



CHAPTER_4

BIOMECHANICS

The overriding principle governing any sports performance is the attempt to perform a task "in the best possible way". This can be very much aided through the study and understanding of biomechanics. In essence, it involves the study, which utilizes the human muscular and skeletal system in the most efficient manner and the full appreciation of the movement and loading of human tissue, such as muscles, ligaments and cartilage. Every coach needs a solid understanding of the role that biomechanics play in developing a sound technique for optimum performance of any particular skill.



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BIOMECHANICS

1_What is Biomechanics?

The definition of biomechanics: Hay (1985)

“The science that examines the internal and external forces acting on the human body and the effect produced by these forces.”

The goals of using biomechanics are to improve:

- Performance
- Technique
- Equipment
- Training methods
- Coaching techniques
- Reduction in injury
- Etc., etc. etc.

The tools used in biomechanics:

- Newtonian mechanics
- Motion analysis systems
(Using reflective markers to study and measure motion)
- High Speed Video
- Digital normal speed video
- Force measurement devices (Force plates)
- Electromyography (EMG)
- Digital Video and computer analysis
- Delayed video playback
- Heart rate
- Insole system
- Etc., etc., etc.



The overriding principle governing any sports performance is the attempt to perform a task **“in the best possible way.”** This is achievable by utilizing the human muscular and skeletal system in the most efficient manner and understanding the movement and loading of

human tissue, such as muscles, ligaments and cartilage. Bear in mind, it only takes a small change in the position of the body to significantly alter the muscle groups involved in the movement. In addition, the forces and motion relating to performance enhancement will be examined, not only for improvement, but also for the prevention of injury.

2–Newton's Laws of Motion

1. First Law of Motion (Inertia)

“Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed upon it.”

Definition of Inertia - “Inertia is the resistance an object offers to changes in its state of motion. Things want to travel in a straight line at a constant velocity.”

Note: Inertia is only revealed when there is a change in velocity.

How can we apply the Law of Inertia to Archery?

One popular statement when teaching beginning archers to draw the bow has been, “Never stop drawing or pulling the bow because when you stop it will take too much effort to get started again, you will lose back tension and it will then not be possible to make a good shot.”

This means that the Law of Inertia has to be applied right from starting the draw. This type of thinking is flawed insofar as to say that the “Holding” position can never be achieved. When we draw the bow, we cannot use our back muscles alone, but we must use a certain amount of forearm and hand as well. However, if we would continue the draw uninterrupted, we would pass the “Holding” position where we need to transfer as much tension as possible from the drawing forearm and hand to the back muscles. Therefore, if no “Holding” is achieved, no tension transfer can take place. During the transfer stage, the back muscles continue to move the Scapulae towards the spine, while tension from the forearm and draw hand are being transferred. This movement of the Scapulae, although very small, must continue through the expansion and therefore the Law of Inertia can only be applied from "Holding" and not from the commencement of the draw.

The Shot Cycle

Set-up

Every sport has a set-up position.

Look at the sprinter getting ready for the start. The body is being positioned in such a manner so as to achieve the best biomechanical combination of all parts. To explode from the blocks requires a very complicated neuromuscular coordination, eliminating at the same time any antagonistic factors which could hinder this process.



Likewise,

- the swimmer on the block ready for the gun;
- the baseball pitcher setting himself up for the pitch;
- the basketball player setting up for the free throw.
- Etc.

Therefore, every sport has its set-up position, which provides the best dynamic balance e.g. a runner on the blocks, or the best static balance, as needed for archery and pistol shooting.

In archery, the body and equipment has to be set-up into the most advantageous biomechanical position possible.

For the best set-up of the body refer also back to step 5 in Chapter 3, The Shot.

The legs must be straight, though relaxed and the pressure distribution on the feet should be about 60-70% on the balls of the feet and 40-30% on the heels.

It is recommended to use an open stance, as it will assist in achieving the preferred posture and counteract the tendency to arch the back. As part of the set-up, the shoulders must be aligned with the target and the rear scapula set back and down, almost in the final position. Rotation must come from the waist to bring the shoulders in line with the target, which will create a little tension just below the ribs, adding to improving stability.

