Training the pitcher: a physiological perspective

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"Bridging the Gap" is a continuing feature of the *NSCA Journal*. Various topics are presented with companion articles addressing the physiological and/or research basis, as well as the practical applications. In this way, the *NSCA Journal* continues to bridge the gap between sports researchers and sports practitioners. **See page 27 for the practical application of these concepts.**

With the ever-increasing array of conditioning and fitness programs available for implementation, it has become extremely difficult for athletic coaches to select programs which will maximize their players' athletic ability. The increasing emphasis on athletes to be competitively successful has led to the improvement of sport-specific skills. Inevitably, so much emphasis is placed on skill development that other aspects related to successful competition remain improperly addressed or even unattended. One area that seems not to receive the proper attention is the physical conditioning of athletes. The problem is not that coaches are ignoring the conditioning of athletes, but that improper methods are being used. It is logical to assume that if the skill levels of opposing athletes are similar, then those athletes who are better conditioned will increase their chances of being successful. The focus of this article will be to examine the different energy systems of the body and propose which of those systems should be trained in order to maximize the success of baseball pitchers.

Traditional Views

Baseball coaches often are either unaware or uninformed as to the proper conditioning aspects that are required of pitchers. Traditional views have supported the belief that physical endurance was best developed and maintained through conditioning programs that emphasized development of the cardiovascular system. This belief led coaches to attempt to condition their pitchers through long-lasting, repetitive activities. These activities include long distance running, swimming, and most recently, aerobic dance activities. The use of high repetition, low resistance circuit training also has been used to condition pitchers. While all of these methods have been shown to increase cardiovascular, respiratory and muscular endurance, they may not be the proper conditioning activities for baseball pitchers.

Aerobic vs Anaerobic

In order to determine what constitutes a proper conditioning program for pitchers, a distinction between aerobic and anaerobic activities must be made. Aerobic metabolism alludes to a series of chemical reactions which occur in the presence of oxygen (2). Aerobic performance is then referred to as the ability to endure hard and prolonged tasks that are of submaximal intensity (1). Conversely, anaerobic metabolism refers to a series of chemical reactions which occur in the body without the presence of oxygen (2). Subsequently, anaerobic performance can then be referred to as the ability to perform hard- and short-duration tasks that are of maximum intensity.

It is this distinction between aerobic and anaerobic metabolism and performance that is important when considering the development of conditioning programs for baseball pitchers. Fox (2) in his energy continuum lists baseball as a sport which is comprised of 90 percent anaerobic metabolism and 10 percent aerobic metabolism. A related study was performed at Auburn University to examine the relationship between anaerobic power and pitching velocity. Using varsity baseball pitchers and a series of anaerobic power tests, a high correlation ($r = 0.82$) was found to exist between pitching velocity and anaerobic power (4). It was concluded that anaerobic performance was a significant contributor to pitching velocity.

Simple observation during a game provides further evidence that pitching is predominantly an anaerobic activity. The act of pitching involves a

series of short-duration, high-intensity contractions followed by extended periods of rest. These observable characteristics also meet the aforementioned explanation of anaerobic performance.

Anaerobic Process

In order for muscle contraction to occur, chemical energy in the form of adenosine triphosphate (ATP) must be readily available (3). Chemical energy is released in response to the splitting of an ATP molecule by the enzyme Myosin ATPase. The results of this reaction yield adenosine diphosphate (ADP), inorganic phosphate, heat and energy. The available energy is subsequently used to help perform the desired movement.

Whereas ATP is in very low concentration in the muscle, and because it decreases only to a small extent, there must be several biochemical mechanisms which are responsible for the continual regeneration of ATP (3). There are three tightly regulated chemical pathways of the regeneration of ATP: creatine-phosphate splitting, anaerobic glycolysis and aerobic metabolism.

Creatine phosphate (CP) is a high energy phosphagen similar to ATP. In skeletal muscle, CP has a concentration approximately threefold greater than ATP (3). A function of CP is to regenerate the ATP that has been used during muscle contraction. Creatine phosphate is considered an anaerobic energy system and is extremely limited in its ability to regenerate large amounts of ATP. After the first several seconds of intense exercise, other metabolic pathways must become active if ATP levels are to be replenished.

Anaerobic glycolysis involves the regeneration of ATP through the breakdown of carbohydrates to lactic acid (3). This method of ATP resynthesis also is an anaerobic process. Large amounts of ATP can be regenerated from this energy pathway, although it is not possible to continue contraction for prolonged periods of time. The phosphagen depletion and the increased acidosis due to the accumulation of lactic acid results in a reduction in work intensity. Anaerobic glycolysis provides enough ATP reproduction for approximately two minutes of intense muscle contraction.

