Introducing the Rate of Recoil Of a golf swing

By Dr Robert Neal

Rate of Recoil *as a phenomenon in golf (it occurs in many other sporting movements as well), is an area that I have been exploring for a number of years.* I believe that examination of this "Recoil Factor" can give us tremendous insights into the physical make-up of a golfer. As a consequence, there are important technical as well as training implications for golf athletes, especially when it comes to developing power.

Whilst many golf professionals will be familiar with the concept of a 'recoil' (occurring between the hips and shoulders) during the down-swing, very few will have great insights into the concept or its importance without the capability of an accurate 3D motion tracking system (with 6 DOF) and a sound understanding of muscle mechanics. One simply cannot examine the subject in any depth if observations are based solely on qualitative information (i.e. video). In other words, you need the "numbers" to make logical arguments and draw sound con-clusions.

The *operational* definition of Rate of Recoil (ROR) is the rate that the golfer closes the gap between the hips and the shoulders (strictly, the upper torso - UT - but in the golf world the term shoulders is used to represent this body segment) as the club head moves toward impact. In a good golf swing, the hips lead out at the start of the downswing, and as they accelerate, the differential between the hips and shoulders increases. In the golfing vernacular, the X-Factor (difference between hip and upper torso rotations at the top of the backswing) is created but then increased (X-Factor Stretch) in transition. Thus, the hips have a head-start on the upper torso as the soft tissues across the torso are stretched (Stretch-Shorten Cycles). As the oblique abdominal muscles as well as those in the back and pelvis contract, the upper body rapidly "recoils" and almost "catches up" to the pelvis by impact. This catching up phase is the **Recoil**. There are many characteristics that govern how this recoil takes place and it is also important to realize that the rate of recoil (speed of recoil) is not constant during the move-ment.

This new term *Rate of Recoil* is closely linked with the X-Factor story. In fact, it is almost like the final piece of the X-Factor story, as it gives important 'dynamic' information about the golfer and puts some of the X-Factor 'numbers' into perspective. So let's take a moment to recap.

The X-Factor theory of McLean (1992) is based on data collected on touring professionals that showed a positive correlation between driving distance and the angular difference between the hip and shoulder turns at the top of the backswing. This concept became a cornerstone of McLean's teaching system, as he advocated that the lower body needed to be stable so that it could resist the turn of the upper body and "coil" was developed in the torso.

One can liken this coil to the winding up of a spring in which potential strain energy is stored in the spring and then liberated when one end of the spring is released. The analogy is very appealing since the golfer has structures in the body such as tendons and parts of the muscles that have spring-like properties.

Our own research has supported the concept that an ideal X-Factor range of values exist for the top of the backswing (TOB). A corridor of 40-50º seems to allow for the variation in the golfing population, from the young adult to the older golfer. As an example, let's say we meas-ure the rotations of the body for a golfer at the TOB and find that the hip (pelvis) turn was 45º while the shoulder (upper torso) turn was 90º. The X-Factor value would simply be 45º (Calculated as 90º - 45º = 45º). This value actually sits in the middle of our ideal corridor. Signifi-cant deviations from this corridor can provide us with additional information not only with regards to our golfer's technical ability but his/her physical limitations, mostly from a flexibility or motor control stand point..

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For example, a low coil at the TOB, or an X-Factor value below 35º, (let's assume the etiology is not technical i.e. the head stays still over the ball), will often indicate a lack of flexibility in trunk rotation. Following the initial 3D swing analysis, a combination of physical screening tests and some form of technical intervention, (either Biofeedback Training or traditional instruction), can help a skilled operator to determine if the lack of flexibility is indeed interfering with our golfer's technical progress and exactly what steps need to be embarked upon to ameliorate the problem once it is identified.

In 2000, Cheetham et al. published a paper in which an extension of the X-Factor idea was presented (it was a comparison of skilled and unskilled golfers). Their theory was that during the backswing a certain amount of "coil" or X-Factor was developed in the body but that this difference was increased during the transition and early downswing phases of the swing where, in good players, the hips bump laterally toward the target and rotate rapidly (initially faster than the upper body). This movement serves to *stretch* the X-Factor, increasing it by sometimes as much as 60% and was highly correlated to power generation in the swing! Their research showed a strong correlation between those players who launched the ball prodigious distances and the size of the "stretch". The common term to refer to this increase of the X-Factor during the transition between backswing and downswing has since become known as the X-Factor Stretch. Now, we should be clear, it isn't that top teaching professionals (McLean 1996 and Leadbetter 2000) were not 'aware' of this movement in the golf swings of good players simply that to this point no one had quantified the 'increase' or discussed its importance in generating power and distance.

