SECTION 2

ENERGY SYSTEM, BIOMECHANICAL, & POSITION SPECIFIC REQUIREMENTS OF LACROSSE

2.1 Lacrosse Energy System Breakdown

The three energy systems introduced in the first section of this manual (Oxidative, Glycolytic, and ATP/Cr-P) are required to each function at a high level for optimal performance to be possible in the sport of lacrosse. Regardless of skill set or hours spent shooting or practicing by an athlete, if these three systems are not trained to the highest extent, the athlete will never be prepared to compete [(24)].

Although these energy systems are trained individually, it is important to understand these energy systems do not function as either “on” or “off,” but are rather in constant flux, like a “dimmer” light switch [(26)]. Regardless of the situation all three energy systems provide energy to the body, but to a different extent. At the initiation of a high-intensity sprint in lacrosse, the ATP/Cr-P and glycolytic energy systems increase dramatically. The oxidative energy system still provides some energy to the athlete, although limited in amount [(24)]. As an athlete begins to fatigue during a competition or practice, the oxidative system begins to play a much bigger role in performance and energy production [(24)]. Each energy system is turned up or down in the body depending on the experiences the athlete undergoes [(26)]. It is important all coaches understand this concept of the three energy systems.

Basically, an athlete undertrained in the three energy systems will constantly be considered as “out of shape” or “one step behind the play.” This type of play can be due to a multitude of reasons, all dealing with the three energy systems. Either the athlete lacks the ability to recover from a high-intensity, sprinting gameplay or the ability to produce the energy substrates required at a rapid rate. Ultimately, it is up to you, the performance coach, to determine exactly what each individual athlete needs. However, the Triphasic Lacrosse Training Manual has been created to ensure each of the three energy systems are trained, and then maintained at the highest level for the entire duration of a season.

Based on the description above, lacrosse is a repeat-sprint sport, meaning success in the sport is dependent on the ability to repeat high-speed movements and sprints multiple times in quick succession throughout the entirety of the game. The team that can dodge, sprint, and create fast-break opportunities late in a game will have a much higher likelihood of winning than its slower, more fatigued opponents [(25)].

Each of the three energy systems are required to a high extent to make quality play possible late in a game. These three systems, when trained appropriately, maximize energy availability, capacity, and a high recovery rate [(24)]. The limiting factors for repeat-sprint athletes can ultimately be boiled down to three scenarios [(26)]. 1). Cr-P cannot be re-synthesized at a high enough rate, 2). metabolic accumulation occurs, whether that be the increase in H+ leading to acidosis or the increase in inorganic phosphate (Pi) leading to inhibited muscle contraction capabilities, and 3). oxygen availability [(26)].

It should be clear repeat-sprint sports, such as lacrosse, require a unique approach as both the power production and efficiency must be highly considered, stressed, and adapted for each athlete. The principles applied to energy system development in the Triphasic Lacrosse Training Model, designed specifically for repeat-sprint sports will be expanded upon throughout this section, with examples to follow in a later section of this manual.

As described above, repeat-sprint sports require a specific, highly structured training program in order to ensure each of the three energy systems are trained maximally. These blocks are trained individually to improve the ability to recover and repeat high-intensity events, such as sprinting, dodging, playing defense, winning face-offs, etc. The oxidative, or aerobic, system forms the foundation of all other performance qualities. The energy system pyramid, shown again below in Figure 2.1, displays the appropriate training progression for these three systems, from the bottom up. Each energy system plays a vital role in the ability to repeat high-intensity sprint situations continuously in a competition.

The availability of oxygen and clearance of metabolites through the oxidative system, the ability to tolerate high-levels of metabolites produced during intense situations by the glycolytic energy system, as well as the resynthesis and utilization of the ATP/Cr-P energy system are all trainable qualities and play important roles in the ability to complete repeated, high-intensity sprints. Notice each of the three energy systems are required in order for adaptations to be achieved that maximize repeat-sprint abilities. For this reason, all three energy systems are required to a high extent. Through the implementation of the Triphasic Lacrosse Training Model, an athlete will improve his ability to utilize oxygen, clear and tolerate extreme levels of metabolites, and increase his efficiency and recovery of the ATP/Cr-P energy system, ultimately leading to improved abilities to produce and maintain high-level sprints and other movements for the entirety of a competition. Without the proper training of these systems individually, as laid out in this manual, no other qualities, such as shooting or dodging, can truly be optimized by a lacrosse athlete.

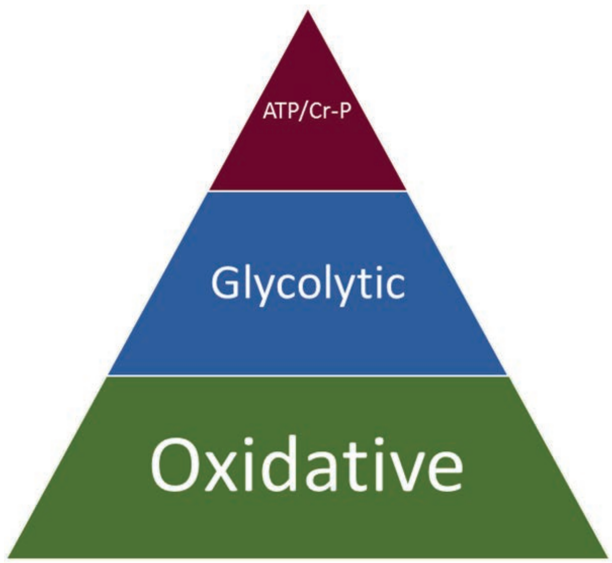

Figure 2.1 - Energy System Pyramid of the Physical Performance Qualities

2.2 Understanding the Energy System Requirements of Lacrosse

Prior to the implementation of specific energy system training to maximize performance in a repeat-sprint sport such as lacrosse, more detailed knowledge of the sport must be attained by the coach. These knowledge points include the sprint duration, sprint number, and the recovery time allowed prior to the subsequent sprint, or high-intensity scenario, experienced in both competition as well as practice by an athlete. Each of these considerations will influence the energy system contribution during repeat-sprint exercise [24].

Notice these three parameters must be considered for both practice and competition. As a performance coach, it must always be remembered the goal is to prepare the athlete for the rigors of the sport. For most, this will include a pre-season training camp of some sort. If athletes are simply prepared for competition, but not for training camp, injury likelihood will increase dramatically. For this reason, all performance coach must understand the practice style and techniques of their sports coaches. This concept will be expanded upon in the annual plan described in section four of this lacrosse manual.

In the average field-based, repeat-sprint sport, the distances reported tend to average between twenty to thirty yards, or two to three seconds [(24)]. Now this does not mean an athlete, such as a defenseman on a fast-break, will never sprint for a greater distance than thirty yards and should not have that capability. However, the majority of training should be completed with these distances and required times in mind in order to optimally prepare each athlete for the rigors of lacrosse. Performance coaches must also remember they are ultimately preparing their players for the practices the sports coaches implement. If longer sprints are required by the coach in practice, then a performance coach must prepare athletes for these in order to reduce injury likelihood. As a performance coach with a well-rounded understanding of the requirements of lacrosse, it is vital you share this knowledge, in an absolutely non-condescending manner, with your sports coaches to benefit the team to the greatest extent. This will allow practices to be completed in a specific manner to the requirements of competition.

Even though a midfielder may cover multiple miles in a single competition or practice, it is more important that coaches understand the intensities those distances are covered by the athlete. Are they short sprints executed repeatedly? Or are they completed at a long slow pace? After the last section it should be clear the short, repeated-sprints are utilized much more often. Every performance and sports coach must take this into account when programming both practice and training sessions.

The number of sprints completed in a field, repeat-sprint sport on average varies greatly as well, from nineteen to sixty-two [(24)]. The large change in number of sprints completed during competition rely heavily upon the position of each athlete [(24)]. The duration of recovery between sprints also varies greatly based on the position of each athlete as well as every individual game. If one face-off specialist is much more skilled than his opponent, one team’s attack can expect to have much less rest time between sprints than their defensive teammates. At this time, successive sprints with less than sixty seconds of rest time is considered in literature to be a repeat-sprint activity [(27)]. However, the average rest time between repeated sprints is somewhere between forty and seventy seconds in competition [(26)]. It has been shown that even with ninety seconds rest, a significant decrease in performance can be seen in as few as the eleventh sprint in repeat-sprint activities [(24)]. Therefore, athletes in lacrosse must be prepared to produce high-intensity efforts continuously with incomplete rest.

Ultimately, all coaches should continue to understand the exact requirements in creating an optimal training and practice plan. If the physiological and metabolic responses of repeated-sprint training are to be specific to the sport of lacrosse, then the sprint distance, number, mode, as well as recovery duration and method must replicate the requirements of lacrosse [(24)].

Taking all of these factors into account, the Triphasic Lacrosse Training Model, during the high-quality, Triphasic training phases, implements bouts of seven seconds on both Monday and Tuesday training sessions, higher quality bouts of five seconds on Wednesday and Thursday training sessions, and finally bouts of ten seconds on Friday. The number of high-quality bouts implemented in each of these days is also determined off of the specific requirements of the sport of lacrosse. By considering both the time and number of high-intensity efforts an optimal program can be created. This allows the energy systems required on the field to be continuously trained to the highest specificity to the requirements of a repeat-sprint sport such as lacrosse. These high-intensity programs will be shown in their entirety in a later section. However, prior to training the high-intensity systems to the highest extent, every athlete must have the appropriate energy system abilities, with the aerobic system laying the foundation on the other two energy systems.

