter to continually reproduce the same shot process. Without being consistent, the chances of performing successfully are low.

Consistency is not just shot-to-shot, or even series-to-series, but also day-to-day. After the basics are learned, next to come is the introduction and development of the shot process or routine. As the athlete enters competitions, a setup routine is also needed. It all boils down to repetition in thought and action as trained.

Legality

Of course any position used in competition must comply with the rules. Rulebooks are generally quite consistent on what constitutes a legal shooting position, but it never hurts to keep up to date on with the fine points of the various rules. It would make no sense to develop and learn a position that would be in violation of the rules. Yet we see these violations too frequently.

For example, in the prone position, the left arm must form a 30 degree angle with the supporting surface and the sling may not touch the gun or shooter except at the attachment points. In standing, the rifle may touch the upper chest and shoulder area only on the dominant side of the body. And in kneeling, the roll may not be used if the dominant foot is at more than a 45 degree angle and the point of the elbow must not be more than 10 cm over or 15 cm behind the point of the other.

Coaches must be ever vigilant that changes to a shooter's position do not violate the competition rules. In many cases, subtle adjustments made over time can suddenly result in a position that is no longer legal. Don't let this happen to you.

Psychological Interconnectedness

Holding still or hold control is as much about the mental efforts used to reduce or control body movement as it is the physical positioning. Conscious thought about correcting the aim almost always results in over-correction of the error and a jerky response. Movement of the rifle can be somewhat controlled by turning one's attention inside the body through the inner position. Ask yourself questions such as: "Muscle tension, is it correct? Where is it too much?" Breathing, as we discussed earlier, helps control emotions, relaxing both the body and mind and reduces unneeded muscle tension. A small change will stand out if the background tension is low.

The mental control of the hold, however, is more about the focused thought or intention of "smaller," "slower" or "center" and will likely be more productive than consciously trying to correct or adjust the hold while aiming.

Top-level shooters from around the world describe this mental control of their position, and thus their hold, in a wide variety of ways. From that of being a granite statue or leaning up against an imaginary wall to resting their elbows on imaginary tables at just the perfect height or holding themselves in the perfect position with an imaginary corset; whatever the mental key, these shooters exert their will to hold still. Essentially it is mind over matter.

All of these images, and more, have been used successfully. It is, of course, a very personal choice and no one should be forced into any specific trick described here, but rather given the idea and the freedom to test and develop their own best solution to holding still.

Of all the fundamentals, holding the rifle confidently on the center of the target is the most critical for shooting success. Everything else follows from that. But without being able to execute the shot, the best hold in the world is useless.

Outer Position

The position of the body and all of its parts along with the shooters clothing and accessories constitute the outer position. For example, in the standing position, the coach can observe the orientation of the hips in relation to the feet and legs, the angle of the arms, back and torso, and how the shifting of weight toward the target tilts the pelvis and provides a shelf to rest the elbow. The coach can also see how the clothing fits and whether it helps or hinders the shooter in obtaining the correct body position. Essentially, it is anything and everything an observer can see.

Inner Position

While the outer position is what the position looks like from the outside, the inner position, is fairly invisible to the observer. Even the shooter is not necessarily aware of what the right feeling should be. What the coach cannot see is the feeling, the muscle tension and the discomfort. A biomechanically sound position, practiced consistently, provides feedback to the brain of the correct feeling of a solid position. Ultimately, however, the ability to precisely replicate the exact same position shot-to-shot and day-to-day is gained over several years of training.

Trigger Release Part I

By Assistant National Rifle Coach Marcus Raab

We now come to the moment of truth; pulling the trigger. It is the culmination of all aspects of the shot. If everything is right, the shot is on its way to the center of the target. Done in the wrong manner, no matter how good everything else was up to that point, the shot will land away from the center.

Proper trigger control is accomplished when the shooter applies increasing pressure to the trigger, without disturbing the sight picture, while the hold is acceptable until the shot is fired. This is another fundamental that is simple to describe in theory but very challenging to perfect and maintain.

