Connecting the Dots

Every day, there is new research out on biomechanics and athletes. The trick is using those findings in an everyday kind of way.

By Vern Gambetta

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For many coaches, the term "biomechanics" conjures up images of sophisticated computerized analyses—angles, vectors, force measurements, and stick figures that don't seem to relate to everyday coaching. Because of this perception, it is easy to dismiss the use of biomechanics in everyday training programs.

But understanding and using the concepts of biomechanics is critical to making your strength and conditioning program efficient and effective. You don't need to conduct sophisticated analyses to utilize biomechanical principles. You just need to be able to interpret movement and understand the mechanics behind your drills.

As a coach, applied biomechanics is a tool I use daily to make my athletes better. Over the years, I have worked to make it a simple way to gain insight into every area of training. My goal is to share with you the approach I have used to apply biomechanical principles to my work on a continual basis.

MAJOR CONCEPTS

Biomechanics is the science of human motion. It helps us understand the human body as a system of relationships and interactions that produce smooth, efficient movement. It includes the effects of internal and external forces on the human body during both movement and rest.

The challenge is to make this science, which can be quite technical and complex, practical and applicable to everyday training. I have found it helps to think of the big picture: of whole movements instead of individual muscles. In athletics, movements should flow. Therefore, it is important to visualize how the parts fit together rather than focus on the working of a specific joint or muscle.

It is also important to remember that biomechanics as a science does not stand alone. To achieve optimum performance, it must be applied in concert with other sport sciences, such as energy systems and neurophysiology. For example, mechanically correct technique will result in more efficient movements, which reduces the amount of energy needed to perform the movement. Think about how the sciences work together when developing your programs.

One way I have simplified biomechanics is by thinking of human motion and athletic performance as the interaction of three movement constants. Those constants are the body, the ground, and gravity.

The body is the central constant. I like to think of it is an intricate system of levers (bones) and motors (muscles) that enable us to produce or reduce force to elicit the desired movement in three planes of motion.

The ground is where we actually derive force, so we must learn to use it effectively. We only get out of the ground what we put into it. This concept is called ground reaction force. When sprinting, for example, the athlete's objective is to apply as much force as possible to the ground in the shortest amount of time. In addition, athletes must be trained to adapt rapidly to varied surfaces.

Gravity serves to load the system. Movement involves attempting to overcome gravity, which is a perpetual source of resistance. Understanding the athlete's center of gravity and how it affects movement is critical. For optimal movement, the athlete needs to learn how to remain stable even as their center of gravity moves.

UNDERSTANDING MOVEMENT

With an understanding of the major concepts, we can look at the biomechanics of movement more closely. Most important to remember is that the body is a link system—a kinetic chain. The kinetic chain principle indicates that there is sequence and timing of body segments during movement. To produce force, therefore, we should use as many joints as possible. The same is true when reducing force.

Because the body is a link system, movement errors can always be traced to a cause-and-effect relationship somewhere in the kinetic chain. Many times it is well removed from the symptom. For example, errors in throwing are often related to some dysfunction at the ankle or the hip. To find the cause of an error, we need to look down or up the chain.

One of the greatest benefits I have gained from using biomechanics has been the ability to pinpoint the cause of a movement error, and not just the symptom. It's tempting to treat the symptom by changing the athlete's mechanics, but correcting the cause will prove more effective over the long term. An example of a symptom might be a sprinter popping up out of the starting blocks—the cause is usually too long a first step. Another example of a symptom is a right-handed pitcher experiencing shoulder pain. One cause may be that his lower leg is too open—his left foot is pointed toward the first base side of home plate.

Also understand that some mechanics can be corrected and some cannot. In my experience, the most easily corrected faults are big movements. Finer motor movements can be very difficult to change. That underscores the necessity of teaching and mastering fundamental skills early.

In looking at the mechanics of my athletes, I think primarily in terms of patterns of movement. Why is this important? Neurologically, the brain does not recognize individual muscles. Rather, it recognizes patterns of movement in response to sensory input.

The athlete's central nervous system calls upon preprogrammed patterns of movement that can be modified in countless ways to react appropriately to gravity, ground reaction forces, and momentum. Each activity is subjected to further refinements and adjustments through feedback from the body's proprioceptors.

This process ensures optimal neuromuscular control and efficiency of function, but in strength training, we have traditionally been taught the opposite. We learn much more about individual muscles than integrated movements. Isolation of specific muscles does not appropriately emphasize dynamic, multi-dimensional development of movement patterns, and those patterns are what the muscles follow.

I categorize movement patterns into six areas: rotating, bending, extending, pushing, reaching, and pulling. Whether you are working with a football player or a swimmer, their movements will fit into these basic categories.

What does this mean for developing training programs? In strength training, for example, this tells us to emphasize multiple-joint movements rather than isolated movements. In speed workouts, it tells us to focus on triple-joint extension—the leg's entire movement when pushing off.

Along the same lines, think about movements in dynamic positions. Researchers tend to study muscles in the anatomical, or resting, position, but athletic movements rarely occur while in anatomical positions. The difficult movements we need to train are those that occur while running, striding, or shifting the body.