2.3 The Oxidative Energy System

As described in the first section of this manual, the oxidative system functions through the use of oxygen and is the primary source of energy at slower paces and/or longer distances. Although the oxidative contribution is small in a single, short-duration sprint (about 10% of total energy provided), there is an increased contribution by this energy system with each successive sprint completed, with up to 40% of energy being provided by the oxidative energy system during the final sprint (26,28). Athletes with a higher VO_2max, which is a common measurement of the oxidative energy system, tend to maintain power output levels better than those with a lower VO_2max in repeat-sprint testing (26). It should be clear this energy system is vital for the sport of lacrosse, specifically the ability to maintain high-level outputs (24).

As with any training implemented within the Triphasic Lacrosse Training Model, there are specific adaptation goals within each training block. For the oxidative energy system, required adaptations include increased oxygen availability, increased mitochondrial density, and improved efficiency, which allow the body to experience less fatigue during competition. Oxygen availability to the muscles utilized in the sport of lacrosse is improved in multiple ways, including adaptations to the heart, lungs, and other aspects of the circulatory system (29). Enhanced oxygen availability, which is one of the training adaptation goals in this block, has been shown to improve high-level outputs over the course of repeated, short-burst sprints (26).

The contribution of the oxidative energy system increases with every repeat-sprint effort, and this energy system relies on the use of oxygen, so these adaptations are critical to improving this performance quality. Through appropriate training, the heart enhances its ability to pump larger quantities of blood, which is responsible for transporting oxygen from the lungs to the working muscles (29). The lungs improve their ability to move inhaled oxygen to the blood (29). Finally, the blood maximizes its oxygen carrying capacity and the capillaries increase the ability at which oxygen is capable of being delivered to the working muscle upon arrival (29). Together, these adaptations due to appropriate training lead to an increase in oxygen availability and reduce fatigue experienced by athletes.

The body further enhances the oxidative energy system by increasing mitochondrial density (29). This increase in the mitochondrial network improves the ability of each cell to utilize the increased oxygen now delivered to the working muscles. This leads to improved Cr-P re-synthesis after a repeat-sprint effort as the mitochondria are the only location where Cr-P is synthesized (26). The increase in mitochondrial density also increases the fat metabolism, further enhancing the efficiency of the athlete at all exercise intensities.

Type I muscle fibers as well as specific movement efficiency are also maximized through the training of the oxidative energy system (29). Athletes who have trained their oxidative energy systems to the highest level tend to have lower high-level outputs in maximal effort tasks, meaning they will be capable of maintaining their outputs for extended periods of time (26). An athlete with a highly-trained oxidative system will be capable of contributing to a greater extent through this energy system, thus limiting the use of the glycolytic and ATP/Cr-P systems to some extent, reducing the amount of inorganic phosphate produced within the body (24). Inorganic phosphate is important in repeat-sprint sports, as it is a potential rate-limiter for these athletes to repeat high-intensity bouts [26]. This metabolite has the ability to reduce muscle power production and increase fatigue levels in a lacrosse athlete [26]. This will ultimately allow an athlete to maintain a high-level of performance for a greater number of sprint repetitions experienced in lacrosse.

The oxidative energy system is important as it allows an athlete to control his heart rate to a greater extent. An athlete with a highly trained oxidative system has the ability to complete identical tasks at a much lower heart rate than an untrained athlete. Athletes who have improved this energy system are able to train, practice, and compete at much higher intensities while maintaining an extremely high-level of efficiency. Ultimately, the trained athlete can complete more work while expending less energy than his untrained opponent.

An example of the importance of the oxidative energy system can be seen below in Figure 2.2, in which two starting lacrosse athletes are shown. Both begin at the same fitness levels at the opening face-off (top black dotted line). However, the athlete on the left has not been trained in his oxidative energy system, while the athlete on the right has trained his oxidative system. For demonstration purposes, both athletes experience the exact same six high-intensity sprint situations. Each high-intensity situation is represented in this figure by a decrease in sprint speed. It is common knowledge that as a player fatigues, his ability to run at high speeds is diminished. However, the aerobically trained athlete, on the right, declines at a much slower rate (green dotted line) than the athlete on the left (red dotted line). This improved performance is due to his optimally trained oxidative energy system, which leads to his ability to recover at a higher rate between every high-intensity sprint.

This example shows the effects of just six sprints, now imagine the difference in performance (in this scenario sprint speed) between athletes trained vs. untrained in their oxidative energy systems late in competition. The athlete on the left represents the athlete that is commonly "a step behind the play" due to his lack of aerobic training. Ultimately, the appropriate training of the aerobic system, and the other two energy blocks, will allow an athlete to sprint faster and shoot more accurately much later in a game than if this foundational aspect of performance is not trained. Clearly, this allows a team more aerobically trained a much higher likelihood of success, or winning the game. The methods implemented within the Triphasic Lacrosse Training Model to adapt the oxidative energy system will be shown and explained in a later section.

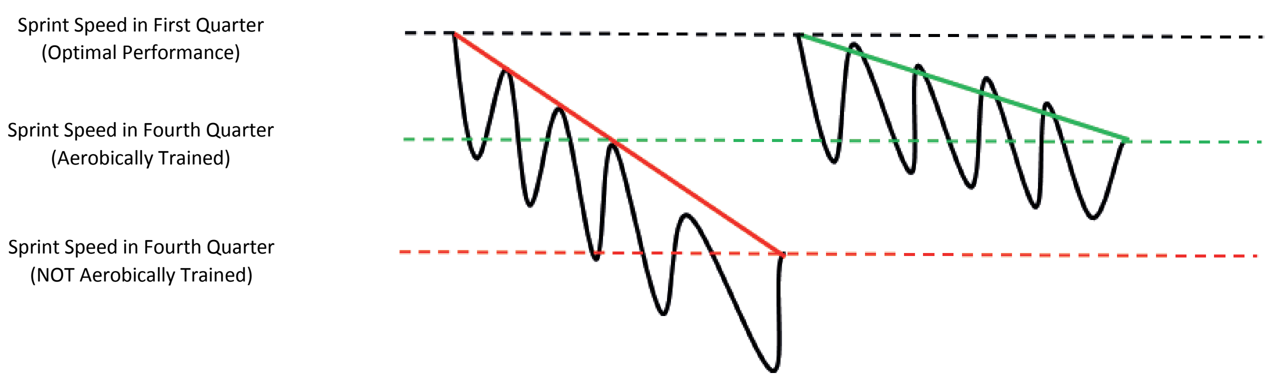

Figure 2.2 - Effects of a trained vs. untrained oxidative energy system

2.31 The Oxidative Energy System and Lactate Clearance

As mentioned above, one role of the oxidative system is the clearance of metabolites, which accumulate during high-intensity activities [30,31,33-35]. These metabolites, in this case hydrogen ions, accumulate and are capable of altering the pH of a muscle [30,34,35]. Ultimately, this accumulation will lead to a reduction in high-intensity performance abilities [30,33,35]. As both power production and efficiency are vital aspects of performance in a repeat-sprint sport such as lacrosse, it is critical that training be completed to allow an athlete to overcome metabolite accumulation. Both the physiological adaptations, as well as the implemented training will be provided throughout this manual.

The reduced power output due to accumulated metabolites is commonly associated with “lactic acid” by many coaches. However, the fact is “lactic acid” dissociates at such a high rate as this substance is immediately broken into two components, hydrogen ions and lactate. As the accumulation of hydrogen ions has been presented as a limiting factor in high-intensity exercise, it is important every performance coach understands the purpose of lactate and how it is utilized within an athlete’s body [30]. Specifically, it is important to understand the clearance of hydrogen ions and how to train every individual to maximize this adaptation [32-34]. Only when an athlete can clear these accumulated metabolites can optimal performance be attainable.

Lactate and hydrogen ions are being constantly produced within every person at all times, not just during high-intensity exercise [32]. Even while you are reading this, likely seated, your body is producing both of these. No one realizes, or feels, this production like when exercising at high-intensities though as your body has the ability to clear these by-products, specifically the hydrogen ions, prior to them accumulating. However, as exercise intensity increases, metabolite production increases as well. Clearance rates continue to match this production, up to a specific threshold [34]. When this threshold is reached and crossed, the athlete is no longer capable of clearing the produced hydrogen ions at the rate of production and accumulation begins to occur [34]. It is this threshold, termed the “lactate threshold” that has the ability to separate an elite athlete from just an average one. This threshold can be improved, or shifted further to the right, with the proper oxidative training described in this training manual [34]. Figure 2.3 below represents both an “untrained” and “trained” athlete, with the trained athlete being capable of producing greater amounts of work prior to the accumulation of lactate. This skill relates directly to the ability of an athlete to function efficiently in high-intensity situations. The “trained” athlete in Figure 2.3 will be capable of recovering at a much higher rate than the “untrained” athlete. This, once again, relates back to Figure 2.2 and the importance of recovery between high-intensity bouts. By improving the ability of an athlete to clear lactate, an athlete is capable of producing more repeat-sprint efforts prior to fatigue due to the accumulation of metabolites occurs, which performance coaches should now understand as a potential limiting factor of performance in lacrosse [31,33,35,36].

