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Ketty PhDee

PART 5: *KETTIE* SHOOTING

Round ball ballistics and groups for precision

Hello Forker, welcome back! In part two, we indexed the unique Slingshot (*kettie*) terms. Can you still remember what a resorta or cubes are? In part three, we learned about the No 1 RULE, discussed aiming sights and P.A.M., discussed Precision v Accuracy, which continued in Part 4 with topics like dynamic and gyroscopic stability, procession rotation (wobble) and a thing – called axial form. In this part, we start with theoretical ballistics and calculating shot groups.

Memo reminder!

To avoid lecturing and conserve every part of the series as a substantive and entertaining article, I typically refer in oversight to various subjects in every part of the series to provide context and functional guidance. But – as the series progress, we revisit these subjects in detail. Remember, the objective of this series is to get you, the athlete, equipped with the (a) core knowledge (technical understanding) and (b) critical equipment – to the 10 m standard discipline shooting-range line, but, you have to be open and ready for an expedient (c) elective knowledge learning curve (self-discovery) to be a competitive athlete.

Theoretical ballistics

Unlike PRECISION (internal ballistics), where every element (metric) is calculable, external ballistics (ACCURACY) is divided in "calculable" (also referred to as "deterministic") variables (pellet velocity, gravity drop, aerodynamic drag, etc) and "incalculable" (also referred to as "non-deterministic") variable elements – typically the "wind" in terms of "speed and direction" over the course of the pellet path. I advocate that we (as athletes) commonly use this "incalculable" envelope (as a loophole) much too conveniently as excuses for poor performance or indeed a lack of understanding of the P.A.M. (precision and accuracy matrix) various metrics (elements) unique interdependencies. I believe that there is a lot more to be done to narrow the "unknown" of Mother Nature down for match-winning advantages, than to simply bow to her majesty.

Before we get "into the wind" – let's have a quick over-review on the five (5) Pellet flight phases, for the benefit of context to shooting groups/shot groupings:

(1) Pellet thrust (propulsion): The thrust phase, where the pellet is in contact with the pouch and forcefully propelled/driven – by the push-pull force (pushed – by the pouch, and pulled by the bands) forward by the mechanical contraction (kinetic energy) of the elastic bands. Note – that technically it is part of the internal ballistics (precision) equation. There are several critical metrics involved in directing the pellet, ranging from offset pellet in the pouch to uneven bands. We will circle back to the subject in future.

(2) Pellet release jump (release): The transition (intermediate) phase of the pellet release from the pouch. This is thought of as the first – of the ACCURACY (external ballistic) phases. Pellet jump – can be described as the "free or suspension phase" - defined and identified by the aerodynamic and gyroscopically unstable conditions (events) caused by several metrics related to the position (proximity) of the bands and pouch. With the next phase of aerodynamic jump added into the equation, the pellet jump phase recovery (stabilisation) time is compounded, influencing the linear vector direction. Pellet jump is often not recognised in communal talk, treated as an ancillary aspect – or confused with, and or substituted by: Aerodynamic pellet jump. We will circle back to the subject in future.

(3) Pellet aerodynamic jump: The transition phase from pellet jump to full aerodynamic exposure (air flow/drag). Also referred to as "band jump" or "start jump", where aerodynamic jump is a direct result of the "wind" (airflow/drag). The principle is that – (either) the torque (force/"wind") applied to an unlikely gyroscopically stabilised pellet (round ball), the gyroscopic response (movement) is 90° upstream (into) in the direction of the rotation, (or and) – an aerodynamically unstable pellet for example due to uneven surface, the aerodynamic friction will cause it to deviate from the energy direction vector. Think of the "jump equation" as unique to every type of pellet (and theoretically every individual pellet). The aerodynamic jump of the pellet jump stage to the stabilisation phase - is quite dramatic, since pressure and drag increase rapidly and escalate the angular degrees of the velocity vector effect. Note – A head (360/0°) wind and tail (180°) wind in the aerodynamic jump phase are practically negligible and, for practical reasons, should rather be discussed as a downrange aerodynamic drag component. It is considered that the "jump phases" are complete when the pellet passes the prongs. We will circle back to the subject in future.