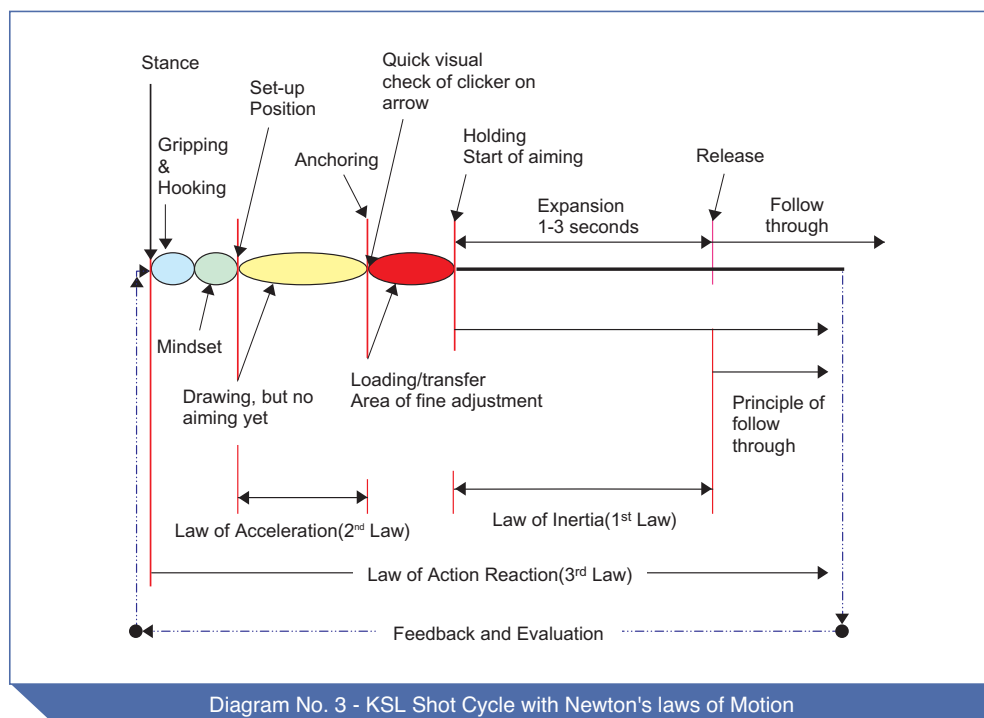
The sternum must be tucked in to provide more clearance and the abdominal muscles tightening throughout the shot for greater improved stability.

It is advisable to lean slightly forward, towards the target, in the set-up position

to counteract the natural tendency to lean back, which comes from wanting to compensate for the weight of the bow.

This set-up position will provide for the strongest biomechanical arrangement.

Even though most archers understand the Law of Inertia, they mistakenly apply it from the draw, which can result in arrows being 1 “to 2” too long. The Law of Inertia only applies from the holding position, where the movement of the draw changes from an external to an internal movement. The Scapulae move towards each other allowing the chest to open up. This provides the expansion necessary for the arrow to come through the clicker. Refer to Diagram No.3 below.





Holding is fundamental for consistency. If the archer shoots with continuous external movement, they will pass the holding phase, thereby achieving no real consistency. As a result, scores will fluctuate greatly and become an obstacle in achieving shooting high scores.

Holding is extremely crucial; in essence, it can be referred to as the “barrel of the gun”. If there is no proper holding, then the “barrel of the gun” is shorter or non-existent and consequently less consistency is achieved. Therefore, the current accepted method of teaching “continuous external movement” is flawed.

When drawing the string to the anchor point, one has to use at least some upper arm, fore arm and hand muscles, as the string cannot be pulled back by the scapula muscles alone. EMG equipment demonstrates this. In addition, it shows that there is no relaxation of the digitorum muscle, which controls the fingers. Therefore, there will be tension in these muscles, which in turn will need to be transferred to the bigger core muscles.

This transfer/loading should normally take about half a second. As already stated, it is only from the holding position the Law of Inertia will come into play. This can be compared to a heavy roller used on clay tennis courts, stationary it has a lot of inertia but once it is moving, it can be pulled with one finger. The same goes for the expansion phase. If this expansion phase is stopped, an enormous amount of energy and muscle power will be required. This is not only fatiguing, but will prevent a smooth and strong shot being made.

In addition, aiming should commence from holding only. If aiming commences too early, the focus will be on aiming and keeping sight alignment, therefore, as such, bypassing the transfer/loading and holding phase.

Heart rate monitors are good scientific indicators to check that holding has been achieved. Refer Chapter 5, Cl.8, Heart Rate Monitor Test.

2. Second Law of Motion (Acceleration)

The rate of change of momentum is proportional to the force applied and takes place in the direction of the straight line in which the force acts.

Definition of Momentum

The momentum of a body is defined as the product of the mass of the body and its velocity.

The Law of Acceleration will apply from the moment the draw commences. It is therefore better to draw faster and in a straight line to about 2 - 3 inches below the chin, as previously discussed. This will also get the drawing elbow into line early.

3. Third Law of Motion; (Action and Reaction)

“For every force applied by the body to an object, the object applies an equal force back against the body”, or To every action there is always an equal and contrary reaction; or, the mutual actions of any two bodies are always equal and opposite directed.