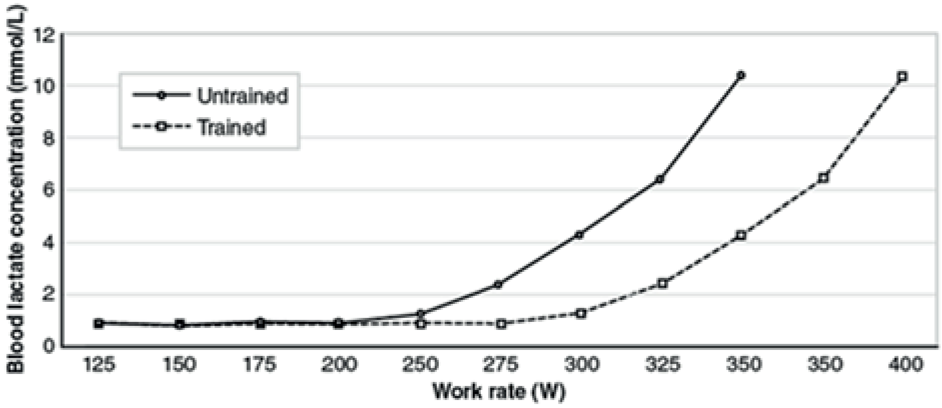

Figure 2.3 - The lactate threshold training effect

One of the primary purposes of lactate is to accept hydrogen ions, which ultimately lead to the pH change in muscle, thus limiting repeat, high-intensity performance [31,33]. This capability of lactate makes it an important buffer within an athlete's body. With muscular pH being one of the limiting factors in repeat-sprint sports such as lacrosse, it is vital to train the body to buffer the produced hydrogen ions as efficiently as possible [31,34]. Lacrosse athletes who complete repeat-sprint efforts have the greatest potential to improve this skill through specific lactate clearance training.

High-intensity efforts, such as those completed in practice and competition in lacrosse, require rapid re-synthesis of ATP. Without the ability to resynthesize ATP, the body will accumulate inorganic phosphate, the other metabolite likely limiting the ability to repeat high-intensity efforts [31,33,36,37]. Lactate, by acting as a buffer and accepting hydrogen ions, allows specific enzymes responsible for ATP replenishment to continue to function at the highest levels. Through appropriate training the body has the ability to increase lactate production, but it cannot increase substrate levels. Therefore, lactate plays an important role in allowing energy pathways to continue to resynthesize ATP, thus limiting the accumulation of inorganic phosphate and increasing the ability to continuously produce high-intensity efforts [35-37].

Finally, lactate can also be utilized within an athlete's body as an energy substrate [32]. Oxidative, or slow-twitch, fibers within the body have the ability to utilize lactate as an energy source, which again increases ATP:ADP ratios and limits the accumulation of inorganic phosphate [36,37]. These fibers able to utilize lactate as an energy source include the type I muscle fibers, heart, and kidneys, with the heart actually preferring to use lactate as a substrate during exercise [32]. Lactate can also be utilized in the liver and can then be translated to a readily usable energy source [32].

When lactate leaves a muscle cell, nearby type I, or oxidative, muscle cells have the ability to utilize lactate as an energy source. If these type I fibers have been trained appropriately, they will have an increased ability to utilize this lactate as an energy source [32]. This specific training will be provided entirely in a later section. If there are no available type I fibers to utilize the produced metabolites, lactate will enter the blood stream, where it can be pulled in by other oxidative fibers, the heart, or the kidneys [32]. If each of these locations are saturated, the lactate will remain in the blood until it reaches the liver. At this point, the lactate can then be converted back to a usable energy source for the body and stored within the liver or sent back into the blood if immediate energy is required [32]. If the energy source is distributed back into the blood, it will be sent to a working muscle to be utilized in order to continue high-intensity activities, such as those required in both training and competition [32,33].

Prior to lactate being utilized in other areas of the body as an energy substrate, the methods in which it is mobilized in and out of a cell, or lactate kinetics, must be well understood. The main source of lactate transport, both uptake and removal, are the monocarboxylate transporters (MCT's) [30,33,34]. Although these are not the only method of lactate kinetics within a cell, they remain the primary source and will be the focus of this section. Studies show clearly that MCT's have an inverse relationship with blood lactate levels post-exercise [32-34]. As MCT concentration increases, blood lactate levels decrease. This demonstrates an importance in the ability to recover rapidly, as shown in Figure 2.2, as an increased MCT concentration improves lactate clearance rates [30,32-35].

In the case of lactate kinetics during exercise, only two MCT's are currently well understood and utilized. This includes MCT1 and MCT4. MCT1 is found primarily on type I, or oxidative, muscle fibers and is responsible for the uptake and removal of lactate [32-37]. With it being located mostly on oxidative fibers, which do not produce much lactate, the main purpose of MCT1 is the uptake or clearance of lactate that is produced and accumulated in high-intensity exercise by the powerful, explosive type II muscle fibers [33,34]. MCT1 ultimately has the ability to clear the lactate from the blood and then utilize it as an energy source within the previous described muscle tissues [32-34]. MCT1 is generally more responsive to specific training than MCT4, making the clearance of metabolic waste the most available training adaptation to improve this process occurring in high-intensity exercise bouts [30,32-34].

MCT4 is primarily located mostly on type II muscle fibers and is responsible for the removal of lactate from these cells, where the majority of this by-product is produced [33,34]. Although there is a much larger variation between subjects for MCT4 than MCT1, MCT4 does show improvements due to training, just not to the same extent as MCT1 [30,32-34]. Once again, the training and adaptation of the oxidative energy system is important as it improves the clearance of metabolites produced in repeat-sprint sports such as lacrosse.

The methods to optimize lactate within the body include both base endurance and high-intensity training [31]. High-intensity methods are already widely used and understood by performance coaches, but it is the base endurance training, which maximizes the oxidative energy system and fibers, that is the most pivotal piece to improve lactate kinetics [33,34].

Oxidative training builds a foundation for future training and, in this scenario, is any type of repetitive movement that increases blood flow while keeping the heart rate in an aerobic zone. During this training the length of the activity is a key determining factor, with the goal being a pace that can be maintained for an hour. It is this training at oxidative intensities that maximizes MCT concentration, particularly MCT1, and also increases mitochondria concentration [32-34]. These adaptations maximize the ability of the body to clear lactate and then utilize it as an energy substrate, while also improving the aerobic abilities of the athlete [32].

Many performance coaches understand and implement high-intensity training, which absolutely has an appropriate place. However, this method of training will not increase MCT concentration to the highest extent possible [30,32,34]. It is for this reason specific oxidative energy system training is absolutely vital for performance in the sport of lacrosse and other repeat-sprint sports. Also, when programmed correctly, this low intensity, oxidative training will prevent any explosive muscle fibers from shifting to a more oxidative state. This is because training is completed at a low enough intensity that powerful muscle fibers will not be recruited, and thus will not shift to a more aerobic state.

For a more in-depth understanding of lactate kinetics, click here and/or here.

Ultimately, by improving lactate kinetics through appropriate oxidative training, which increases the MCT1 content and mitochondrial density, which assists in energy production, every athlete will have the ability to recover at a much higher rate [30,31,33-35]. Less hydrogen ion accumulation will occur, even at high-intensities, the three energy systems will produce greater ATP levels, as hydrogen ions that prevent the ability of each energy system to function to the highest extent will be reduced, and inorganic phosphate levels occur due to an increased ability to resynthesize ATP by the three energy systems [31,36,37]. All of these adaptations are capable of being achieved through an improved oxidative energy system.

Clearly the oxidative system plays a vital role in performance in the sport of lacrosse and must be trained appropriately. An athlete will have the ability to maintain pH levels as well as ATP:ADP ratios, even when producing large amounts of metabolites and power, such as those seen in repeat-sprint situations, all while functioning efficiently and utilizing minimal energy sources [31,34-36]. The better an athlete is at buffering during high-intensity exercise, the greater his ability to perform repeat-efforts with short rest bouts [31,33,35].

Even if the other five physical performance qualities were left untrained, athletes with a highly functioning oxidative energy system will have increased abilities to sustain performance throughout the duration of competition. This can be seen again in Figure 2.2 above. The specific methods of oxidative training will be covered in section four of this manual. However, it is vital the importance of the oxidative energy system is well understood by all coaches.

2.4 The Glycolytic Energy System

The importance of the glycolytic energy system is much better understood by coaches in its relation to performance in the sport of lacrosse, as it is responsible for high-intensity efforts for greater than ten seconds and can produce energy for up to two minutes [24]. Extended shifts or sprinting the full length of the field are primary examples of this energy system in the sport. Many coaches are familiar with the training of the glycolytic system, as it was discussed in section one. The mentality of pushing athletes to their physical limits with longer sprints, where they feel they have nothing left and are utterly exhausted is a prime example of this energy system being utilized. However, as stated in the first section, if this is the only method of training the athlete will have a disproportional glycolytic energy system compared to his oxidative and ATP/Cr-P energy systems and optimal performance will not be possible.

It is important to approach the training of this energy system utilizing a well-thought out, systematic program to ensure appropriate physiological adaptations occur, just as the oxidative system was described earlier. Although the specific training of the oxidative energy system lays the foundation for the glycolytic energy system, this anaerobic energy pathway must still be specifically trained to maximize its use within practice and competition.