4) Down range pellet fight: The "stable" flight phase after full aerodynamic exposure. There are two major external environmental metrics (elements) that work on the deviation of round balls in free (straight) flight: Relevant to this (A) gravitation (pellet drop) (B) wind deflection on the pellet, resulting in vector/directional changes. As reference - Aerodynamic surface drag and Axial form were discussed in part 2. We will discuss "wind effects" hereunder.

If your draw and pouch grip is 100% perfectly aligned with the *kettie* – it should result in the pellet flying 100% straight to the target. However, it is important to understand that any influence on this 100% fight direction (disturbances of the actual "degrees of direction") on the pellet in the first "pellet release jump" and "pellet aerodynamic jump" – phases of flight results in angular effects with linear vector (change) results. In other words, the pellet will maintain the degree of angle at which the direction of the pellet's flight trajectory is changed, during pellet and aerodynamic jump. The second (medium-range) and third (long-range) phases of the pellets' original linear vector and trajectory are influenced by the two major environmental elements (A) gravitation (pellet drop) and (B) wind deflection on the pellet (vector/directional changes).

(5) Pellet impact: The impact phase of the pellet on the target, is referred to as "Terminal velocity", expressed in various forms and facts like foot-pound energy (fp/e), penetration, knock-down power, etc. Perhaps more relevant to slingshot hunting, one of the basic principles of "angular impact" is important for our target objectives. The energy transferred to the target (knock-down power) diminishes rapidly as the angle changes form 90^0=100% (full impact value) to just 80^0 of angle. We only tend to think of horizontal angles (left to right) when we shoot at an angle to the target, but, pellet drop (downward/vertical) is a very real part of the equation, where the pellet "comes down" at an arch (angle) to the target. Also, one should consider the kinetic energy displacement model on the actual target, from centre to the edges and from top edge to the bottom edge. **Take-away:** Always align yourself / shot at a 90^0=100% (full impact value) to the intended target.

Wind

Does the wind blow your pellet off course downrange? The obvious answer is: Yes – because it is observed that the pellet impact moves to the direction of the wind force. The smart technical answer is: NO – because the pellet is actually deflected off the wind. Round balls, whether it is spinning or not, have the same wind forces working in on it, trying to deflect it from the linear trajectory. However, "spinning" and static round balls behave quite differently, and we have discussed the metrics (elements) in part 4. By default, wind will deflect a round ball quite severely because of its very poor aerodynamics, because of the large surface aspect ratio to the ball size (geometry). "Wind" is obviously an aerodynamic drag component. Yet, theoretically, there has to be some "blowing" interference? Do the simple experiment that disproves the "wind blowing" myth. Experiment: In a wind of let's say 5 mph

(miles per hour), drop a pellet, from 1 meter high and you will note that the wind effect to where it impacts on the ground impact was negligible. In ballistic terms, rather think of the pellet as static and the wind velocity example of 240 fps (at which the pellet travels as you shoot it) as the oncoming wind is 163 mph. That should have an effect? The airflow (wind / presure) is directly from the front, flowing over the round ball at 240 fps. Science tells us, in a full-strength (side) wind – at 90 degrees – to the ball from the left (nine o'clock), the pellet will find a stable position between the headwind and the side wind. Keeping the above in mind, and remember part two – axial form, surface imperfections and axes offset, which may cause a procession (wobble) rotation will exponentially increase in gyration magnitude and thus the time off-centre (to the right), increasing exposure to the wind deflection on the left because of yaw drag indifference, veering right. Simple right? Let's just stick to wind "deflection". But how much and how fast and far off does it deflect (deviate) from the vector – set by your 100% perfect draw and release (and the pellet pouch release and aerodynamic jump) phase?