It is therefore extremely important to adopt a stance using principles to achieve the strongest static stance balance possible.

When asking archers what are the main muscles they shoot with, you will get a variety of answers. Some will say, “I am pushing with my left hand”, some say “I am pulling with my right hand” Again others will say, “I am squeezing my elbow”, which indicates mainly right-hand side, or some might say “pushing my grip”. Basically, they are telling you what they feel. However, irrespectively,



there has to be a 50/50 balance.

During the expansion, an archer could feel more push from the bow arm side or on the other hand, the archer could feel the drawing side being more dominant. These feelings are all right, as long as the balance is maintained between both sides (Third Law of Motion).

The right hand side is generally the more dominant side for right-handed archers. It follows then that this side has a tendency to lead, which would cause a change of the center of gravity and consequently result in the loss of balance and stability. When bearing this dominance of the right hand side in mind, it can then be said, that the left hand side is proportionally weaker. Accepting that the muscles are weaker on the left hand side, they would need to do more work to maintain their spatial position during the expansion. For that reason, the archer could use more bow hand side than string hand side. However, the 50/50 balance between the front and rear units need to be maintained at all times.

For better coordination, it is recommended that right-handed archers, being left eye dominant, shoot right-handed and vice versa for left-handed archers being right eye dominant.

FITA in their latest coaching manual states “To date, good results have been achieved using either criterion. However, hand (preference) gives a better manual ease, control and strength”.

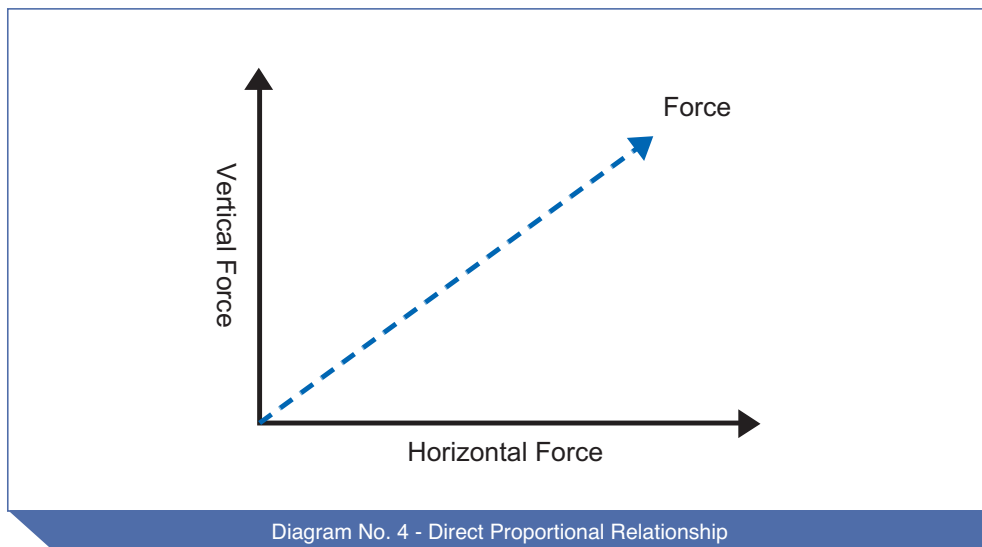
Most archers think too much about aiming. Archery is a technical sport and not an aiming sport which is why we should follow the hand dominant side and not eye dominance.

3_Principle of Horizontal and Vertical Force

Before we examine how this principle applies to archery, let us examine some of the other sports to get a good idea of the principles involved.

For instance, let us study a basketball player. To be able to create the maximum horizontal distance for a shot, a certain amount of vertical force has to be generated.

Based on data taken from Miller, S. and Bartlett, R, Journal of Sports Sciences, approximately 81% of the speed is generated by the upper body and 19% comes from extending the knee, hip and ankle. Even though only 19% of the ball speed is generated by using the legs, it will mean that less effort is required from the muscles of the shooting arm. If a shooter has to put less effort into the shot, it is more likely to be successful.





Similarly, in shot-put, most of the world top shot-putters now use a spinning motion coupled with a strong vertical force, generated by the rapid flexing of the legs, to generate maximum power. The more vertical force the shot-putter can generate, the more horizontal force is feasible, increasing the release angle closer to the optimum angle.

To illustrate the effect of vertical force and horizontal force, try running on soft sand. As the legs push against the sand to generate vertical force, the sand will give way and less horizontal force can be developed, resulting in less forward speed.

Basketball, shot-put, running and any other movement sports require a more dynamic balance in which the stability can easily be altered, while archery demands a more static balance, which has to be maintained throughout the shot. However, in archery too, being best biomechanically balanced will assist in establishing a sound technique with less muscular effort. Proper body positioning will create less tension in the body, allowing a steadier hold and aim, thereby producing a flowing shot.