As already described, the glycolytic energy system is primarily responsible for high-intensity efforts of greater than ten seconds for up to two minutes [24]. However, this energy system also leads to the production of the hydrogen ions responsible for pH changes, the same metabolites the oxidative energy system is trained to improve the clearance of [30,31,33-35]. Athletes that produce extremely high levels of energy from this energy system tend to fatigue more quickly due to the increased accumulation of these hydrogen ion metabolites [26,35]. Through appropriate training of this energy system, an athlete can learn to produce and then tolerate extreme levels of metabolite accumulation [31,35]. There are training situations where it is absolutely necessary to push athletes to their "tolerance limits," coaches simply must make sure these training sessions are implemented appropriately and athletes have been prepared to handle those stressful sessions. This will ensure the glycolytic energy system does not become disproportionate in any athlete. This energy system is important for lacrosse, but not the most important.

Even in extremely short sprints, such as those experienced in a lacrosse competition, an athlete can experience high concentrations of accumulated hydrogen ions [(24)]. Clearly this energy system, as with any of the three energy producing systems, is active at all times and important for elite-level participation in lacrosse [(24)]. The ability of an athlete to produce high-intensity bouts is greatly diminished when this energy system is undertrained, as the distance covered in the second half of competition is significantly reduced when this energy system is not available to an athlete [(24)]. This energy system relies on glycogen in order to function at a high-intensity, if glycogen is limited, this pathway is unable to produce energy at a high rate [(26)]. Therefore, nutritional factors, which will be discussed in greater detail in the next section, must be considered when preparing to train or utilize this energy system to a high extent.

The glycolytic energy system can be trained to maximize an athlete's ability to produce and tolerate high levels of accumulated metabolites [(31,35)]. This is vital in the sport of lacrosse as high-intensity efforts are a requirement to compete at the elite level. However, this energy system cannot be enhanced without first training the oxidative energy system to increase lactate clearance, as described above. Every athlete must first have a method of ridding his muscles of metabolites prior to being capable of producing and tolerating them to extreme levels.

By training these two components of performance, the ability to complete repeat-sprint efforts is improved to a greater extent as an athlete can clear and tolerate high levels of produced metabolites, ultimately increasing the ability of an athlete to go "harder for longer" and continue to perform at high-levels late into a competition [(31,35)]. However, these physiological benefits are only possible when a scientifically-backed program, which optimizes these two energy systems on an individual basis according to their specific requirements is implemented. An athlete following the workouts laid out in this Triphasic Lacrosse Training Manual, which are provided entirely in a later section, will be capable of producing extremely high levels of force and intensity, while also having the ability to recover rapidly.

2.5 The ATP/Cr-P Energy System

The ATP/Cr-P energy system plays the largest role in generating energy needs for maximal-intensity activities occurring for a duration of less than ten seconds [(26)]. Clearly, this energy system is highly active during many situations within the sport of lacrosse, such as sprinting, defending, face-off wing play, and many other scenarios. For this reason, the importance of this energy system must be well understood by all coaches.

As with any of the three energy systems, training must be completed specifically in order to guarantee maximal desired adaptations are achieved by every athlete. For the ATP/Cr-P energy system, the primary adaptations include both the power production capabilities and the ability to resynthesize Cr-P at the highest rate. Every athlete has the ability to utilize the ATP/Cr-P energy system to a high extent, and it remains speculative as to whether enhanced utilization of this substrate is truly trainable [(24)]. As sprint performance is positively related to the rate of utilization of the ATP/Cr-P energy system, it is important this energy system be developed to the highest extent [24]. However, faster sprinters, or those utilizing the ATP/Cr-P energy system at a higher rate, deplete their stores of this energy system significantly faster than slower sprinters [24]. This brings us to the second, and primary, adaptation goal of the ATP/Cr-P training block, the rate of Cr-P resynthesis. The ability to resynthesize Cr-P to a high extent varies tremendously on many factors, such as creatine and oxygen availability, as well as enzyme availability [38].

The energy source in the ATP/Cr-P energy system occurs as Cr-P is rapidly broken down into creatine and a phosphate molecule. This now free phosphate molecule can then be joined to create an ATP molecule, which is utilized as an energy source. At almost the same instant ATP breakdown begins, the Cr-P energy system begins to restore ATP in order to continue activity [26]. Thus, the rate of resynthesis of the ATP/Cr-P energy system plays a critical role in the ability to repeat high-intensity efforts. The resynthesis rate of Cr-P, following intense exercise, has both a fast and slow component and is best described by a bi-phasic manner [38]. Initially, the recovery of this occurs rapidly, with approximately seventy percent of the ATP and Cr-P being replenished in a sixty-second recovery period [38]. However, for complete recovery of this energy system up to three minutes are required [38]. During team-sport repeated-sprint exercise, where typical recovery periods are too brief to fully resynthesis Cr-P (i.e. 20–30 seconds), there is a decreasing absolute contribution from Cr-P to the total ATP production. For this reason, a coach must attempt to improve rate of resynthesis when training the ATP/Cr-P energy system. Although these rest times are not realistic for all scenarios such as training or practice, a minimum of thirty seconds recovery must be allowed when training the ATP/Cr-P energy system specifically. Without this appropriate rest time, the ability to utilize this energy system will be diminished, and training will become more glycolytic based.

As stated above, the resynthesis of Cr-P is the primary adaptation desired from the ATP/Cr-P training block. When an athlete completes a high-intensity bout, the Cr-P energy system attempts to resynthesize rapidly and prepare for another high-intensity effort. The ability to resynthesize Cr-P at a high-rate is critical for athletes competing in repeat-sprint sports such as lacrosse. The value of Cr-P resynthesis becomes apparent as the recovery curve of this energy system tracks closely with the recovery curve for power output [26]. As an athlete increases the amount of Cr-P, he increases his ability to produce high-power levels. Once again, this returns to the concept that athletes competing in the sport of lacrosse, which requires repeat-sprint efforts, must be capable of both producing high-power outputs, while also having the ability to recover at a high-rate from those power outputs.

The ability of this energy system to resynthesize Cr-P at a high level is affected by other physiological aspects, including accumulation of metabolites and oxygen availability. For this reason, the oxidative energy system plays a critical role in the resynthesis of the ATP/Cr-P energy system as this foundational energy system functions to clear metabolites and relies on oxygen to the body [24]. It is for these reasons the oxidative energy system lays the foundation for the other two energy systems and is trained first.

2.6 Nutritional Requirements to Support Energy System Training

As the understanding of the energy systems continues to grow, combined with the concept that each of the energy systems are in a constant “flux,” both turning up and down depending on intensity of exercise and the availability of substrates, it should become clear that supplying the body with appropriate nutrition is vital for performance. As it is the nutrition consumed by each athlete that supplies the energy sources, or substrates, to each energy system, it is critical athletes are getting the appropriate intakes of each substrate. Each training phase implemented for the three energy systems has clearly defined adaptation goals, and therefore requires an individualized nutritional approach to maximize these goals. Ultimately, a performance coach has the ability to control the amount of "flux" each energy system experiences, or turn certain energy systems "up" or "down," by incorporating specific nutritional protocols. However, as this is a manual on training, rather than nutrition, only basic, easily applied principles for each phase will be covered in this section.

The oxidative energy system adaptation goals ultimately include increased oxygen availability, increased mitochondrial density, and improved efficiency of the body. As described previously, these adaptations allow the body to recover faster, leading to the ability to compete at higher intensities for a greater duration. The training methods, which will be described entirely in section four of this manual, include low-intensity, high-volume training. Adaptations to this energy system are maximized in a reduced glycogen state. This has commonly been termed the "train low" strategy. This low glycogen state can be achieved by reducing carbohydrate intake, particularly prior to oxidative training sessions. Notice this statement says reduce, not remove. There are major implications of attempting to completely remove carbohydrate from an athlete's diet. Each athlete must be considered as an individual throughout this nutritional approach, as each will require different amounts of carbohydrate to function appropriately in everyday activities. This aspect absolutely cannot be overlooked. For this reason, coaches should always err on the side of caution while implementing this nutritional strategy.

By reducing the carbohydrate intake of an athlete while they train, the body is required to rapidly mobilize and then utilize stored energy substrates within the body, thus increasing the efficiency of the body when using these sources at low-intensities. However, it is important for coaches to understand this training method will reduce an athlete's ability to produce repeated, high-intensity bouts. Therefore, the "train low" strategy should only be implemented on training days in which oxidative adaptations are the top priority. The appropriate use of these energy sources through training will maximize the ability of the oxidative energy system adaptations and increase efficiency to the highest extent, which will play a vital role during the brief recovery periods seen in lacrosse late into competition.

The glycolytic energy system, as the name implies, requires glycogen as an energy substrate. As the goal adaptation of this energy system is the "tolerance" of produced metabolites, the "train low" strategy would be inappropriate. This is because the glycolytic energy system would never be activated to the fullest extent, and therefore never produce extreme levels of metabolites.

Proper stores of muscle and liver glycogen, through the consumption of carbohydrate, allow the glycolytic energy system to be activated to the fullest extent, ensuring metabolites are produced and then "tolerated" to the highest extent. It is important to not underestimate the ability of an athlete to utilize glycogen in high-intensity situations. An elite athlete has the ability to burn up to 100 grams of glycogen in a single 400 meter, all-out sprint, with the body only having the storage capacity of 400 grams of glycogen at one time. At this rate of utilization, an athlete would only be capable of completing two or three quality 400 meter runs per day before the body began to feel sluggish due to low glycogen stores. For this reason, the importance of carbohydrate, as well as the timing of intake are critical for the maximal improvement of this energy system. Athletes with the goal of increasing their glycolytic energy system to the highest extent must ensure they are consuming high-levels of carbohydrate, especially prior to training. This will allow the body to activate this pathway to the fullest extent, leading to optimal adaptations to this energy system and the ability of the body to "tolerate" metabolites.