Again, our research also supports the fact that high-quality ball strikers have a very good X-Factor Stretch. Some of our recent measurements of PGA Tour players showed an X-Factor Stretch average in the vicinity of 15-25º! Angel Cabrera, one of the longest hitters on the tour today, exhibited an X-Factor Stretch of 24º! This result demonstrates remarkable flexibility in trunk rotation – let's remember that this is after a 40-50º differential at the TOB (a total differential of approximately 70º!). To put this into perspective, the average 15-20 handicapper generally has an X-Factor Stretch ranging from 0º - 6º.

The graph below (Fig. 1) has been taken directly from the Golf BioDynamics (GBD) 3D Reporting System. This graph illustrates the X-Factor as it is measured throughout the entire swing. Our subject is top Teaching Professional and professional colleague Jim McLean. The blue line illustrates how the differential between the hips and UT increases throughout the backswing movement. At address (time=0s) very little differential exists and as the backswing commences the differential increases until, at the TOB, an X-Factor of approximately 49º is measured. The change in line color from blue to red line indicates the beginning of 'transition phase' or the start of the downswing movement as the hips lead out.[1] The 'dip' evident in the curve is the increase in angular difference between the hips and shoulders and defines the X-Factor Stretch – noted here as being 13º. The total X-Factor therefore, or the largest differential that occurs between the hips and UT at any point during the golf swing is 62º (49º+13º). For a golfer in his early fifties, Jim exhibits a fairly good range of motion in trunk rotation!

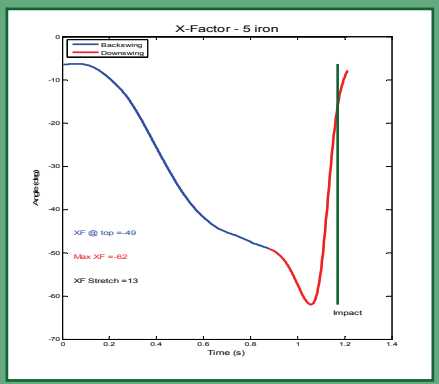

Figure 1

X-Factor Graph: Jim McLean's X-Factor (2008) measured throughout the golf swing. The blue line indicates the developing differential (between hips and UT) during the backswing and the red line, the downswing portion demonstrating the X-Factor Stretch of 13º - very respectable!

[1]**We define the top of the backswing as the maximum hip turn. This point demarcates the wind-up movements of the body and the transition phase where the body segments change direction. In skilled golfers, this change of direction for each segment occurs in sequence, beginning with the lower body and ending with the club.**

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In considering the value of the X-Factor Stretch (and consequently the ROR) movement in the modern golf swing, we are in fact investigating one of mechanisms by which our body efficiently produces muscular force and thus power – the advantage gained by exploiting the stretch-shorten cycles that occur in our muscles. A stretch-shorten cycle basically combines an eccentric contraction, in which the involved muscles undergo tension through lengthening or stretching (negative work), and a concentric contraction, in which the muscles shorten (doing positive work). In summary, because of chemical, mechanical, and neurological factors that influence the force and stiffness of the contracting muscle (see Komi 1973), eccentric lengthening (before rapid concentric shortening) allows skeletal muscle to produce the greatest force and power (Radcliffe and Farentinos 1999). And perhaps an important point to be reminded of is that eccentric actions performed at moderate to high speeds preferentially recruit the fast-twitch muscle-fiber units. Due to higher firing frequencies and a greater fiber size they produce more force per motor unit than other muscle-fiber types (Radcliffe and Farentinos 1999).

It should also be noted that while in the GBD System of Analysis we consider the TOB to be demarcated by the maximum turn of the hips on the backswing, we believe Cheetham et al. measured their TOB position differently (likely it was a change in direction of the hands or clubhead) and as a result their X-Factor Stretch values will differ markedly from ours. Therefore, the reader should be aware of the differences not only in measurement systems used by various researchers but by the definitions each group use to describe the various phases of the golf swing. Thus it becomes problematic to make direct comparisons when we do not have an industry standards, particularly in terms of describing the various phases of the swing. But that is another topic altogether!

