Applied Kinesiological Concerns For Athletics

Do not be put off by the scientific-sounding title! This is a presentation which evolved from Schexnayder's research and experience and it is aimed at the coach. Schexnayder is one of the mainstays of USATF Coaching Education, and gets plenty of opportunities to practice what he preaches with the fabulous LSU track team.

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INTRODUCTION

In this paper, the author will attempt to apply sport science to practical athletic situations in a non-traditional, yet more direct way. Often traditional sports sciences such as biomechanics, physiology, and motor learning exist as separate bodies of knowledge. We will here examine some of the gray areas between science and application, and try to bridge the gap between technique and training. In doing so the author hopes to bring about a greater understanding of why effective techniques are indeed effective, and why we experience so much difficulty as coaches in teaching them.

MOVEMENT ORGANIZATION

Factors Affecting Movement Strategy Formation

We will use the term movement organization to describe the processes an individual uses to construct and perform strategies to accomplish motor tasks. When an individual undertakes some type of motor task, the precise pattern of movement decided upon is governed by several factors, including:

1) Cognition. Volitional thought processes are employed to trigger the use of some generalized motor program or devise some original plan of action to undertake the task.

2) Nature of the task. The demands of the task itself, or the results classified as success, determine the strategy employed.

3) Perception of the task. The manner perceived to be most appropriate for undertaking the task determines much of the pattern of movement. However, sometimes the manner which instinctively seems to be most appropriate is in fact a poor strategy for achieving success. In these situations, coaching the correct pattern of movement is doomed to failure if the athlete's perception of an appropriate technique is faulty.

4) Reflexive Action. Certain movements or actions may elicit reflexes which cause other movements to occur, negatively or positively affecting the effectiveness of the movement undertaken. Stretch reflexes and some proprioception concerns fit into this category. We must teach techniques which elicit proper reflexes, yet do not elicit reflexes which negatively affect performance.

5) Injury prevention mechanisms. Self defense and injury prevention reflexes may thwart complete execution of certain movement strategies, or cause the originally planned movement to be modified in some way. We must design techniques that do not invoke these reflexes.

Also, as coaches we must differentiate between what is a dangerous situation that evokes these responses and unfounded fear.

6) Environmental concerns. Prior positioning of the body, prior movements of body, and the posi-

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tioning of related pertinent objects, have some effect upon the pattern of movement chosen.

7) Prior motor experience. Generalized motor programs and patterns of movement already constructed and in place, and the adaptability of these to the task at hand, may invoke their usage in movement situations. Often a generalized motor program that is in place provides a convenient option when devising a movement strategy, yet this program may or may not be appropriate.

8) Mechanical concerns. The laws of physics which govern the production and application of force make certain strategies more efficient and appropriate. Athletes may inherently sense these laws and operate accordingly, or they may be taught movement strategies that are efficient in this regard.

9) Anatomical concerns. The anatomical construction of the body, specifically the structures responsible for the production and transmission of force, affect the movement strategies we choose. We must beware, because sometimes a strategy that may seem appropriate when considered in light of the laws of pure physics may seem effective, but anatomical concerns make the strategy inappropriate. Also falling into this category is the architecture of each particular muscle and its attachments, as these characteristics make it unique.

10) Proprioceptive concerns. Preferred proprioceptive patterns serve to affect the perception and execution of movement. The effectiveness or patterns of proprioception in a particular body part may determine the muscle recruitment patterns used in the movement.

11) Biomotor concerns. An individual's personal set of strengths and weaknesses in the areas of strength, speed, endurance, coordination, or flexibility help to determine the strategy chosen to perform a task. Also imbalances in these qualities among body parts can set up preferred patterns of muscle recruitment that affect movement patterns.

When we examine this list, ramifications for the coaching profession are profound. When involved in the business of altering and refining movement patterns, any or all of the above can be contributors or disrupters of what we consider good choices of movement patterns. We must as coaches be prepared to address any or all of these items in our work.

There are many more specific principles and parameters that fall into one or more of the above categories. The purpose of this paper is to examine some of these in an effort to distinguish favorable, effective movements for athletic endeavors.

MUSCLE ARCHITECTURE

Introduction to Muscle Architecture

No two muscles in the human body are identical. They are all constructed differently, and even though the makeup of the actual contractile mechanisms is similar, there are other factors which cause the force production and speed of contraction characteristics of muscles to be quite different.

When designing athletic techniques, we must ask a muscle to perform a task it is best suited to do, a task that these variances in design deem it most suited for. Factors which determine the force production and speed of contraction characteristics of muscles—besides the physiological activity within the contractile mechanisms (fiber types, length tension curve)—will be examined here. We will examine these factors in the hope that in designing athletic techniques, we will call upon a muscle to do something it is indeed capable of and designed to do.