The actual physical act of pulling the trigger is no more than a small muscle contraction of the index finger. Yet, sometimes the finger just won't bend or pulls at the wrong time! In the first part we will look at trigger release from two of four different angles:

- *Mechanical—the types of triggers, adjustment and weight and how they influence technique.*

- *Technique—position, contact between the hand and the pistol grip and trigger, trigger pull variations and recommendations.*

In Part 2 we will look at:

- *Mental Tasks—what processes does the brain perform to make the best possible decision about when to pull the trigger?*

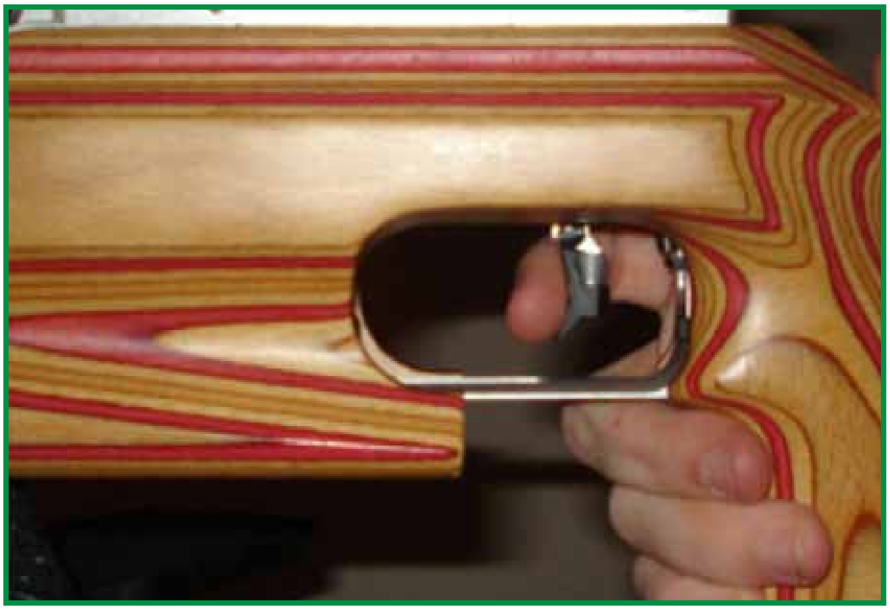
- *Psychology—what effects do excitement or caution play in triggering during competition?*

THE TRIGGER MECHANISM

The link between the finger and the firing of the shot is the trigger mechanism itself. Most target rifles have various adjustments for the trigger. But first we need to understand some basics about triggers in general.

THE TRIGGER

Using a series of internal mechanical levers and springs, the trigger of a competition gun is a complex device that holds the firing pin in the cocked position until the shooter is ready to fire the shot. The trigger can normally be adjusted within design limits for weight of pull as well as other variables to adapt to the desired feeling for a shooter. The actual interface between the shooter's finger and the firing mechanism is the trigger lever or "shoe,"



which projects below the rifle action into the trigger guard. This part is itself often adjustable either forward, backward or laterally depending on the size of the hand and how the shooter grips the rifle.

If you think of the trigger as a simple mechanical lever, the resistance that must be overcome to fire the shot depends where the finger is placed on the trigger. Placing the finger high increases the pressure needed to fire the shot while placing the finger low on the trigger will increase the mechanical advantage of that lever and reduce the force needed, thus making the trigger feel lighter. It is important to always place the finger in exactly the same spot to get a consistent feeling.

The trigger width can also change the way one trigger feels over another. A wide trigger shoe spreads out the pressure over a larger area making it feel like it takes less pressure to fire the shot. One of the risks with wide trigger shoes is that more pressure may be applied to one side or the other resulting in lateral displacement of the gun.

Another factor is the curvature of the trigger. Curved triggers can help the shooter consistently place the finger in the middle of the trigger. But the risk is that the pressure may be exerted upward or downward, potentially disturbing the aim. Straight triggers often have a small clip or marking point that can help the shooter place the finger on the same spot for each shot. Since trigger shoes are often interchangeable, one can choose a trigger shoe that suits the shooter. Trying out a teammate's trigger to see how it feels is a good exercise. Remember to ask permission first!