The production of ATP by aerobic metabolism involves the breakdown of a metabolic fuel in the presence of oxygen (3). For aerobic metabolism to contribute significantly to ATP resynthesis, oxygen must be supplied to the mitochondria of the muscle cells in sufficient amounts. Aerobic metabolism requires a significant amount of time to activate the processes involved in the reproduction of ATP. Therefore, aerobic metabolism does not contribute significantly to ATP resynthesis until approximately two minutes after initiation of muscle activity.

It must be remembered that all three processes occur to some extent concurrently. The proportion of ATP supplied to the working muscle from each process will vary according to the intensity level and duration of the exercise. During normal resting conditions, the majority of ATP regenerated in skeletal muscle occurs via the aerobic processes. Any rapid increase in exercise intensity is immediately followed by an accelerated rate of ATP resynthesis from the creatine phosphate stores and anaerobic glycolysis. If exercise continues there is a gradual increase in aerobic metabolism. If, however, the intensity of the activity remains extremely high, then the anaerobic systems will continue to supply the major source of ATP. This is due to the inability of the aerobic system to supply enough ATP to meet the energy demands of the muscle (3).

Conditioning for Pitchers

An important consideration for the baseball coach is how anaerobic and aerobic metabolisms relate to the conditioning of pitchers. The primary energy system that is used during an athletic event is a function of the intensity of the exercise and the duration of the event. **Tables 1** and **2** show the relationship between the different systems, rate of ATP production and duration of the event (5).

Pitching in a game involves intermittent high-intensity contractions of relatively short duration. When throwing a baseball, the athlete is required to exert high-intensity force for only fractions of a second. This ability to repeatedly generate force is a function of many factors. Technique, skill, strength and probably some psychological variables are all involved in the production of force. One factor that must not be forgotten is the energy system responsible for the reproduction of ATP. Due to the intensity level and duration of pitching, it can be concluded that the predominant energy system involved is the ATP-PC system. It is imperative that when implementing conditioning programs for baseball pitchers that the coach concentrate on developing the anaerobic energy systems.

The concept of metabolic specificity to training provides for the selection of approximate intensity and duration training activities. By focusing conditioning activities on specific energy systems, the coach can favorably affect those energy systems which predominate during an athletic event. In other words, if an athletic event is predominantly anaerobic, then conditioning and training programs should focus on the anaerobic energy systems. The opposite is also true for those activities that are predominantly aerobic. Since baseball pitch-

Table 1. Energy System - Rate of ATP Production

System	Rate ATP Production
ATP-PC	Fastest
Anaerobic glycolysis	Fast
Aerobic metabolism	Slower

Table 2. Energy System - Duration of Event

System	Duration
ATP-PC	0-10 sec
ATC-PC, anaerobic glycolysis	10-30 sec
Anaerobic glycolysis	20 sec-2 min
Anaerobic glycolysis-aerobic metabolism	2-3 min
Aerobic metabolism	> 3 min and resting

ing is an anaerobic activity, the preseason and in-season conditioning of pitchers should be entirely anaerobic.

The use of training programs that involve weight training and high-intensity, short-duration interval running and jumping can provide the necessary improvements in the anaerobic energy systems. The concentrations of ATP-PC and carbohydrates in skeletal muscle are central to maintaining high-intensity work rates (5). Increases in ATP-PC and carbohydrate stores have been observed after strength training and interval running. These increases provide for greater endurance during high-intensity work. It can be concluded that an increase in ATP-PC stores has been observed after strength training and interval running. These increases provide for greater endurance during high-intensity work. It can be concluded that an increase in ATP-PC stores and an improvement in anaerobic glycolysis will result in the potential for improved performance during competition.

Conversely, the use of aerobic training programs will provide little benefit to the anaerobic energy systems that predominate during pitching. It is also possible that the use of aerobic conditioning programs may be detrimental to the development of a successful pitcher. Research has indicated that the use of aerobic conditioning programs may interfere with the development and expression of muscular strength and power. Although the reasons for the compromise of muscular strength and power are not completely understood, several theories have been proposed.

Regardless of the mechanism responsible for the compromise of anaerobic endurance, strength and power, it must be remembered that a mixed training program produces mixed results.

Considerations for Developing a Program

When developing a conditioning program for pitchers, it is important to remember the following points. A conditioning program should closely mirror the actual athletic event in terms of intensity and duration. This is done in order to maximize the development of the predominant energy system. In the case of baseball pitching, the development of the anaerobic energy systems is of paramount importance. These systems provide rapid regeneration for ATP in an effort to meet the high intensity and power demands of the activity.

Conversely, an aerobic conditioning program will not develop the predominant energy systems that are used while pitching. It is also possible that extensive use of aerobic conditioning may reduce the muscular strength and power of the athlete. ●

References

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