General Arrangement of Sarcomeres

Generally speaking, each sarcomere is capable of contracting to a certain percentage of its normal resting length. If the predominant arrangement of these sarcomeres is end to end, the excursion of a muscle (distance covered in an contraction) is significant. If the sarcomeres are arranged predominantly in a parallel fashion, then force production is enhanced but the excursion of the muscle is reduced.

Thus, muscles vary in their effective speeds of contraction and their force-generating capabilities in accordance to the primary arrangement of their sarcomeres. Long, slimly constructed muscles are thus more able to achieve high effective velocities of contraction, while shorter, thicker ones are more effective as force producers, but the velocities of contraction are slower.

Parallel and Pennate Fiber Arrangements

We generally think of the line of pull of a muscle fiber as acting along the line of pull of the entire muscle. This requires an arrangement of fibers parallel to the line of pull, yet this is not always the case.

Individual muscle fibers often act in a line of pull that differs somewhat from the muscles line of pull. In these situations, again the excursion of the muscle is reduced, and effective speed of contraction is reduced. However, these slanted arrangements, called pennate arrangements, allow more fiber to be fitted into an available area, enhancing force production abilities.

Single- and Double-Jointed Muscles

Some muscles are single-jointed in nature, meaning that they act across only one joint (only one joint is found between their attachments). On the other hand, some muscles are double-jointed, meaning that they cross two joints, and can thus act upon either joint, depending upon the stabilization patterns taking place at those joints at that time. Many muscles in humans, particularly leg extensors, operate this way. This more complex arrangement functions similarly to a rope and pulley arrangement, resulting in heightened efficiency as movements can be transferred into other movements.

Lever Systems and Angle of Pull

The angle of pull of a muscle against the bony attachment varies throughout the range of movement in a joint. Most muscle/joint resistance systems in the body operate as third class lever systems. When the joint moves from a fully extended position to a flexed position, the angles present at the start of movement cause force to be applied in a manner that compresses the joint, and the displacement-creating component of the force is small.

As flexion continues, however, the component of the force causing displacement proportionally increases, and movement becomes easier.

Finally, a large part of the force applied becomes a dislocating force, working to separate the joint itself. This means that during the portion of the range of motion in which the angle of pull of the muscle is most like the line of desired force application, greater efficiency occurs.

POSTURAL INTEGRITY

The Importance of Posture

In teaching sports skills, we spend a large amount of time teaching proper movement patterns of the periphery of the body, while often neglecting the body's core. Postural integrity is a large component of good athletic performance, since effective movements of the limbs are in a great way dependent upon proper positioning of the core of the body. In our discussion of posture, we will concern ourselves primarily with the function of the head, spinal column, and pelvis in three primary realms, those being stabilization, alignment, and uniformity of movement. We shall examine each of these in turn.

Postural Stability

When force is applied to any elastic body which is not properly stabilized, the force intended to cause displacement will instead cause distortion within the body. Insufficient stabilization causes forces to be absorbed as individual angular movements of body parts rather than producing displacement of the entire system. Postural stability is essential for this reason. During running, jumping, and throwing, forces must be applied to and from a stable base to produce efficient movement and maximal displacements and minimize the internal distortion of the system.

Postural Alignment

Postural alignment concerns in running and jumping involve proper alignment of the head, spine and pelvis along with stabilization by appropriate musculature to establish this base. The head, throughout most athletic endeavors, must be kept in proper alignment with the cervical spine, so that associated musculature is not overused and vestibular function is not disturbed. The spine must be stabilized in its correct alignment as to best accept the loading it receives from the forces produced by the legs and gravity. The pelvis should be aligned in a manner that best facilitates force production and proper leg movements. Training implications for muscle groups responsible for pelvic alignment are profound.

Uniformity of Movement

At the same time, this stabilized and aligned unit must be kept in place and moved predictably as a unit so that forces may be applied appropriately. Radical or erratic movement makes force application difficult, as the force producers must then in effect hit a "moving target." Thus, in running and jumping endeavors, the head, spine, and pelvis must be moved in a predictable, consistent manner without radical deviations to facilitate high force production. Also, in throws, a predictable pattern of movement of the body and implement is essential to proper force application to the implement.

SUMMATIONS AND TRANSMISSION OF FORCES

Usage of All Available Joints

In athletics we are generally concerned with producing maximal forces. Nearly all of the joints of the body possess associated musculature capable of creating force and movement in a given direction. In designing athletic techniques, we must position any joints that may potentially contribute so that the forces created are in the desired direction. Also, we must use all joints available in the desired line of force application in order to maximize force production.