In general, the trigger pull weight should be in the range of 80 to 120 grams for smallbore and precision air rifles. There are no rules based requirements on triggers for these rifles other than being safe, with the only exception being that set triggers are not allowed on air rifles. Sporter air rifles, being low cost introductory rifles, do not have high quality, finely adjustable triggers found on precision air rifles. They typically come from the factory with trigger weights in the range of three to five pounds. There are ways to make them feel better and reduce the pull weight, but the minimum trigger weight is still 1.5 pounds. Older smallbore rifles found in many clubs may still have three pound triggers.

TRIGGER TYPES

Regardless of the weight, there are several different types of triggers. Most factory produced target rifles arrive equipped with a two-stage trigger. It is characterized by an initial, free movement or take-up in the trigger until a point of resistance is felt. This is the first stage. The rifle is fired after the application of additional pressure on the second stage. There are some characteristics of this kind of trigger that you need to know about to make it fit the particular shooting style.

The first stage should not be very long. It shouldn't take much time or allow the finger position to change much during movement. It should have the same resistance throughout its travel and never stick or catch before the second stage is reached. If it does not feel right, look for help from a gunsmith or coach.

The weight of the first stage is important to the overall feeling of the trigger. For example if the total trigger weight is 100 grams and the first stage is 50 grams once the second stage is reached only 50 grams more pressure is needed to fire the shot. Pulling the first stage has already taken up half of the total pressure and only the remainder needs to be applied. What you feel as the pressure to fire the shot is really the differential resistance or extra pressure needed after the first stage in order to overcome the second. In general, the resistance of the first stage should not be less than half and may approach two-thirds of the total.

Once the second stage is reached, correctly adjusted triggers will exhibit absolutely no movement until the shot fires. Shooters call this a clean break or crisp release of the trigger. If the trigger still moves slightly without releasing the shot you have trigger "creep." This condition can irritate and distract the shooter, and is usually caused by incorrect adjustment or mechanical wear. Regardless, the trigger needs to be adjusted or repaired before the shooter begins to doubt their shooting abilities. Any creep should be adjusted out of the trigger by adjusting the engagement of the sear following the manufacturer's directions. Adjusting the engagement too finely can cause premature wear of the sear surfaces, and ultimately requiring replacement of parts or the entire trigger itself.

Another type of trigger is the single-stage which has no perceptible movement during the application of pressure until the pull weight is overcome. Sometimes referred to as a "direct" trigger, when finger contact is made with the trigger, the next movement will release the shot. Creep in this kind of trigger is also frustrating to good shooting and should be adjusted.

An advantage of the single-stage trigger is that it can save time and energy since there is no first stage to take-up or rush through in a high stress moment; you are ready to go right away. Some shooters may have problems initially with the light single-stage trigger because they are afraid of touching the trigger before they are ready. But with a little practice they soon get used to touching the trigger a little more carefully.

To emulate a single-stage trigger, the first stage of a two-stage trigger may be set to a very small movement; try it out to see if you like it. But this is not the ideal way to use a two-stage trigger. The best solution is to replace the trigger with a single-stage design. If you like the feeling and want to convert your gun to a single-stage trigger, always seek out a gunsmith. Some rifles cannot be safely converted to single-stage triggers. Air rifles in particular may accidentally discharge during loading if the trigger is not adjusted properly.

An older trigger type that has been used in the past but has lost favor with shooters is the set trigger. A set trigger functions normally as a two-stage trigger but when a secondary lever is pressed or engaged to "set" the trigger it functions like a single-stage trigger with a release weight as low as 30 to 50 grams.

SETTING THE TRIGGER PRESSURE

So how light or heavy should the trigger be set? As always, this depends on personal considerations, so everyone has to find the ideal solution for him or herself. But there are some hard learned lessons that you may find helpful.

Know your trigger. Become familiar with all the possible adjustments by reading and learning the manual that comes with the gun. Try out different settings in practice and develop a feel for the trigger.

Test your trigger in a match. Lighter is not always better! What works in a low-pressure practice situation may not be right in the high excitement of a major competition. If you have ever pulled through both stages of a two-stage trigger in a match, you might consider a heavier trigger.