Let's look closer at one aspect of movement: the gait cycle, which is the basis for all human motion. Gait is characterized by a stance phase and swing phase in walking, and a stance phase and flight phase in running. It is a reciprocal activity, which means the limbs are working in opposition. Muscle activity and the timing of muscle firing are predictable as gait progresses from walking to sprinting.

That's not too complicated, right? But understanding this has global implications for your training programs. For me, thoroughly understanding the gait cycle has greatly influenced the postures and positions that I use for various exercises.

For example, my athletes now do core training while standing and moving—seldom while seated or lying down. This engages the muscles of the core in the diagonal rotational patterns they function in during athletic activity. Because walking and running are very different biomechanically than sitting, doing core exercises while seated does not train the movements the athletes experience during competition.

TECHNIQUE IMPROVEMENT

Ultimately, understanding biomechanics will improve athletes' movements and the techniques they use to excel in their sport. One of the key areas to understand here is the distinction between technique and style. The high leg kick that Florida Marlins pitcher Dontrelle Willis uses in his motion is an example of individual style. At the point of release, every pitcher must do certain things to achieve results, regardless of how they look getting to that point. Willis has a unique way of getting to the point of release, but it is his technique at that moment which makes him effective.

Do not ask an athlete to copy another athlete's style. Look beyond individual style points and find the underlying principle that enables a movement to be effective. Look for the keys that make them able to achieve their performances. Then, teach those to your athletes.

Similarly, when critiquing an athlete, remember that everyone has a movement signature that is as unique as a fingerprint. Therefore, it is important to carefully observe and study the athlete before making any significant changes in their technique. Make sure that what you are trying to change is actually what is detracting from their performance, and not just an element of their style.

Another important rule to understand is the difference between similar movements and same movements. For example, it is common to see pitchers and quarterbacks throwing from their knees with the stated goal of improving arm strength. But from a biomechanical perspective this may be counterproductive. Throwing involves the whole kinetic chain, and taking large segments out of the action will interfere with timing and could affect coordination during the complete throwing motion. Throwing from the knees is similar, but not the same, as throwing with the legs in the equation.

Another example is using alternate leg bounding to improve speed. The goal of this drill is to decease contact time. But, in fact, alternate leg bounding results in twice the contact time of actual sprinting. It looks like the movement that occurs in running, but it is not. It is similar, not the same.

How about the use of underweight and overweight balls for a pitcher? In this case, we found through biomechanical analysis that there was virtually no difference in biomechanics between throwing an underweight or an overweight ball, as long as they were not too heavy or too light. Therefore, this is a viable training activity that is biomechanically the same for the pitcher.

The key is to use knowledge of biomechanics to design drills and exercises that will provide maximum return for the time invested. For example, looking at a relatively simple movement like distance running from a biomechanical perspective can be quite revealing. The average distance runner makes approximately 3,000 foot strikes per mile. Each leg bears the weight of the entire body, as both feet never touch the ground at the same time. The force of landing is approximately three times body weight in three- or four-tenths of a second depending on speed. That means a 150-pound runner places 450 pounds of force on each leg, every stride.

How can this information be used to define or modify a training program or rehab an injured runner? The fact is that strengthening the legs has the potential to increase stride length and help absorb the shock of landing. Therefore, from a biomechanical perspective, distance runners should do specific leg strength work. Most distance coaches hold strength training for the legs in disdain, but our analysis proves its value.

NEXT STEP

While I like to use biomechanics in a simple way in my daily analyses, I have also had success taking it to a higher level. By partnering with experts in biomechanics, I've been able to more precisely solve problems and develop better protocols.

As Director of Conditioning for the Chicago White Sox in the late 1980s and early 90s, I used biomechanics extensively to guide our conditioning program. For instance, Lois Klatt of Concordia University studied the biomechanics of stance and base running for us. From her research we were able to identify the most biomechanically correct starting position and stance for base running.

We also worked with the ASMI Biomechanics Lab in Birmingham, Ala., to study the biomechanics of pitching. We analyzed most of the top pitchers in the White Sox organization and devised adjustments to their conditioning programs based on the analysis. We also looked at training methods like overweight and underweight ball throwing and throwing a football to ascertain the specificity and transfer of these methods to throwing mechanics, and found that they did work.

I've also used a deeper look at biomechanics to help prevent injuries. For example, from several published studies and specific analyses of elite sprinters and hurdlers, I was able to determine exactly how the hamstring muscles functioned in sprinting. This enabled me to systematically eliminate exercises that were counterproductive and focus on exercises that trained the movements that involved the hamstring as it is used in sprinting. This resulted in a significant reduction in hamstring injuries among the athletes I coached. Efficiency of movement goes a long way toward preventing many common injuries.

From all of these situations, I was able to learn how to apply biomechanics to my coaching in order to improve the athletes I work with. Even though not everyone will have similar opportunities, virtually anyone can employ biomechanical principles to enhance what they already do. You can start simply by understanding what biomechanics can do and applying a few of its basic concepts and principles.