Variances in Joint Structure and Capabilities

The joints of the human body are all different in their construction. They have differing bony structures, connective structures, and associated musculature. Because of these differences, they vary greatly in their force production capabilities. Some joints are capable of producing large forces, others are relatively weak. Some can produce peak force very rapidly, others are slower in operation.

Since these joints all have varying characteristics, and we wish to use all of these joints in some way so that we can maximize force production, it makes sense that there would be some optimal point for each joint to contribute, and that optimal point would be determined by that joint's characteristics. Proper sequencing of the contributions of each joint is as much a part of producing large forces as developing the amount of force each joint can produce individually.

Efficient Summations

In most athletic endeavors, inertia must be overcome early in a skill, then speeds increase as the skill progresses. Joints capable of producing large forces should appropriately be used early as these large forces are needed to overcome inertia. The fact that they may act slower is immaterial since in the early stages of the skill the speeds we encounter are not great anyway.

As speeds increase, then faster operating joints should become involved. These joints may not be capable of producing large forces but since inertia has been overcome resistance is effectively less anyway.

Generally speaking, in the human body we find the slower, stronger musculature proximally, while we find faster joints capable of less force production distally. For this reason, we generally employ firing orders in the upper body involving the trunk muscles first, then the shoulder, elbow, and finally the wrist.

In the lower limbs we generally use the hip, then the knee, and finally the ankle. The term "generally" is used as a disclaimer, since there is overlap in these joint contributions. Also there are unique aspects to some joints, biarticular joints especially, that make them partial exceptions to this rule. Still, the principle is valid.

If we wish to produce maximal forces, then it stands to reason that we would want to use any joint movement capable of producing force in the intended direction. We must teach techniques, that allow all of the extension or flexion movements in the intended direction of force to contribute in some way. Correct positioning of body parts prior to this force generation and application is prerequisite to this occurring. Joints must be placed in position to generate force before they can be asked to do so.

Distal Positioning and Recruitment Patterns

Often, the position of one body part determines the chain of muscle recruitment elsewhere in the body. Positioning of the distal joint especially determines which muscles are out of the line of intended force application, are not prestretched, and are effectively turned off.

In the same way, positioning of a joint also determines which muscles are placed on prestretch and which joints are cocked and ready for immediate contribution. Positioning of the distal joint of a limb greatly determines the firing patterns of that limb and can affect posture as well.

Transmission of Forces

Often joints and bones are used not as producers of forces, but as transmitters of forces produced elsewhere in the body. For example, as the hip joint initiates the pushoff from the ground in a stride or jump, the forces are being applied to the ground through the ankle joint.

In this portion of the movement the ankle has not yet begun to contribute to force production, but is transmitting the force of the hip extension to the ground. Because of this force transmission function, the ankle must be stabilized so that transmitted forces are not dissipated in the joint.

In any summation of movement, the distal segments must be correctly positioned and stabilized during the action of the prime movers so that maximal forces can be applied. This principle poses great implications for the knee and ankle joints in running and jumping, and for the grip and prior positioning of the implement in the throws.

Also, the positioning of distal segments should occur so that the line of force application of the prime mover occurs along the long axis of the distal segment. In this way, maximal forces are transmitted and dislocating forces are minimized. This principle is especially important when we consider that these dislocating forces are frequently the cause of the recurring injuries we see so often In athletics.

ELASTIC ENERGY

The Stretch Reflex and Elastic Energy

Muscles can create much greater forces when contractions are initiated by a prestretch of the muscle and its tendons. This prestretch evokes a stretch reflex, making the succeeding concentric work much more forceful and efficient.

We will refer to the additional energy created when muscles are used in this stretch-rebound arrangement as elastic energy. The fact that this energy creates no metabolic fatigue, yet produces greater forces than purely concentric contractions means that the development of elastic energy is a desirable goal in a variety of athletic endeavors.

The processes of running, throwing, and jumping occur much more efficiently when these stretch reflexes are invoked and elastic energy is developed. In designing athletic techniques, thought must be given to creating situations that produce prestretch situations in muscles.

While we often concern ourselves with creating these situations in the musculature of the limbs, we should remember that postural muscles can also he used in the same way, again enhancing elastic energy production and efficiency of technique.

Forceful contractions we desire in athletic endeavors are usually initiated in an elastic, reflexive fashion, which sets up a powerful volitional concentric response. If at any time the volitional contractions are improperly timed, or too much voluntary involvement by any muscle group is used, then the elastic energy generation of the entire system is diminished and efficiency is reduced. The possibility of injury due to cocontraction is increased as well.