Trigger pressure and grip pressure are related. If you hold too tight with the grip hand the trigger finger won't be as sensitive to pressure. Make certain that you can accurately feel the trigger pressure with your normal grip.

If you shoot in cold weather, you might consider raising the total trigger pressure since you lose sensitivity in your finger as the temperature goes down.

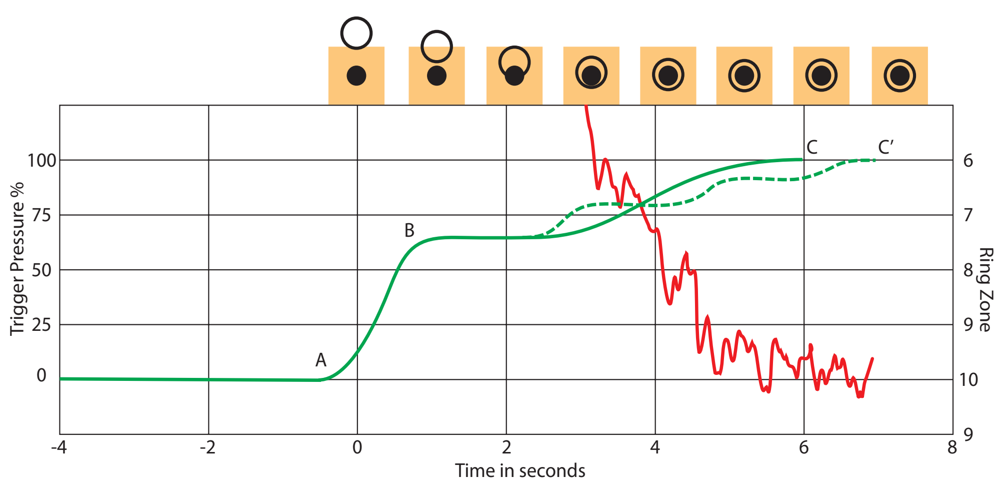
If you are a three-position shooter, adjust the trigger so that it suits your most unstable position (usually standing).

Over-travel is the movement of the trigger after the shot has fired. Very often the trigger is set so that the pressure drops off significantly. Depending on the shooter, this may cause the rifle to move during the shot. If shots are going off-call and everything else looks correct, experiment with adjusting the over-travel so that it is relatively short and near the overall trigger weight.

TRIGGER MAINTENANCE

Just like any other moving part, the trigger can suffer from wear. In such a precise mechanism, tiny amounts of wear can cause major problems. So you should check frequently that the trigger is functioning the way you want it to.

A way to do this is to cock the unloaded gun and rest it on a solid surface



10 Meter Air Rifle Standing Idealised Shot Process
Two-Stage Trigger with Dynamic Aiming

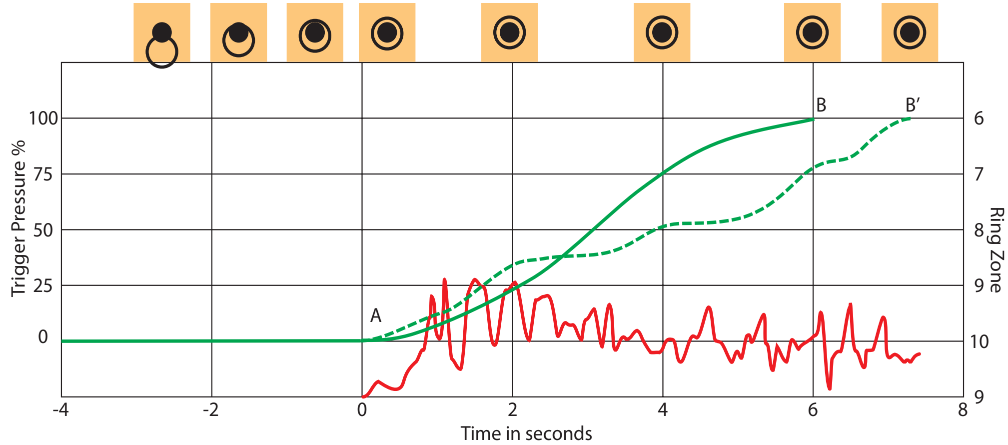
and watch the trigger movement as you pull it. Another way is to hold the gun in a stable position and, with your eyes shut, test the feel of the trigger. You should be able to quickly check that the trigger is indeed OK or determine if it needs adjustment.