Wind direction

When shooting Field Target, outside wind is a factor – and the wind direction is much more important than the actual wind speed. A 0 (zero) wind value (windage/lateral drift) is from dead ahead (at twelve o'clock) from the line of sight to the target and the full wind value is 90^0 perpendicular to the pellet (at nine o'clock); importantly - half wind value is not at 45^0 (13:30/10:30) since the "wind component" is an "actual wind *SIN (wind angle)"/trigonometric function (component vector) if your pellet is viewed as a cylinder. In practical terms, memorise the angle percentages of the wind component, the real *SIN numbers 12:00/0^0=0% (zero value) wind, 12:30/15^0=25%, 13:00/30^0=50%, 13:30/45^0=71%, 14:00/60^0= 87%, 14:30/75^0= 96%, 15:00/90^0=100% (full value wind). I round off the silly numbers, 71/70, 87/85 and 96/95, and practically from 60^0 to 90^0 – just use 90%; it will put you first hot on target. In practice: If you stand on a shooting station (stand) and you shoot compact field target in various directions, the wind angle affecting the pellet changes from shot to shot. **The take-away:** The larger the wind angle (wind angle value), the bigger the "deflection" – the more you have to compensate (gap shoot) in your aiming.

Wind speed

At full value (15:00/09:00 - 90^0) – 7 miles per hour (11 km/h): Zero 220 f/s – 20 m 175 fs/s deflection: 4.3" (10.92 cm), Zero 240 f/s – 20m 192 fs/s deflection: 3.8" (9.65 cm), Zero 220 f/s – 20 m 210 fs/s deflection: 3.1" (7.87cm). At Full value (15:00/09:00 - 90^0) – 10 miles per hour (1610 km/h): Zero 220 f/s – 20 m 176 fs/s deflection: 6.1" (15.49 cm). It is also obvious that the slower the pellet velocity of a set distance, the bigger the wind influence (deviation). Because the round ball (pellet) is moving slower, it is longer exposed to the influence (pressure) of the wind. Use the above basic *SIN (wind angle)/trigonometric function (component vector) to calculate the angular influence. If the 7 miles per hour (11 km/h) wind was at 13:30/45^0=71%, Zero 220 f/s – 20m 175 f/s deflection: 3.05" (7.74 cm) – a 3.18 cm difference. The same as you would underestimate the wind at 5 mp/h (instead of 7 mp/h). Example: But, if you underestimated the direction – actually 14:00/60^0= 87% the deflection is: 3.74 cm. **Take-away:** Accurately determine the wind direction and speed – in relation to the ideal shooting angle (linear vector). We will circle back to the subject in field target discussions.

Gravity

It is one ("constant") element that works in on the linear velocity vector of the pellet, with a vertical impact effect. Imagine your *kettie* is level (1 m off the ground, over a perfectly flat shooting range); the time recorded from when the pellet is released from the pouch (pellet jump) to when it impacts the ground at a distance, is exactly the same (time) - if you have simply dropped the pellet from the *kettie* height to the ground. The faster (higher velocity/speed) the pellet travels, the more distance it will travel downrange, but it will always impact at the same time. However, the pellet does not travel at a constant speed and thus for example covers the first 10 m in a very short time but the last 10 m in a relatively longer time.

The longer (time) the pellet (over a set distance) is exposed to gravity, the bigger the gravitational effect (faster the drop). We overcome this time-space (distance issue my shooting at elevation (at an upwards angle – to extend time to cover more pace). Of cause gravity works in differently on larger and smaller pellets, their actual density – we will circle back to ideal pellets sizes and mass for fit for purpose.

PHDee

We generally consider gravity a "pulling force" – but we should also consider gravity as a push-space-time continuum – to challenge the convention. We consider gravity a constant – for the purpose of our series, but - gravity is not a constant around the globe. The average gravitational "pull" of the earth is 9,807 m/s^2, with a variation of 0.7% because the earth consists of materials of various densities, such as rock, air and water, with a certain amount of space (density). At the Arctic Ocean level, gravity is measured at 9,8337 m/s^2 and in the Nevado Peruvian Mountains, at 9,7639 m/s^2. Remember that, in principle, gravity also gives weight to objects; for example, your 8 mm carbon steel pellet at 32.6 gr is the earth's gravitational force exerted on the pellet. As stated above, to extend the range of the impact, we shoot (start off) at a higher angle (elevation vector) to allow the pellet more flight time (against the gravitational pull) to cover more distance (space). **Take away:** The slower your pellet is over a set distance the lower the impact point would be, the faster the pellet over that distance the higher the impact would be –to the centre (zero) line.

Now that we have a better understanding of some of the elements (metrics) that works in on (influences) our pellet "accuracy", such as – the internal ballistics, the pellet itself, how the pellet is positioned in the pouch, your exact release to aspects like the external ballistics of wind and gravity – we can now attempt to shoot a "shot group" mindful of the odds (probabilities).