We should also note that there comes a point at which the quantity of prestretch placed upon a muscle may be so great that the succeeding concentric contraction of the muscle is weakened. We must realize that these prestretch situations *should be optimized, not necessarily maximized.*

Postural Integrity and Elastic Energy Generation

The process of postural integrity previously discussed is complex. Body parts must be stabilized in an ideal alignment so that forces applied produce displacement without excessive distortion and rotation. Excessive instability and/or postural misalignment cause postural muscles to overwork to compensate for this instability and to maintain balance. This restricts their ability to function in elastic fashion.

However, the parts of the postural unit must be stabilized in such a way that the development of elastic energy is not impaired by restricting movement. Proper posture during athletic endeavors should not be associated with total rigidity, as elastic energy production would be compromised. Much recent research seems to indicate that postural musculature is involved dynamically and elastically in locomotion to a greater degree than previously thought.

STABILITY

Stability and Dynamic Stability

We know from the science of mechanics that an object remains in an upright, stable position as long as the object's center of mass lies somewhere above the object's base of support. in athletics, the maintenance of stability is a much more complicated procedure because of the fact that motion occurs.

Let us briefly examine human locomotion. At initial touchdown of any step, the center of mass of the body is generally located over the planted foot which is acting as the base of support, therefore the body is stable and in no danger of toppling. However, as the end of the stride approaches, the center of mass of the body lies a considerable distance outside the body's base of support, so the body is experiencing considerable instability.

This instability exists until the next stride grounds, and stability is reestablished. Thus, during running, walking and most other dynamic athletic endeavors, the body constantly experiences alternating phases of stability and instability, and the stride pattern serves to continuously relocate the base of support. We will refer to this state as dynamic stability.

Effects of Compromised Dynamic Stability

When some error occurs which introduces excessive instability into the locomotion pattern, the body seems intuitively to increase stride frequency as a compensating strategy. The body hastens the next stride in order to quickly reestablish stability to the system.

As frequency increases, amplitude of motion must decrease to facilitate this change. For this reason, when we see instability in athletic endeavors, without fail we also see these decreased amplitudes of motion, but also reduced displacement of the entire system.

Dynamic Stability and Elastic Energy

In situations where dynamic stability is compromised, elastic energy production is generally compromised as well, and efficiency of motion is decreased. The unstable situation the body experiences forces muscles that would normally be operating in a dynamic, elastic fashion to become stabilizers to deal with this problem. Also the decreased amplitudes of motion we see in cases of poor dynamic stability are not conducive to creating prestretch situations on muscles. In short, it is impossible for an unstable body to operate efficiently, and performance suffers.

REFLEXIVE AND ANTICIPATORY CONCERNS

Repetition and Compounding of Errors

Consider an athlete in the process of running. Someone running at relatively low speeds can demonstrate great accuracy in aligning the body into correct technical positions, because prior mechanical errors can be easily corrected. However, when dealing with the high velocities we see in competitive athletics, the correction of errors occurring during a run is limited due to time constraints, and is often impossible without great compromises. Also, at these higher velocities, reflexes play a much greater part in the pattern of movement, again minimizing the chances to correct earlier errors in body positioning. The execution of any part of an athletic endeavor is largely dependent upon the proper execution of prior parts.

We find that in athletics, mistakes tend to produce other mistakes. When the activity is cyclical, the mistake tends to reproduce itself on every cycle. In cyclic tasks such as running, the correct execution of one cycle is prerequisite to the correct execution of the next cycle.

Backtracking as a Troubleshooting Tool

This principle has great ramifications for the coaching profession. Often a mistake we see is triggered by some prior mistake. Therefore, it is good coaching practice to backtrack to earlier points in the event to find the roots of the trouble. Many a well meaning coach has spent time futilely attacking an error when correcting a prior error would have solved the problem.

Anticipation as a Cause of Errors

There are times as well when a mistake in technical execution is caused not by faulty motor strategies, or even by prior errors, but by anticipation. The expectation of a certain sensation or set of circumstances can cause an athlete to alter movements in a negative manner. In the same way, failure to encounter a familiar set of circumstances as performance approaches (even though this new set may be correct) can invoke modification of movement patterns.

CLOSING

The purpose of this paper has been to examine some of the factors that contribute positively and negatively to the creation of effective, consistent motor patterns in the athletes we coach. A special effort has been made to examine nontraditional aspects—those lying outside or on the fringes of traditional sports sciences. This paper is not intended to be all-inclusive, nor can all the points made be backed up unequivocally by research. The author has simply attempted to point out some seemingly ignored factors in athletic performance in the hopes of attracting the attention of researchers.

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