Most people thought that this was the end of the X-Factor story, but that is far from the case! Like any simple theory, it helps us to understand the movement but does not account for many individual variations. There is little doubt that the higher than average X-Factor Stretch value of our 2007 US Open winner Angel Cabrera contributes significantly to his ability to produce power. But how much does it actually contribute to the 'power equation' in the golf swing? And, can those individuals who are still able to hit the ball tremendous distances, but do NOT demonstrate similar range of motion in trunk rotation (and thus a lower potential for an X-Factor Stretch movement), generate the same amount of power in their golf swing with less 'Stretch'?

Our recent work adds an extremely important piece to the puzzle. Interestingly, this idea not only "gels" very well with coaching ideas but it is built on sound principles of human muscle physiology. Put simply, positional variables (e.g., X-Factor or X-Factor Stretch) are important but they do not tell the whole story! Higher order kinematic variables or the 'dynamics' of a golf swing (e.g., Rate of Stretch [ROS] and Rate of Recoil [ROR] - the speeds of movement) are equally important.

Some very simple mechanics will help explain the ideas presented below. For most of us, it is very easy to picture positions in the golf swing. Thus, we can develop a picture in our heads if, for example, we return to our golfer, who on their backswing, has turned their hips 45º and shoulders 90º - the "gap" or X-Factor between them at the top of the backswing was 45º. What is much harder to picture is the 'dynamics' of the golf swing; the way in which these angles change during the backswing and downswing. We will use the image of a pendulum to help make the point here.

A simple pendulum serves as an ideal model. If you can imagine the movement of the mass at the end of the pendulum, as it reaches the high points of its motion, its speed is zero. As it *falls* down during the swing, it speeds up until it reaches its maximum speed at the bottom of the arc. During the next part of the cycle, it slows down (decelerates) such that by the time it reaches its highest point on the "other" side, its speed is zero once again. This pattern of acceleration-deceleration continues as the pendulum oscillates.

By now you must be asking "what is the connection with the Rate of Recoil (ROR)"?

The reason for this analogy is to point out that the speed of a pendulum is **NOT** constant throughout the motion. It changes (continuously) reaching maxima and minima at certain times in the cycle. The same idea applies to the ROS and ROR. The (X-Factor) Stretch and 'Recoil' do **NOT** take place at a constant speed. Muscle physiology and mechanics research has shown that the speed of stretch of a muscle has a dramatic effect on its ability to produce force!

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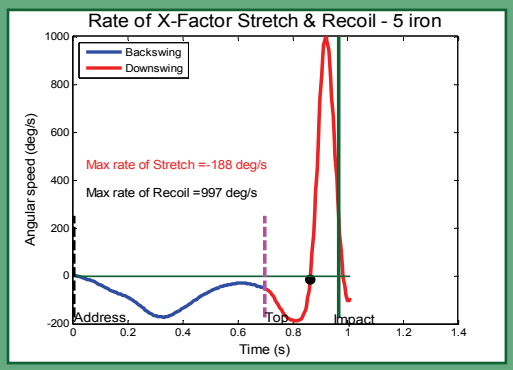
So let's now return to the golf swing! Careful analysis of the angle between the hips and shoulders (UT) during both the backswing and downswing movements show some similar patterns to the situations described above. During the backswing, the gap (between the hips and shoulders) opens, but it does so at different rates. For instance, initially, the gap does not increase by much as the club, UT and hips begin the backswing (one-piece takeaway) together. During the next part of the backswing, the gap opens quickly, as the UT winds past the hips. Interestingly, as the top of the backswing position approaches, the gap opens comparatively slowly as the UT (shoulders) approaches its maximum turn. The speed that this gap opens on the backswing although not critical is important. What is crucial however is the speed that the gap opens during transition (how the hips accelerate when the X-Factor Stretch is experienced). As we know, following that *stretch,* the "gap" between the hips and UT decreases so that by the time impact occurs, the UT has just about "caught" up to the hips. I strongly believe that investigation into the rates at which these two events (the stretching and recoiling) occur, not only give us tremendous insight into the individual variations observed, but the body's strengths and weaknesses.

The "successful" combinations of stretch-recoil and rates of stretch-recoil during the golf swing are numerous. If you have access to data on tour players, you will see that almost all of them have the ability to increase the differential between the pelvis and upper torso during transition and early downswing. The "right" combination for any person is dependent on many factors but flexibility, strength and power are important contributors. A concrete example that might help you understand to the stretch-recoil debate is elastic training straps. The "easy" ones stretch a long way but when you release them, they do not spring back as quickly as the "hard" ones that are difficult to stretch a lot but snap back very rapidly. Different golfers have bodies with different spring stiffnesses. Thus, each golfer has his/her own combination of stretch and recoil that is effective for him/her. Furthermore, changing ones flexibility without addressing strength and stability simultaneously may actually cause a decrement in performance resulting from poor mechanics!