Objective of shooting groups

To confirm the **zero** and **stability** of the **mean POI** (point of impact) factor of the *kettie*, measured against the relative point of aim (POA). But, why do I have to shoot groups – and determine the Circular error probable (CEP) or Median Error Radius (MER) of my *kettie,* if I knock down the target with good consistency? It is the difference between being a competitor and a champion! Every now and then, a shot is missed – and it is rationalised (mentally dismissed) as some frivolous excuse, in reality – stop assuming and rationalising your *kettie* accuracy, simply measure it. Remember – we do not work with assumptions, we measure, to make science-based decisions. Shooting groups is a test – (the frequency) of repeatability, and repeatability and consistency are synonyms in the winning recipe.

Random grouping POI (point of impact) generator

The elements discussed on internal and external ballistics – suggests that your ***kettie* system is a random pellet point-of-impact generator** on target, because of small inconsistencies (metric deviations). Only if a proper scientific random sample (a statistically valid 30-to 50-shot data set) representative of the "precision" of your *kettie* is recorded the natural dispersion phenomena pattern will be evident for that one "set of conditions": Ranging from elements like – the pellet (size, weight, aerodynamics, etc), band-set (dimensions, draw length, etc) to atmospheric conditions, (pressure altitude, temperature, etc), since the *kettie* would randomly generate the imperfection's pattern (group) actual representative results -for that set of conditions. You will observe the impact picture (group) from the target impact dispersion observation. It is important to understand that if the *kettie* internal precision elements are optimised (band geometry, perfectly affixed band, pouch, etc), then there is a reasonable expectation of a good result. However, the shooting methodology and actual shooting technique, as well as the *kettie* system, determining the tolerances and repeatability, obviously play into the precision metrics. The first task at hand is to try to consistently deliver a "pellet thrust" (propulsion) phase. We will circle back to this topic later in the series.

Statistical deviation

In addition to the well-known basic Bell-Curve distribution model, the **Circular error probable (CEP)**, or- (*as I think of it*) "circle of equal probability", as a measure of the *kettie's* precision as a measure of error, in a radius centred circle on the (one) point of aim, expecting to land and enclose 50% of impacts (in that circle). Think of it as the: **Median Error Radius (MER).** A simple three-shot group will have metric elements (example – standard deviation (SD)) deviating 60-70% up (bigger) or down (smaller) – from the full 30- 50-shot data set average SD – signalling a significant speed and POI variation. I believe a *kettie* "fit for purpose" precision tolerance – must be able to deliver 50% of the impacts in a 2 cm circle (1 cm radius) at 10 meters. In other words – if you setup your *kettie* for precision test (GP_POI/Group for Precision – Point of Impact), in a fixed vice (scientific laboratory exercise) and fire off 50 shots precisely (consistently), 25 of those shots must be in the 2 cm circle. Similarly, you can simply see and measure from the results the circle size (Median Error Radius (MER)) that captures the smallest 25 (of the 50 impacts) and use it as a gauge/reference to measure your improvements. The deviation (from the centre of the 2 cm circle) suggested by theoretical ballistics for a 5-shot group could be 40-50%, for a 10-shot group 30-40%, for a 20-shot group 20-25%, for a 30-shot group 15-20% and, for reference purposes, for a 50-shot group it will be 10% deviation – in relation to the full shot data set average. In other words, if you shoot one shot at the centre, that shot can impact randomly anywhere in that

MER (Median Error Radius). The more pellets you shoot, the higher concentration of impacts will be gradually recorded closer to the centre. **Take-away:** Your *kettie* is only as "good" (precise) as the MER – period. Every shot can be on the outer rim or the centre or anywhere in between – in the MER circle. If you understand the size of the pellet dispersion circle (mean radius (MR)), at any (or the precise event distances), then you would be able to aim (place your MR centre on the target) and statistically shoot the most accurate (the least % of miss shots). That, my Forked friend, is the winning recipe. Remember: The Occasional point-point shot is not the true reflection of the predictive % score. **The takeaway:** Understand – that you cannot shoot (score) better – than the intrinsic scoring capability of your *kettie*. We will circle back to GP_POI (Groups for Precision) and GA_POI (Group for Accuracy) in future.