As the ATP/Cr-P energy system training is completed at the highest intensities, it is again critical the athlete has enough stored substrate to continue to produce these efforts. The ultimate adaptation goal of this energy system is the resynthesis of Cr-P at a high-rate after its utilization to create a usable energy source for the body (ATP). For this reason, the adaptations are achieved through appropriate work:rest ratios, rather than nutritional supplementation. Even though the ATP/Cr-P energy system is only capable of supplying energy for a short amount of time, this energy system, as described earlier, still requires significant recovery time to be repeatedly utilized to a high extent. It should be noted again that this energy system is improved to the greatest extent by maximizing the oxidative energy system, as recovery time and oxygen availability will be increased.

Many coaches and athletes supplement the ATP/Cr-P energy system through the addition of creatine. Creatine is well documented as a performance enhancer in short, high-intensity situations and has the potential to fit into this training phase. Through the addition of creatine, an athlete has the ability to increase storage levels. The increase in creatine levels will allow an athlete to produce greater power in short, high-intensity bouts. However, the supplementation of creatine will not necessarily increase the rate at which creatine is paired with phosphate. These adaptations to the ATP/Cr-P energy system occur due to the repeated, high-intensity bouts completed in training, which will be shown in section four of this manual.

Ultimately, coaches must ensure each athlete has the appropriate stores of energy substrates depending on the adaptation goal of the current training phase. Only when this level of detail is considered is true, optimal performance possible from each of the three energy systems.

Nutritional strategies must also be applied during competition. As lacrosse is played at high-intensities and utilizes each of the three energy systems, all three must be fueled appropriately. Glycogen loading and resynthesis are the primary methods implemented in order to prevent performance decrements during competition [(26)]. This can include halftime nutritional strategies to improve second half intensities during play. This simple method can make a large impact on the outcome of a competition, as players in a reduced state of glycogen covered significantly less distance than those with an appropriate nutrition halftime approach [(26)]. It is important to not overlook these potential performance boosters, as they may determine the outcome.

2.7 The Combination of the Three Energy Systems

When the three energy systems are each adapted to the highest level, performance in the sport of lacrosse, which requires the ability to repeatedly produce sprint efforts, can be optimized. Any athlete training and competing in a repeat-sprint sport must have the ability to both produce high-power outputs, while also recovering from them in the most rapid fashion.

On one hand, studies have shown a strong positive correlation between initial, high-level outputs and repeat-sprint performance. However, others have shown that athletes with extremely high-level outputs in the first sprint show the largest reduction in later sprints [(26)]. It is important for athletes to be capable of producing high-level outputs, or “turn up” their ATP/Cr-P and glycolytic systems, but it is also important the athlete is able to recover quickly from this output. Put simply, some of your most explosive, or twitch, type II athletes have trouble producing in the fourth quarter due to their inability to recover from these high-level outputs. Consider the difference between an elite level 100m sprinter and a marathon runner. The sprinter is good for one extremely high-level bout, while the marathoner is capable of maintaining his speed for an entire 26.2 miles. The goal of a performance coach for a lacrosse athlete is to create an athlete that can produce the explosive, high-output efforts of a sprinter, while also having the capability of recovering and repeating those speeds continuously, like a marathoner. To create an elite level repeat-sprint, or hybrid athlete, a coach must create the appropriate mixture of these two elite level athlete types.

When an athlete has appropriately trained each of the three energy systems, which is programmed specifically in the Triphasic Lacrosse Training Model, the specific sprint requirements described earlier (sprint duration, number, and recovery time) are able to be met and surpassed by every athlete for both practice and competition.

A repeat-sprint athlete's energy systems can be broken down simply into a "sink and drain" concept. With every high-intensity effort complete, the "sink" is filling up; the amount the sink is filled depends upon the intensity and duration of the effort. This represents the accumulation of metabolites. As the sink continues to fill up, the body will reduce its ability to produce high-intensity efforts to prevent an overflow. The sink also has a drain, which represents the ability to clear the accumulated metabolites and produce energy from them. The "tank" represents ability of an energy system to produce energy. Clearly each of the three energy systems are represented within this simple example, along with the potential adaptations from training when programming is implemented as laid out in this manual.

Figure 2.4 below represents the pre- and post-training adaptations of each energy system when programmed according to their layout described above. By training the oxidative system, oxygen utilization, mitochondrial density, metabolite clearance, and efficiency are improved to the highest extent. These adaptations through the training of the oxidative training increase the "tank" size for the aerobic energy systems, or the ability to produce energy via the oxidative system. This training also increases the ability to clear accumulated metabolites, or increases the size of the "drain" and the ability to produce energy from them, which allows repeat-sprint efforts to be completed.

Glycolytic training improves the tolerance of the accumulated metabolites, or the "sink" is increased in size. An athlete has the ability to produce a greater number of intense efforts prior to his sink filling up. The body does have the ability to increase its "tank" size, although this is completed through nutritional strategies more than specific training adaptations with this energy system.

Through increasing the abilities to complete repeat-sprint efforts, the resynthesis of the ATP/Cr-P energy system can then be improved. When the energy systems are trained and work in combination, all athlete will have the capabilities to produce greater amounts of energy by increasing their "tank" size, "tolerate" increased levels of metabolite by increasing their sink size, and finally increase their clearance of those metabolites by increasing their "drain." Ultimately, this leads to the ultimate goal of repeat-sprint sports, which is to produce high-power outputs while also having the ability to recover at the highest rate possible.

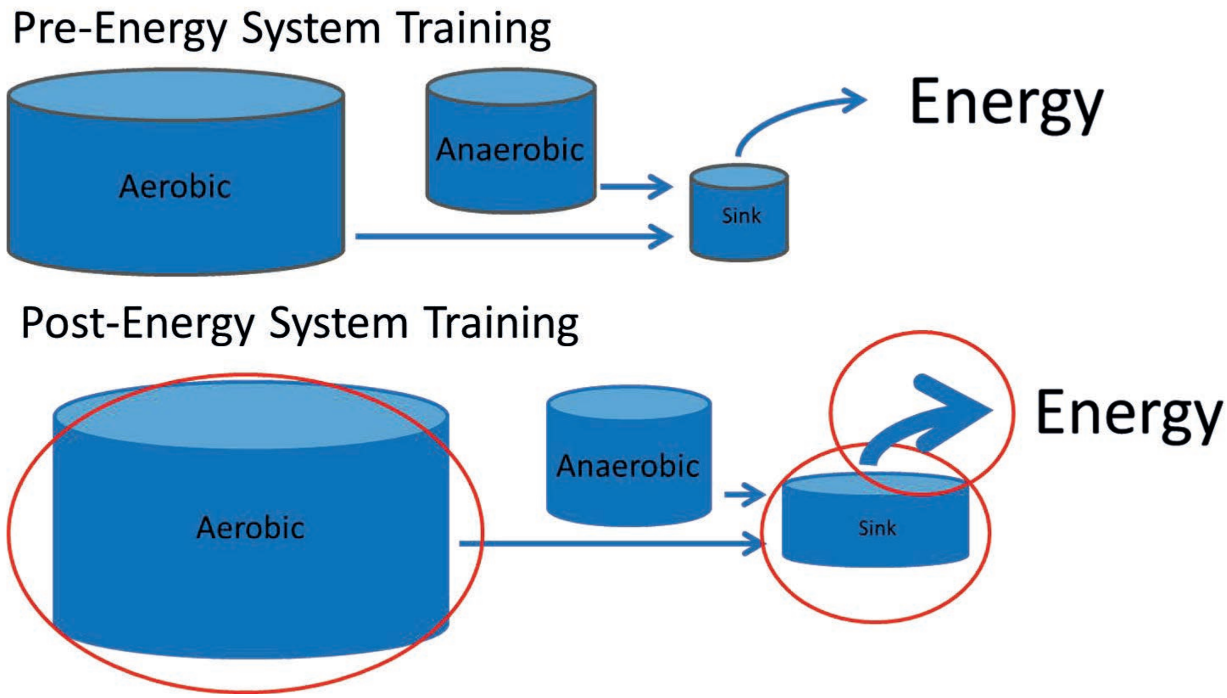

Figure 2.4 - The Effects of the Triphasic Lacrosse Training Model on Energy System Development

Ultimately, all coaches must work to understand the requirements of the sport of lacrosse to the finest details. As the knowledge and understanding of these specific energy system requirements of this sport continue to grow, the ability to periodize and program an optimal training plan is improved. Each of these systems play a vital role in lacrosse and must be trained appropriately before other performance qualities, such as strength, power, and speed can be improved to the greatest extent. With the training of the energy systems as laid out in the Triphasic Lacrosse Training Model, athletes will be able to perform with a higher quality (faster sprinting speeds, more accurate shooting, improved cognitive functioning) for a greater duration of time. The Triphasic Lacrosse Training Model considers each of these energy systems and appropriately trains them according to their needs based on the most up-to-date research and data.

2.8 Biomechanical Requirements of Lacrosse

As a performance coach, the goal remains to prepare every athlete for the sport being completed, in this case lacrosse. The specific requirements of lacrosse have been considered in regards to energy system development, which must be completed first, as an athlete must be capable of providing the body with the energy required to be successful in sport. This is a requirement of any repeat-sprint sport. However, lacrosse also has biomechanical requirements that must be trained for and improved in a highly specific manner. These biomechanical requirements include acceleration and sprinting, along with the skills of shooting, passing, and checking must all be maintained at a high-level, as they are the most specific skills to the sport. Each of these skills will be broken down into their basic components and described according to how they are trained in the Triphasic Lacrosse Training Model.