It must therefore be recognized, that the pressure distribution of 60-70% on the balls of the feet and 40-30% on the heels is a very important component of the horizontal and vertical force distribution. Unfortunately, many Western archers are standing more on their heels and as such cannot achieve optimum stability.

A direct proportional relationship between horizontal and vertical forces in archery cannot be shown using force plates; however, with the right posture and balance, we can be stronger, develop forces more beneficially, thereby achieving greater stability.

Nevertheless, force plate analysis has shown that the movement of the center of gravity is much greater in lower level archers when compared to elite archers. This especially becomes evident on release. The elite archers were also shown to improve their stability during the last few seconds preceding the release, while in contrast, the lower level archers showed a significant difference in balance parameters already 4-6 seconds prior to and up to release.

4_Principle of Eye Control

Once more, let us look at the way some other sports do it.

Looking at baseball, the hitter will not only try to look at the ball, but also try to focus on the stitching of the ball. They want to see the ball very clearly, which can be further enhanced by going to a narrow external focus.

Similarly with tennis players, when they hit the ball, they do not look where they want the ball to land, but they focus totally on the ball to ensure proper timing and impact and will not take their eyes off the ball.

The same goes for golfers hitting the ball. Golfers, like the tennis players, have made up their mind where they want the ball to land and the distance required. They then totally focus on the ball itself, right throughout the follow through. If the eyes are taken off the ball to see where the ball is going, then very likely a miss-hit will occur.

Equally, in archery, the final focus has to be the target, not the sight pin and not the arrow. The eyes have to stay focused on the target until the arrow hits. Many archers try to watch the arrow and that is why they lose control of the shot. This



is another reason why many archers have trouble aiming off during windy days.

Keeping the eyes focused on the target until the arrow hits, we can call **“Eye Control”**.

For further information on eye control, Refer to Chapter 6, Cl. 31, Shooting in the Wind and Aiming-off Practice.

5– Principle of Follow Through

When running, 100M sprinters must really aim to run say 110M. If they aim to run only 100M, they will subconsciously slowdown coming to the finish line. Similarly, golfers, baseball players, cricketers or tennis players have to hit “through” or beyond the ball and follow-through, otherwise momentum and velocity is lost. Obviously, this applies to all sporting disciplines.

In archery, we do need to keep direction and tension during the follow-through. Keeping direction does not mean that the drawing elbow goes straight back in line with the arrow. The drawing elbow will have to come around because there is quite a big arc in the back tension movement. The bow arm will move slightly left, due to the back tension. Refer to Chapter 6, Cl.6 SCATT System Tests.

Archers will need to be taught how to move the Scapulae correctly together on release and maintain back tension. If the Scapulae are set too far away from the spine or too high, it will be difficult to develop good back tension. If the Scapulae come more together, we are able to expand and open the chest more and in so doing, we can come through the clicker those last few millimeters.

To this purpose, exercises with a Formaster, will teach and assist in maintaining back tension throughout the release and follow through.



6_Principle of Relaxation

The principle of relaxation in itself is very basic, but is also very important for any sport. A good example would be the World Champion swimmer Ian Thorpe; watching him break world records, one can only marvel at his very relaxed style, almost as if he is doing training laps.

Another example would be a baseball pitcher, when he pitches, he can produce a faster ball when he pitches with more relaxed muscles. A tensed muscle is a much weaker muscle.

Similarly, elite level athletes have the ability to perform with the least amount of tension, producing the maximum amount of power.

In archery, we will see the top performers execute their skills in a seemingly totally relaxed and effortless manner. To be able to relax, we have to make more



use of the bigger muscles right from the beginning, as using the smaller muscles creates more stress in the body.

Most Western archers when asked how much tension there is in their body when they shoot a single arrow will generally respond with, between 50%-70% compared with Korean archers who report between 10-30%. This is one of the fundamental differences between Western and Korean archers. Because most Western archers shoot every single arrow with too much tension, they tire over a whole FITA round of 144 arrows. The last shot of a FITA round should be made with the same amount of energy as the first.

Korean archers can shoot up to 1,000 arrows per day compared with most Western archers who could perhaps only control 200-300 arrows per day.

Most Koreans archers do not use weight training to strengthen their shooting muscles. Most of their training is archery muscle specific, which means special attention is given to Specific Physical Training (SPT). Either it can be done with a bow about 2 - 3 lbs heavier than the competition bow or some Theraband, can be used around the bow and string to provide some extra poundage for SPT training. Refer Chapter 7, Cl. 4, Specific Physical Training.

Therefore we can say, that the more relaxed we are, the greater the output.

Input < Output