TRIGGERING TECHNIQUE

How the trigger is released is decisive in producing an accurate shot. A proper release requires a few things; it does not disturb the aim of the rifle on the target. Regardless of the type, or weight of pull, the shooter must pull the trigger smoothly, applying pressure directly in line with the barrel. Trigger release also must be coordinated with the visual perception of the sight picture so that it happens at the exact time that the sights are properly aligned on the center of the target. Coordinating this action while the gun is constantly moving is challenging to say the least.

The trigger hand has several functions. It is a very important contact point between the shooter's body and the stock of the gun. It helps hold and support the gun; that makes it important for the steadiness and balance of a position, but its main function is to place the trigger finger in the ideal position. The grip of the hand must be the same for each and every shot; the same placement, with the same firmness without excessive muscular effort. There must also be a space between the trigger finger and the stock as well as the trigger guard so no movement of the gun is induced while pulling the trigger. The trigger finger must be consistently placed on the trigger in the correct location and its movement must be directly in line with the barrel and the line of fire.

Where the finger is placed on the trigger shoe itself is also an important consideration. For heavy triggers, like those on 300 meter Standard Rifles (1.5 kilograms) or sporter air rifles, placing the trigger in or next to the first joint of the index finger usually provides better control. For smallbore and air rifles with light triggers, the better place is not the tip of the finger, but rather just behind the pad but before the first joint. The potential problem with using the tip of the finger



50 Meter Rifle Prone or Kneeling Idealised Shot Process
Single-Stage Trigger with Static Aiming
AB—Continuous Smooth Release AB′—Graduated Release

is that pressure will be applied at an angle to the side and not directly in line with the barrel or the designed functioning of the trigger mechanism itself. Placing the first pad on the trigger is also potentially problematic since the fleshy part of the pad can act like a shock absorber, cushioning and slowing the application of the decisive pressure when applied. The point just behind the pad and before the joint is closer to the bone.

As a test, when the shooter pulls the trigger several times in quick succession, the gun should not move. Adjust the trigger, your position or the grip until you are satisfied.

The shooter must begin the process of releasing of the trigger during the approach to the target. As the aim is refined the pressure is smoothly increased as the oscillations of the rifle become smaller and under control in an attempt to fire the shot at the moment when the rifle is moving minimally or appears to stop. Beyond this point the movement tends to increase and further attempts to release the shot increase the risk of a poor result. The best course of action is to abort the shot and make another attempt.

There are generally two distinct methods for applying pressure to the trigger. In the first method the pressure is smoothly applied to the trigger in a continuously increasing manner until the shot fires. The rate of increase may change, but during the process it is *always* increasing. This method has the most utility in stable positions where the movements are consistently centered and small as in prone or kneeling.

The second method is a graduated release technique where the pressure is increased while the aim is acceptable. When the aim becomes unacceptable the pressure is held on the trigger until the aim becomes acceptable again, with pressure increasing in steps until the shot is fired. This method is especially useful in positions that are less stable or with heavy triggers.

With a two-stage trigger, the technique is modified slightly but only in the application of the initial pressure, as it is taken up immediately as the sights approach the target. After this point the shooter uses either the smooth continuous smooth release or the graduated release method.

There are of course many possible variations of the two methods. One of these is a pulsating pressure where the shooter adds and reduces pressure to the trigger during the preparation for the shot but as the aim becomes refined, the pressure is quickly applied using a smooth, continuous method. This variation was often used with set triggers.

The successful shooter must learn the correct method of applying pressure to the trigger, gradually and evenly. This does not imply slowly, but rather smoothly without jerking. The time to complete the trigger pull can be very short (<1 second) but not so long as to miss the best opportunity. The ability to pull the trigger smoothly is not enough on its own to produce an accurate shot; it must be coordinated in time with proper aiming.

By Major Dave Johnson, National Rifle Coach

Holding and Working Hard– or Overholding?