It is important every coach remember the goal of this training manual is to prepare an athlete for the physical aspects of lacrosse, not necessarily the skill learning involved in these sport specific tasks. For example, a performance coach must prepare the athlete's body to complete the repetitive skills of sprinting and/or shooting. However, it is not the objective of this manual to improve an athlete's shooting efficiency, which remains the job of the sports coach.

These primary biomechanical skills must be applied at nearly all times throughout training, progressing from general to more specific as the lacrosse competition season approaches. This once again returns to the principle of transfer of training, described in section one. Select specific desired skills, or the six physical performance qualities along, and maximize them according to their requirements in lacrosse.

2.81 Acceleration, Max Velocity, & Change of Direction

Just as the energy system training laid the foundation for high-quality work, the ability to accelerate, sprint, and change direction in the most powerful, efficient manner is required before an athlete can utilize any other skill on the lacrosse field. That does not mean an athlete cannot improve other skills such as shooting or checking, which are important for high-level performance. However, an athlete will not be able to utilize these skills of shooting or checking to the greatest possible extent if they are not able to move efficiently on the field.

The skills of accelerating, max velocity, and change of direction require intricate, constant coaching. That being stated, this manual will cover only a few of the basic requirements to coach these to a high-degree. At the most foundational level, an athlete must be able to maintain appropriate body position and transfer high-amounts of force into the ground.

Acceleration, is ultimately based around the ability to maintain a forward angle while keeping the hips from falling behind. This position, displayed in Figure 2.5 below, will look like a falling plank, with the body in a straight line from the extended back leg up through the hips to the neutral position head. By keeping the hips in proper position, power and transfer of force is optimized throughout the kinetic chain used in sprinting by allowing maximal knee drive to be achieved. Knee drive action should work in a piston motion with the ball of the foot striking behind the hip at full extension. An understanding of simple biomechanics proves the behind the hip ground contact propels the athlete forward while maintaining the desired acceleration angle. Training of acceleration is associated typically with 10 yard bursts and is highly related to starting strength of the athlete. These short distance bursts are used to ensure acceleration is the only quality being focused on during the session. As an athlete improves his ability to transfer force into the ground, an appropriate angle can be maintained, which maximizes the acceleration phase of running.

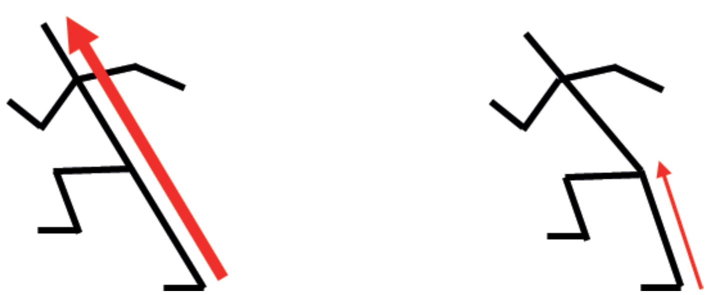

Figure 2.5 - Proper position of the hips "locked in" during acceleration vs. improper position with the "hips breaking"

As described above, the ability to transfer high amounts of force into the ground allows the hips to be locked into a good position while “falling” forward. This angle training is crucial to maximizing knee drive, thus increasing ground reaction forces. When the hips “break,” force is lost by the increased vertical output needed to maintain the position. This leads to less force production and less distance being covered with each step. Training examples for acceleration angle, such as broad jumps and wall-drills will be provided in section four of this manual. Elite sprinters can accelerate with a greater angle because they have learned the skill of applying more force to support that angle. A coach must be careful when coaching this angle specific training that the hip positioning of an athlete is not “breaking.” If the hips are breaking the athlete does not currently have the force producing capabilities to support running at that angle.

Maximum velocity training is the ability to maintain proper posture and technique once the acceleration phase has been successfully completed. The ability of the foot to strike directly beneath the hip is of upmost importance to ensuring minimal breaking force is applied through the ground. Throughout technique work shin angle can be used to determine much of the force application direction. If the shin is angled back toward the hip, the athlete is reaching rather than cycling through. This will not only create a braking force, but also increases the likelihood of a hamstring injury occurring.

It is important that coaches realize the amount of time spent for most team sports in maximal velocity running is relatively small compared to the time spent in the acceleration and change of direction phases of running. Even though this skill is not used often it is important to not overlook the importance of its training. Teaching an athlete how to properly cycle while maintaining an upright posture and strike directly below the hip has the potential to make the difference on an explosive play in any game. Maximal speed is dictated not only by ground reaction forces, but by the ability to produce that force rapidly. It is important to realize speed is a learned quality and must be trained appropriately to see improvements.

An example of cycling the leg through to ensure foot strike is below the hip can be seen below in Figure 2.6. The understanding of shin angle and its correlation to force application direction is vital to cueing athletes through these first two phases of running.

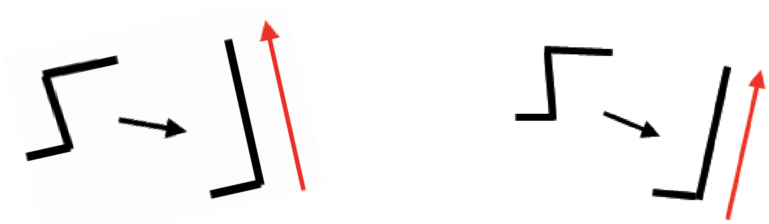

Figure 2.6 - Proper position of the foot strike beneath the hip vs. reaching with a “braking force”

Change of direction training is improving the ability of athletes to decelerate, or absorb force as they come to a stop, and then reapply that absorbed force in the desired direction, all while utilizing safe mechanics to reduce the likelihood of injury. The eccentric method of training will work in conjunction to improve this ability as no athlete can produce what he cannot absorb in regards to force. Even with this specific training block in the weight room, it is important the skill of absorbing force is applied to the specific means each sport requires. These specific means can range from sprinting and changing direction, shuffling, cross-over running, etc. Ultimately, the ability to control your body and the forces while decelerating, and then redirecting those forces through the use of proper edge work of the foot in the desired direction will determine the success of this ability in sport.

Clearly, the shin angle of an athlete determines the direction of force an athlete produces. This can be seen in acceleration, sprinting, and the ability to change direction. Body positioning is critical in achieving these appropriate angles. However, the commonly overlooked ankle plays the biggest role in the ability of an athlete to achieve these positions. The ankle absolutely cannot be overlooked in training a lacrosse athlete. The ability of an athlete to dorsiflex, evert, and invert through his foot and ankle creates the possibilities of driving shin angle to accelerate, sprint at high velocities, and change direction while maintaining a low hip angle. The movement of the ankle in these different planes of motion are improved through the implementation of 3-D training, discussed in an earlier section.

The ankle must not only have the appropriate range of motion in all three planes, but it must also be trained to optimize the transfer force through the body. As described in section one, the foot plays a vital role in ensuring the loading of the glute with every step. Only when an athlete achieves appropriate dorsiflexion, subtalar eversion, and tibial rotation can the glute be loaded to the highest extent, leading to powerful and efficient movement.

All coaches understand the basic premise that increased force production in the lower limbs is correlated with power production and improved running speeds. This idea is well accepted because it is absolutely true. Rapid force absorption, redirection, and production through the lower limbs are vital for the majority of athletic competition movements, particularly in sprinting and change of direction. However, this mentality commonly leads to an oversimplified view of the forces occurring within an athlete's body. It is more important to realize that the legs function as a chain system, each relaying force from one link to the next. Regardless of how strong some of the links may be, the maximal force producing capability will always be determined by the weakest link. This principle is well understood throughout the training world, yet the ankle and foot are commonly left untrained, even as the muscles around the hip and knee are continuously trained. Ankle and foot training must be completed appropriately to guarantee maximal force production capabilities are achieved in competition.

It is well understood, discounting inefficient technique, the athlete who is able to produce the highest forces into the ground will cover the greatest distances in the shortest amount of time. Simply put, increasing power means increasing velocity and ability to change direction, which is the ultimate goal of many athletic events. This simple idea has been applied by performance coaches for many years and forms the foundation of many training principles. Running at maximal speeds is a simple example that requires forces to be translated from the hip down through the knee and finally through the ankle and foot before it is applied into the ground, which leads to the propulsion forward in running. These aspects of the legs (the hip, knee, ankle, and foot) form a chain of force production, with any "weak link" leading to a reduction in the force production capabilities.

Through the use of well-rounded training tactics, the force-producing capabilities of the major muscle groups, specifically those correlated with the hip and knee, are typically well trained. Particularly in Triphasic Training these major muscles are well trained in the actions of eccentric, isometric, and concentric means. This training strengthens the major force-producing muscles of the legs in the most efficient way possible, leading to maximal force absorption and production capabilities. However, the majority of training programs leave the training of both the ankle and the foot in an untrained, or at least less than optimal, state. This lack of training or mobility, based on the lower limb chain, could lead to loss in overall power development as the ankle or foot are not capable of absorbing and applying the high levels of forces produced by the now trained hip and knee.

Based on the requirements of lacrosse, specifically the distance covered with each high-intensity effort, the ability to accelerate, run at high-speeds, and change direction at a high-rate is imperative to being successful on the field. By training every athlete to maintain proper position and transfer the greatest amount force through his kinetic chain, the power produced and efficiency of running is maximized.

