Introduction to Strength & Conditioning
Introduction – **Fitness vs. Athletic**

In a comedic dialogue between an aspiring triathlete and a down-and-out baseball player, the endurance athlete introduces himself looking for reciprocal camaraderie: “Looks like we have a common bond, we’re both athletes.” The baseball player replies with a harsh chuckle, “I’m a real athlete, I don’t try to be the best at exercise. I compete at a sport.” This banter embodies the interesting dynamic between exercise and athletic performance. When the body encounters a routine physical challenge, it makes system adjustments to become better in the environment. In some cases, the environment is consistent and predictable, while in others it has varying conditions and unforeseen challenges. Either way, there is no question that human performance is improved when general and activity-specific stress is routinely and appropriately applied in a manner that promotes system adaptations.

Regardless of the nature of the competitive endeavor, there are training techniques that will enhance the performance of an athlete. Each sport has specific aspects that make it unique; which explains the concept of sports aptitude, where certain individuals are born with the genetic infrastructure to succeed at specific activities beyond that of others [1,2,3,4,5,6,7,8]. For instance, professional baseball players demonstrate exceptional visual acuity and reaction time, allowing them to hit a major league pitch. Soccer players display amazing shifts in dynamic equilibrium, allowing for rapid foot work to manage high speed ball control, while elite sprinters have the ideal morphology and muscle conditions for rapid stride turnover. Interestingly, physical aptitude for a sport is so strong that reaching an elite status in a given sport rarely suggests a seamless transfer to other sports at the same level. This is due to the skill-specific nature of each activity as well as varying emphasis in the support systems of the body. Therefore, being “world-class” in more than one sport is a very rare occurrence.

A remarkable degree of neuromuscular efficiency is commonly seen amongst elite-level athletes. However, being born with a responsive nervous system is not enough (unto itself) to ensure success. Exposure to a given sport at an early age makes a significant difference, particularly with appropriate instruction and motivations. Equally important is participating in sports that reflect an individual’s relative strengths and morphology. Sports are so aptitude-specific that even the world’s most genetically-gifted athletes are only elite in one. It has been argued that Michael Jordan is one of the most talented athletes of all time, but when he attempted to play baseball he drew an audience based on his reputation, as his skills were below average at the elite level. Deon Sanders and Bo Jackson experienced greater success between sports; however, Sanders was inducted into the Hall of Fame for only one, while Jackson’s hip injury displaced his expected accomplishments. Another illustration of athletic skill specificity can be seen with former UFC heavyweight champion Brock Lesner. Lesner is an undeniably imposing specimen, yet the former collegiate heavyweight wrestling champion did not make the cut in the NFL (he was released by the Vikings during tryouts). Recognizing his skill set, he moved back to his roots to become the...
world heavyweight champion in mixed martial arts. Interestingly, numerous former NFL players have attempted the opposite transition and failed; they played starting roles in the NFL, but never made it to the competitive level in the UFC.

These examples unmistakably reflect the fact that unique skills, (outside of requisite anthropometric measures) are necessary to successfully compete at the higher levels of sport competition. But what about possessing a key athletic quality such as speed? Is being faster than everyone else enough to support a sport transition? Carl Lewis never played football, yet he was drafted by the Dallas Cowboys as a wide receiver. It was quickly obvious that the track was a better home for him, begging the question – what are the key elements that make a complete athlete; or maybe more relevant, what makes the best athlete?

It has been reasonably established that the first step toward athletic success is being born with an aptitude for a specific sport. A competitive athlete is nearly impossible to create without the physiological/genetic framework requisite to the sport, but you can make a good athlete better. Undoubtedly, one can become more efficient, faster, bigger and stronger; but, all of these improvements do not fully ensure playing time, or even the likelihood of making the team. Performance enhancement is derived from many contributing factors ranging from improvement within supportive systems (e.g., functional efficiency of the skeleton) to movement pattern proficiency developed from quality coaching. In some cases, the necessary skills take time to develop, and an adequate maturation process is necessary. This becomes blatantly apparent when one considers the fact that even Michael Jordan was cut from his varsity team in high school. In any case, there must be a strong neurological foundation for eventual success. Therefore, to become a better athlete, one must first establish efficiency in the movements of the sport, and then optimize the underlying physical systems which support higher performance of those skills.