In Fig. 2, an excerpt from the GBD 3D Report—The Rate of X-Factor Stretch (ROS) and Rate of Recoil (ROR) is illustrated.

Figure 2



Rate of X-Factor Stretch and Recoil Graph: Jim McLean's ROS and ROR (2008) measured throughout the golf swing. The blue line indicates the rate at which the developing differential (between hips and UT) occurs during the backswing. The red line shows how the rapidly the X-Factor changes during the downswing. The area "below" the zero line, immediately following the top of the backswing (dotted purple line) shows the Rate of Stretch (ROS) while the section of the red line above the zero line between TOB and impact is the Rate of Recoil (ROR). The peak values of each of these are reported on the graph and represent the maximum separation and closing rates. You should note that the ROR (positive peak) is much higher than the ROS (minimum peak).

As previously mentioned, there are a large number of combinations of *Stretch* and *Recoil* that have been observed amongst good players. In fact, there have also been quite large variations in the ROR in those golfers who hit the ball very far! You might ask why? The best answer to this question lies in the multi-faceted nature of human anatomy and physiology. Firstly, those golfers who have long levers have an advantage over the shorter golfer. Thus, virtually all those people who hit the ball terrific distances are tall in stature. Secondly, overlaid on the size of the golfer are the physical properties of the muscles, including muscle fiber types and distribution, length of the muscles and level (and type) of training that is being done. For those athletes who were fortunate to be *given* lots of fast twitch fibers, long levers and great flexibility, the potential to generate power and create high *Rates of Recoil* is much higher than the short, slow golfer who has limited flexibility! For those interested in the 'numbers', the first type of golfer referred to would have ROS values of the order of 200 °/s and ROR values over 1100 °/s. The other golfer probably has a ROS as low at 20 °/s and a ROR as low as 200 °/s! Quite a difference.

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Thus, the 3D Systems available today for golf swing analysis are incredible tools as they ultimately help us to better understand the physical make-up of our golf athletes and amongst other things, give us valuable insights into their potential for developing power. Equally important, however, is their value as a monitoring tool, so that we may accurately gauge the effects of intervention, whether it comes in the form of technical changes and/or specific training regimes.

This seems like a good time to revisit our definition of ROR. ***Rate of Recoil*** (ROR) can be more precisely defined as the speed with which the upper torso (UT) catches up to the lower body (hips/pelvis) on the downswing. Ideally, in the golf swing we want to see the upper and lower body of the golfer reasonably well matched (with respect to axial rotation) by impact (as measured in the 3D world). That is, both the hips and shoulders (UT and pelvis) should be well "cleared" or open to the target line at impact. In the 3D world the hips and UT should be approximately 25-45º open in a better player with the hips just slightly more open than the UT.

To summarize, it is important from a technical perspective that the golfer is in a good position at impact with their body in order to maximize power and consistency. It is a fundamental of all the top golfers. To use the Instructors vernacular, we say the golfer should be "stacked" or 'over the top of it' at impact. The "Recoil" measurement now gives us fantastic insights into the golfer's rotational power. It is a measure that also helps us to understand the emphasis we can place of a golfer's flexibility in trunk rotation and how important the X-Factor and X-Factor Stretch combination are in terms of developing power and ultimately speed of the club head at impact.

Finally, in terms of physical training and preparing our golf athletes to perform at their best, I feel that more emphasis will be placed on Plyometrics in the years to come. Plyometrics as a type of exercise training works to maximize the effect of the stretch-shorten cycle that occurs in muscles in order to produce muscular power. Generally speaking it involves varying combinations of hops, jumps, trunk rotations, tossing and throwing. These exercises and their specific placement within a periodised training program are designed to produce fast, powerful movements, and improve the function of the nervous system. Radcliffe and Farentinos (1999) state that an important feature of Plyometric Training is that the exercises enhance the ability of the muscle groups to respond more quickly and powerfully to slight and rapid changes in muscle length, conditioning the neuromuscular system to allow faster and more powerful changes of direction. It sounds just perfect for developing some of our golf athletes, doesn't it?

Obviously, there is much more investigation that needs to occur into this subject of ROR and ROS as I have only just touched on these issues with my field research. I trust healthy debate will ensue as we work towards better understanding of this complex phenomenon.

The End