Each of these skills, acceleration, max velocity, and change of direction, require high-quality training, which allows an athlete to learn each to the highest extent. The programming implemented for each of these aspects required, as well as the specific ankle training completed, in the sport of lacrosse will be provided in section four of this manual.

2.82 Shooting

The skill of shooting and stick work should remain a top priority for all lacrosse athletes as this is a primary ability that determines success on the field. However, as a performance coach, one must focus on the muscular requirements of every shot and prepare every athlete for the high-volume of shooting. Athletes must be capable of producing high force levels from their hips and then transfer it through their kinetic chain to their trunk and finally shoulders where the ball is released. Every athlete must also be capable of decelerating this violent movement safely and appropriately to reduce injury likelihood. When the biomechanics of the lacrosse shot are well understood, programming can be completed to increase both the velocity of the shot as well as the ability to safely execute the increased volume of shooting that occurs in practices and competition.

Coaches must also understand that shooting remains an open-skill. This means the shooting motion is constantly slightly changed according to the current situation, such as a defender being in front of the shot, the goalie positioning, or body contact occurring. A player must be able to adjust his shot to his current situation. This fact only reiterates the fact that a performance coach must focus on the biomechanical requirements of the shot in lacrosse, and not attempt to train an athlete's exact shot.

The lacrosse shot can be completed in an overhand, sidearm, and underhand shot [39] and consists of six phases. These phases include the approach, crank-back, stick acceleration, stick deceleration, follow through and recovery [40]. Although the lacrosse shot is an open-skill, these six phases remain relatively consistent during the completion of this skill. However, the exact completion, duration, and position and execution of the shot will change based on each situation encountered. The different shot types available to an athlete, as described above, include the overhand, which is the most common shot performed, sidearm, and underhand shot. These different shot types may not all follow each of the six phases laid out above exactly as listed, thus the phases of shooting should be used merely as a guideline for coaches [40].

The approach phase in a lacrosse shot begins with the athlete taking several steps towards the goal with the intent of shooting [41]. Once again the skill of shooting is an open-skill, meaning these steps can be taken in almost any fashion at any position on the field, such as off of a dodge, running ahead at the goal, or even while running laterally across the goal. These different approaches and positions on the field lead to these steps completed in the initial phase of the lacrosse shot to be completed in a straight ahead, laterally, or even a cross-over hopping motion [41]. This first phase concludes when a player plants his "drive leg," or the back leg that pushes the body forward, into the ground [41]. For example, in a right-handed shot, the drive leg is the right leg. It is this drive leg that is responsible for the creation of power through the extension of the back hip, knee and ankle, leading to the transfer of force through the trunk of the athlete in a rotational pattern. This is the force-producing leg in the lacrosse shot and plays a major component in producing high-velocity shooting. Once again the force producers are the hips, with energy being transferred outwards. This returns to the principles of Be-Activated and the creation of explosion rather than implosion in athletes. However, this first phase ends as the drive leg is planted. Thus, the power creation, transfer, and deceleration will be described in the remaining phases.

The second phase of a shot in lacrosse is the crank-back phase, but it has also been termed the wind-up or cocking phase [41]. This phase consists of the movements required in order to prepare for stick acceleration [41]. These preparation movements ultimately begin with the planting of the drive leg and end with the top arm reaching maximal elbow flexion [41]. However, for simplicity, this phase has been subdivided in phases A and B [41]. Phase A deals with the lower extremities while Phase B deals with the upper extremities.

As Phase A of the crank-back phase in the lacrosse shot deals with specifically the lower body actions, it begins with the drive leg contacting the ground and is terminated when the lead leg makes ground contact [41]. As described earlier, it is the drive leg which creates the rotational power produced from the hips and is translated through the kinetic chain up to the arms ultimately dictating the velocity of a shot. The lead leg is also critically important for the velocity of a lacrosse shot. As the drive leg produces the power through extension of the hip, knee, and ankle, the body begins to rotate. However, it is the planting of the lead leg that is responsible for the absorption of this produced force of the drive leg and ultimately creates the rotation of the hips, trunk, and upper body in the shot. The greater the ability of the lead leg to rapidly absorb the hips, the greater the shot velocity. Think of a shooter like a whip, the drive leg produces high levels of force that the lead leg must decelerate as rapidly as possible. This leads to a greater differentiation between the hips and the trunk and thus greater transfer of energy. The greater force a shooter is capable of producing from the drive leg and then immediately decelerating with the lead leg, the greater the velocity of the shot. The lead leg sets the stage for the trunk to rotate through at the highest velocities. More force absorbed through this leg allows more force to be transferred through the body, leading to a greater shot velocity.

Phase B in the crank-back phase deals with the upper extremities and their placement into a wind up position to prepare for the acceleration of the stick [41]. This phase begins with the lead leg ground contact and finishes when maximum elbow flexion is achieved by the top arm [41]. When utilized correctly by an athlete a stretch-shortening cycle (SSC) response will be achieved in this phase, leading to a maximal and efficient transfer of force through the kinetic chain.

Stick acceleration is the third phase of the lacrosse shot and is an extremely short occurring phase [41]. This phase begins with maximal elbow flexion of the top arm and finishes with the release of the ball. During this briefly occurring phase, the athlete experiences a rapid extension of the elbow and forward acceleration of the stick. The trunk will execute a rotational pattern based on the hand an athlete is shooting with and then finishes with the ball being released [41].

At this point a coach may consider the lacrosse shot to be completed, as the ball has been released. However, as the athlete has just produced a large amount of power through his body. It is critical he has the ability to decelerate. The stick deceleration phase begins with the release of the ball and will vary in technique based on the type of shot utilized by the athlete [41]. It is in this phase that the ability to decelerate the stick and shoulder safely play important roles. Just as a pitcher in baseball must slow his arm down, a shooter must do the same. However, in the case of the shooter, he must also be capable of decelerating his lacrosse stick, which adds even more toque on the shoulder joint.

The follow through phase also deals with deceleration, in this case the slowing down of the body. This phase terminates with the completion of trunk rotation [41]. Once an athlete has slowed down the head of his stick, he must then be capable of dissipating the forces experienced throughout his body. In order for an athlete to compete safely in the sport of lacrosse, he must be capable of decelerating his body rapidly. This task of slowing the body down is completed in the follow through phase.

Finally, the lacrosse shot ends with the recovery phase [41]. It is during this phase the shooter is preparing to complete his next task. It is hopefully celebrating as a goal has been scored from the executed shot. However, it could be running, shuffling, or other methods to either continue the offensive set or get into position to prevent the clearing of the ball by the opposition. As the sport of lacrosse is a constant reaction to players on the field, this phase will never look the same as an athlete prepares to complete his next movement in competition [41].

Many coaches will argue the importance of the "core" in the lacrosse shot. The core is important for rotational movement [42]. However, it is the hips that are the primary force producers in the shot, while the core acts as a translator of this power from the hips to the shoulders [42]. The primary role of the core is actually to "stiffen;" this can be seen as there is relatively zero rotation through the core during the lacrosse shot [42]. As the core stiffens and creates stability, higher levels of force are able to be transferred from the hips up to the shoulders, it is the serape core that assists with this force production and translation [42]. The serape core is also responsible for the deceleration of the rotation during the lacrosse shot [42]. This skill is critical in preventing injury from occurring during high-volume shooting periods and can be specifically trained. The core's ability to stiffen is continuously fine-tuned to enhance the utilization of the SSC through its appropriate use and training, which is considered throughout the Trphasic Lacrosse Training Model [42].

For more information on the serape core, click here.

The shot in lacrosse is highly technical and is a skill that must be executed to a high-degree if elite status is to be achieved by an athlete. As a performance coach in the sport of lacrosse, it is important to train specific requirements from this skill. These requirements include the ability to produce and decelerate high-levels of force throughout the entire kinetic chain utilized in the shot [43]. The drive leg and hips produce the power which is transferred through the core and up through the lacrosse stick. The lead leg, core, and shoulder musculature must then safely decelerate the athlete to prevent any possible overload injury [44].

The velocity of the shot is ultimately determined by sequential activation of the utilized segments [43]. The drive leg produces the force through the hips, which the lead leg then decelerates. That energy is transferred through the core musculature which begins to rotate. Then and only then does the shoulder and stick begin to move forward as the ball is accelerated toward the net. Energy must be efficiently transferred from the hips through the upper body and shoulder as it is this skill that limits the velocity of the shot [39,43]. As thoroughly presented in section one, the hips must serve as the primary force generators, creating an explosive, rather than implosive athlete [39]. It is also critical an athlete learns to shoot utilizing both hands. This will prevent one side of the body becoming over-developed, reduce injury likelihood, and will also allow an athlete to become more well-rounded in the sport [45].

This sequential pattern required in shooting can be seen as higher-velocity shooters had maximal pelvic rotation earlier in the shooting motion [39]. Therefore, there was a greater differentiation between the shoulders and hips, leading to an increased utilization of the SSC [39]. Think of the entire body functioning through a shot like a rubber-band. As stretch is placed on the rubber-band, the force produced is greater as it is released. The same applies to the body. As a tissue is capable of decelerating force and experiences stretch, the body is then capable of producing greater amounts of power as it is released and shortens. This forms the idea of the SSC, which is a foundational principle implemented in the Triphasic Lacrosse Training Model. This concept will be discussed in great detail in section three of this manual.