A common challenge that I run into with athletes at all levels is hesitation and over-holding. Over-holding can be defined as continuing to hold past the prime of your hold, before executing the shot. The prime of your hold can be when you are at your most stable; all your body systems are at their best window to produce a good shot within the movement you have.

Our sport attracts the "perfectionist" personality trait athletes on a regular basis. Often, athletes will struggle trying to constantly be "perfect" in the result (i.e., shoot a 10) and simply hesitate beyond their ability to shoot a perfect shot. They will wait for the perfect or motionless hold or a perfect timing of the hold they have. The perfectionist trait is not the problem; what they are trying to make "perfect" is the issue.

One of my junior coaches who mentored me when I was competing in my teenage years, watched me at a competition use every minute of the time allowed, holding and hesitating, until I literally had to throw the shots down range in a panic to finish within the time allotted. I shot poorly but I thought I had "worked hard." He took me aside and said "shoot the hold you have—shoot YOUR quality hold, stop waiting and fooling around waiting for something else!" He was right—I was trying to shoot a motionless hold in standing that I didn't have instead of executing the shot cleanly in my hold. (Ray Anti, USMC (Ret.) still works with shooters today).

If you are an athlete or a coach reading this and have the over-holding challenge as an issue, try the following technique to create better execution:

Be "perfect" in the PROCESS: Do the steps correctly to set up your best hold and execution without fail, every time. Evaluate yourself on your consistency of doing this and the score will follow.

Example in Standing:

- Pick up the rifle and mount your position without looking through the sights. Look over the top of the sights. Important—if you go directly to your sights and start working your sight picture while you are stabilizing your body you will achieve neither—do one thing at a time.
- Focus on your body and stability from the feet up.
- Make sure you set your support elbow in exactly the same place as you have trained.
- Make sure your support hand is placed correctly for what you have trained.
- Take three relaxing deep breaths as you settle in to your position, still looking over the top of your sights or even just to the side.
- When your inner position feels stable and correct, then go to the sights.
- If your hold looks normal (YOUR quality hold for whatever skill level you have built so far) execute the shot. As a rule of thumb, at this point you have about 7-10 seconds after you stop breathing to shoot within your prime physical window before lack of oxygen starts degrading your visual acuity and relaxed state.
- If you go beyond 10 seconds, stop and restart. The whole process from mounting the gun to shooting the shot or rejecting the shot can be about a minute.

Use your coach! Ask the coach to run a timer on you when you are setting up and executing. Do this over many shots to evaluate the time you are actually spending in the process and look for ways to be efficient and consistent. Compare training and matches.

How do I evaluate my hold? No matter what skill level you are at in development, beginner or Olympic Champion, your best hold and execution occurs when you can accurately call your shot—not just when you shoot a ten as a result. Your coach can help you evaluate your hold and execution just by taking your scope from you and making you call the shot each time you shoot.

"Laser" or optical trainers: Systems such as SCATT and NOPTEL can be good tools for evaluating hold and execution. They also have built in feedback tools such as sound that can help you gain confidence in knowing the actual quality of your hold. Most athletes hold much better than they perceive they are. Laser systems can often show athletes holding very well in the center and simply, watching and waiting for something "better" to occur. This feedback and playback with your coach can help you gain confidence and understanding into your actual holding.

Training drills: Use time and quantity drills to test and train your efficiency in your process. Example: Give yourself 10 minutes preparation time, followed by 10 minutes to shoot eight shots. Have your coach watch and time you. When you can shoot eight quality shots in 10 minutes, reduce the time or increase the shots to help challenge your efficiency and quality. One minute to execute a quality process and shot in standing indoors is a reasonable goal and measure for efficiency. Coaches can help you adjust this guideline to fit your process—some are faster, some can be a little slower.

The one thing you can control absolutely in any setting, match or training, pressure situations or in relaxed atmospheres, is your process. If you are a beginner or a veteran, focus on the process of setting up your position and hold and make your consistency in this effort "perfect." You will then execute the hold you have very well. Your hold will improve with training and work over time—and so will your scores if you make your process ready to take advantage of it.