Mean radius (MR)

This is the average measurement from the actual (true) **centre of the group** to the centre of **each** shot (pellet hole) and will provide a higher confidence measure of precision than "extreme spread". Extreme spread – is only the distance between the **two** furthest outlying pellet impacts, measured centre pellet to pellet impact, providing a "group size". The MR will be closer to the same value for 5, 10 and up to 30 shots, and the actual centre of the MR should be used as the **zero** sighting point. MR, in effect, is a predictive tool, that will practically predict future outcome (score) results.

Velocity

The importance of velocity as a dynamic metric regarding only group size results such as dispersion is important, but - absolute velocity *per se* is actually a secondary consideration. Though you can sacrifice speed for better groups, in real-world performance, velocity plays a critical role in terminal ballistics, for example, hunting, or- knocking down targets. Velocity/pellet speed – is critical, on so many levels and because it is one of the metrics an athlete can measure relatively easily and fairly exact. Velocity is an inexpensive to measure, but very valuable practical scientific metric data to the disposal of the athlete – in the maize of elements that requires expensive scientific equipment. Consistent velocity is directly dependent on quality bands that can deliver repeatability during the band-set life cycle is critical to *kettie* performance. That is why I only shoot with KETTY Pty Ltd – Ketty Pro Elite – natural latex slingshot competition bands.

Extreme spread (ES)

This is the difference (subtracted) between the highest and lowest velocity recorded within a shot string test data set. It is only a record of a past event, **not** a predictive instrument, as opposed to SD (Standard Deviation). To simply take the average (middle) of a high and low measurement – and call it a ballistic valid average is injudicious. To commit ballistic suicide – use a small data set like 1 (?) to 5 shots and rationalise an average speed.

Standard deviation (SD)

This is the total of (all) the recorded velocities in reference to the average of the total recorded velocities. It is a predictive instrument that can provide insight into expected future performance if a statistically valid data set is used. The well-known Bell Curve is the most simplistic applicable data distribution model.

Precision shot group expectations

We need to understand generic ballistic performance possible consistency in terms of what is really (actually) considered practical *kettie* efficiency and look past the array of misguiding dogmas relating to methods and perceptions. GP-POI groups for precision (reflecting internal ballistics) should be a scientific process where you precisely replicate every shot of the shot string by aiming at the same point of aim (POA), irrespective of the actual impact point. The general perceptions of *kettie* shooting POI groups to determine a *kettie's* performance metrics – and the amateur validation methods are totally distorted. Silly trick shots at objects like a water drop, or razor blade – proofs nothing, except the tenacity of the athlete. Frankly, all the conventional practices and traditional believes regarding slingshot "accuracy" is a menace to the common precision *kettie* shooting community. Do it scientific!

USSP

To calculate your *kettie* performance for comparison, with – **circular error probable (CEP)** use the: Uniform Standard Slingshot Precision (USSP) measurement technique, i.e. scientific goal (objective): Also called – the "2 cm circle test" / "1 cm radius test". Based on 50 shot string data set, results/standard: 50% (25) shots in 2 cm circle (dia) at 10 meters. This is the standard against which a *kettie* (slingshot) set-up (rig) – for precision, should be measured. This is a practical universal uniform testing method to compare *kettie* rig set-up performance comparison – anywhere in the world. The test: Set-up the *kettie* in a controlled environment on a scientific test bench and fire 50 perfect shots. **Results Example:** 25 Shots in 2 cm on 10 meters –100% rated (10/10), 12 shots 50% rating (5/10) as a precision slingshot. Though statistically 43.7% (21.85) of the 50 shots will be naturally distributed in the next cm circle (i.e. 4 cm diameter) in total, and 6.1 % in the next 2 cm circle (total of 6 cm). **The takeaway:** Stop listing to manufacturer's posturing and grandiloquence about their perceived product performance, pay attention to actual performance results.

Remember the No 1 Rule

Always shoot with eye protection – shooting / safety glasses.

It is great to have you with on this "Ketty PhDee" journey of precision *kettie* shooting. Next time we will discuss "Applied Shot Group Shooting", and start shooting GP_POI and GA_POI. Till next time, safe shooting!