The greater power output an athlete shooting can generate, during the acceleration phase of training, and then decelerate almost immediately, the greater velocity that player will be capable of producing. It is for this reason lacrosse athletes must be trained to both accelerate and decelerate their motions at the highest velocities. Each of these aspects required in high-velocity shooting are considered tremendously throughout the Triphasic Lacrosse Training Model. Principles to develop a high-level of force, transfer it through the entirety of the utilized kinetic chain, and then decelerate safely is of the upmost importance for all skills in the sport of lacrosse. This skill and its implementation will be demonstrated in section three of this manual.

2.83 Passing

Passing is another skill critical for successful performance in lacrosse. Without the ability to pass effectively, a team will lack the ability to create quality-scoring chances or even clear the ball from its defensive end of the field. The pass, although it looks similar to the shot, only requires two phases. These two phases include the draw and the release [44]. In these two phases, the stick is drawn back and then accelerated forward to release the ball in the desired direction. Just like the shot, this is an open-skill that is constantly adjusted to the situation being experienced. Different passing methods include the overhand, underhand, side-arm, and backhand passes [44]. However, regardless of the technique utilized, the primary motion of the lacrosse pass is similar to the shot described above. The force to complete the pass is generated initially from the hips and transferred to the trunk, leading to a rotation and creating angular velocity as the ball is released. For this reason, every athlete must be trained to transfer energy through his chain as efficiently as possible.

2.84 Checking

The skill of checking is another aspect that every athlete must be capable of completing. Checking in lacrosse is a violent, physical force. Thus, athletes must be trained to withstand and deliver these body blows on a daily basis at practice and competition. Checking is utilized primarily in a defensive situation in order to prevent an attacking athlete from gaining a position in which scoring likelihood increases. At this point all coaches should understand the total body action of any movement must begin in the hips. Checking is no different as an athlete must utilize his hips to extend and transfer force up through his shoulders and arms. This skill requires both strength from the hips and legs to execute a check, while shoulder stability is also maintained to guarantee the safety of the athlete.

2.9 The Triphasic Lacrosse Training Model & The Biomechanics of Lacrosse

Each of these skills required to be successful in the sport of lacrosse are considered and trained to ensure every athlete will be equipped to compete at the most elite-level possible. An athlete's strength, utilization of the hips to produce force, and ankle capabilities will be improved through the Triphasic Lacrosse Training Model. When programmed correctly, this specific strength will allow greater acceleration, sprinting speeds, deceleration and change of direction ability. Specific strength also increases a lacrosse athlete's velocity of shooting and power produced during the execution of a check. Ultimately, this leads to a more powerful, efficient, and resilient lacrosse athlete, one that can produce extreme levels of power in the specific movements and skills required in lacrosse, while simultaneously executing these movements in the most efficient manner possible. Only when an athlete is trained in this manner is optimal performance possible.

2.10 Training Based on Position Specific Requirements

Each position in lacrosse is highly specialized, and therefore, requires individualized energy system, biomechanical, and other specific skill set training. The positions considered in this section will be the attack, midfielders, defensemen, face-off specialist, and goaltender. It is important to note there are also different styles of play even within the same position. There are attack players of both size and strength as well as athletes that rely on speed and explosiveness. The size-based attackman relies on his ability to power through a defender and physical presence to create scoring chances, while the smaller attack athlete must rely on speed and quickness to create offensive opportunities. Defenders can be of varied sizes as well. The smaller, more mobile defenseman is required to cover the explosive-type attack player, while the larger, strength-based defender plays directly against the more physical attack athlete. Each of these players would require slightly different training methods to maximize his individual needs. However, as stated above, this individualization requires immense and intricate planning and execution at all times. As a performance coach, the goal is to create an optimal athlete based on his individual requirements in lacrosse. This section will present a few of the primary differences between each of these positions.

2.101 Attack

The attack position requires quick, explosive movements and efficient agility or change of direction. Athletes competing in this position tend to rest and recover between possessions and occasionally during the offensive set, depending on the scheme being executed. An attack athlete must be a skilled shooter with accurate passing. He must also have an improved ability to absorb body contact and continue to control his body. These requirements allow an attack player to focus more on production of force and rapid movements as he tends to receive more recovery than other positions. This fact should not diminish the importance of the oxidative energy system for the attack position, as attack athletes typically play the entire game and the ability to produce these high-intensity efforts late in a competition is vital for success. Strength is also an important quality for an attackman, as his ability to absorb body contact and execute repeated shots without placing his body at risk of an injury is of great importance. Strength also lays the foundation for speed, which is critical for an athlete to be successful in this position. The ability to beat a defender one-on-one in order to create a scoring chance or draw a slide to open up a teammate will separate the elite lacrosse athletes.

2.102 Midfielders

A midfielder requires significantly greater endurance and repeat-power than the attack position. This is due to a midfielder being responsible for covering much greater distances than any other position on the field. A midfielder will frequently cross midfield, can run the entire length of the field, and play both offense and defense. A feat no other position completes consistently. In a highly-specialized team, midfielders must also be prepared to run on and off the field immediately based on a transition from defense to offense, or vice-versa. Unlike the attack or defenders, a midfielder competes in shifts. Taking an average of nine to fourteen shifts per game [46]. For this reason, midfielders must achieve the highest levels of fitness and repeat-power. Their glycolytic energy system must allow them to tolerate the high-intensity metabolites produced during each shift, while their oxidative energy system must be maximized to allow the most rapid recovery possible between each shift. Their power production must also be high to match the demands of sprinting with an ability to repeat these efforts throughout every shift they complete. The midfield position is considered to be the most physically demanding and pivotal role due to its link between the attack and defenders.

2.103 Defenders

Defenders need size and strength more than either the attack or midfield positions. However, these athletes must also be capable of producing rapid movements in order to prevent a scoring chance from being created by the opposition. These athletes must also be highly reliable and capable of anticipating play as well as recovering from a defensive breakdown. Athletes playing the defensive positions are typically the largest and most physical on the field, relying on their footwork and checking abilities to prevent their opposition from creating a scoring chance. Strength and size also play important roles in the skill of picking up loose ground balls. An athlete that is able to absorb contact while maintaining focus on technique and the execution of picking up a ground ball will be a valuable asset to his team.

2.104 Face-Off Specialist

The face-off specialist is one of the most overlooked yet important positions in the sport of lacrosse. Possession time commonly dictates the winner in competition, and this position has the ability to affect the amount of possessions in the most direct manner. The team with an exceptional face-off specialist will have a clear advantage as possession time will increase dramatically [46]. The face-off athlete requires quickness, explosiveness, strength, and the ability to recover quickly. Quickness is required to execute the clamp maneuver, which is the most successful and widely utilize method [46]. Explosiveness and strength are required in a scrum and breaking away from the group if possession is achieved. Another important aspect commonly overlooked for the face-off specialist is the ability to recover quickly, particularly in a high-scoring competition. This athlete must have the ability to repetitively produce quick and explosive efforts in an attempt to guarantee possession for his team.

Each face-off is essentially a three on three battle including the face-off man and the two wings from each team. Until possession is achieved by one of these battling athletes, the attack and defenders must remain on their respective side of the restraining line. Ultimately, the goal of the face-off specialist and two wings should be to either gain possession or create room for a teammate to achieve possession of the ball.

2.105 Goaltender

The goaltender is much different from the other four described positions. This position still requires the six physical performance qualities, but to a much different extent. Although he does not cover the same distances as a field player, a goaltender must still have the physical capabilities to produce high levels of power to move explosively in order to save potential goals from being scored. The mental focus and reactive abilities of the goaltender are critical for success in a game setting. Appropriate energy system training will allow a goalie the ability to continue to mentally focus and execute rapid, explosive movements throughout the entire duration of the competition. As saves are executed in extremely brief time periods, the ATP/Cr-P energy system is critical, as well as the oxidative energy system to maximize recovery abilities. As goaltenders commonly end up in awkward positions, proper mobility and range of motion are also important in order to reduce any injury likelihood. Each of these required aspects to be successful at the goaltender position is covered through the Triphasic Lacrosse Training Manual.

2.11 The Combination of Energy System and Biomechanical Training to Create the Triphasic Lacrosse Training Model

Although there are differences in the requirements of each position, it should be noted that the individualized training based on position requires significant planning and proficient execution. For this reason, the programming presented in section four will represent a model from which all lacrosse athletes, playing any position, will achieve performance improvements. The program demonstrated follows the Triphasic Lacrosse Training Model, which considers each of the six physical performance qualities required of elite performance in lacrosse.

Ultimately, the job of the performance coach is to prepare athletes for the rigors experienced in the sport of lacrosse. This can be completed by carefully considering and implementing the stress applied and sound injury reduction protocols, and by creating a high-level of transfer of training. Each of these principles are discussed in section one of this manual. However, these can only be accomplished when the energy system and biomechanical demands of the sport of lacrosse, and even those of each position, are understood to the highest extent.

By considering each of the energy systems' roles in a repeat-sprint sport, such as lacrosse, the number of sprints, their duration, and typical rest time a protocol can be created to maximize these specific energy systems. Once these needs have been met, biomechanical requirements including sprinting, shooting, passing, and checking can all be maximized to the greatest levels through programs completed in training. The Triphasic Lacrosse Training Model considers each of these requirements specific to lacrosse to create the most systematic training program available. The Triphasic Lacrosse Training Model takes into account multiple programming aspects and is designed to train each of the six physical performance qualities to the highest extent without negatively affecting any of the other five. Application of these principles allows optimal performance to be attained and maintained by every athlete. Each of these applied principles of training will be described in the upcoming section.