◆ Health-Related Components of Fitness

The opening remarks argued that a team sport requires athleticism, whereas movement-specific activities such as running or biking are simply measures of system efficiency. Although a triathlete does compete based on the efficiency of several health-related components of fitness (HRCF), what makes the event an athletic competition are the demands of system interaction, most notably the psycho-physiological factors that enable one to drive through pain. To the contrary, a baseball player does not require a maximally-efficient cardiovascular system; rather, he must possess speed and power attributes as well as hand eye coordination. Clearly, each sport has requisite physiological factors that distinguish an individual’s propensity for success during participation. These factors may be movement specific, reflecting a need for neuromuscular characteristics such as speed and agility; or metabolic dependent, reflecting a greater need for optimization of energy-based components such as cardiorespiratory efficiency. In most cases,
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two categorical groupings communally referred to as components of fitness, are used to sum up relevant training parameters. These groupings include health-related activity and performance-related activity. HRCF include cardiorespiratory fitness (aerobic efficiency); muscular fitness, which includes strength and anaerobic endurance, flexibility, and body composition. Although attributes of each are equally important for health, different sports require varying degrees of each. Therefore, to suggest that one must present with exemplary values in each category to be a successful athlete is false. In reality, there are quality athletes that are obese, others that are relatively weak, some that have low cardiorespiratory efficiency, and many that present with poor levels of flexibility. Surprisingly, these athletes include those who compete at the professional level. To the contrary, some athletes demonstrate exceptional characteristics of the HRCF but never earn any playing time during competitive events. For example, it is not uncommon for the strongest player on the football team to play second string, the leanest basketball player to play limited minutes, or the soccer player with the highest VO₂ max to rarely see the field during competition. Although scoring well within each parameter can help an athlete perform better in their sport, the aspects of fitness unto themselves will not necessarily make an athlete successful; except possibly in the case of endurance activities, as alluded to in the introduction.

DEFINITIONS

Strength –
The ability to produce maximal force

Anaerobic endurance –
The ability of an individual to sustain a continual muscular exertion over a given period of time

Flexibility –
The ability of a given joint to move through a full range of motion

Body composition –
The relationship of fat mass to fat-free mass on the body; often expressed as percentage of body fat

VO₂ max –
The highest rate at which oxygen can be taken up and utilized by an individual during exercise

Athletic performance is built on foundations of health:

The three HRCF are considered general fundamental attributes

Performance-related training relies on HRCF to build specific neural attributes

Example: speed results from the development of power, ROM and optimal body composition

Figure 1.1 The Relationship Between Health and Performance-Related Fitness
Interestingly, most sports are more negatively affected by poor levels of fitness than are positively benefitted by high levels of fitness. An athlete with an acceptable level of conditioning in each component is generally in good enough shape to perform sport-specific skills during a competitive event with minimal loss of performance, whereas a poorly-conditioned athlete will fatigue prematurely and therefore will not be able to keep up with the speed of the game. Lack of flexibility is likely the least respected component of fitness but can be detrimental to training and competitive performance. An athlete with tightness, particularly in the hips and shoulders, will have significant limitations in movement and a high susceptibility for injury. For instance, lack of flexibility is implicated in an inability to properly perform Olympic compound strength exercises such as front squats. Tightness often leads to premature fatigue from the drag of movement resistance and is clearly associated with performance limitations (e.g., back pain). Likewise, each sport has minimal strength requirements necessary for competitive performance. Interestingly, in non-collision sports, strength imbalances are likely the primary cause of performance injury.

Although satisfactory levels of fitness are requisite to all sports, some rely more heavily on the HRCF than others. Athletes who participate in these sports should see this need reflected within the training program and preparation for the competitive season. A key aspect to successful strength and conditioning for any sport is to establish and maintain the health-related components in the offseason to ensure that the preseason emphasis is on sport-specific improvements rather than supporting foundational conditioning. A strength and conditioning coach that must work on improving an athlete’s conditioning during the skill-specific phases of training is wasting valuable time and energy that could be used to improve sport-specific skills. Clearly, athletes should always maintain a foundational level of fitness, regardless of their sport, making the fact that so many fail to do so quite astounding. Many laypersons believe that all athletes are “in shape,” but as many experienced coaches will attest, this is a clear misconception. A strength and conditioning coach needs to be cognizant of the physical condition of his or her athletes, and ensure that adjunct training and counseling are properly employed. This can help to make certain the athletes begin pre-season training in shape and ready to accelerate their athletic skills.

**Performance-Related Components of Fitness**

The HRCF are considered rudimentary athletic attributes, but they do not differentiate conceptual athleticism. Power, speed, agility, quickness, balance, and coordination are considered to be the true foundations of an athlete. Each of these performance-related components of fitness (PRCF) relies heavily on the nervous system, whereas the health-related components are more independently system-specific. Performance-based fitness builds upon the health-related components and connects them through neural mechanisms. To illustrate this concept, consider that speed is a factor of power, flexibility, and stability connected by neural recruitment factors. Without adequate flexibility, stride length is compromised and resisted; and without stability and strength, power cannot be effectively produced. It should be evident that a comprehensive analysis of essential components for each sport is relevant to programming. This will be explored in greater detail in the next chapter.

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**DEFINITIONS**

**Performance-related components of fitness (PRCF)** –
Fitness measures related to overall function, commonly associated with sports performance but are also related to overall health and quality of life; includes power, speed, agility, coordination, and balance

**Power** –
Rate of work performed expressed as (force x distance) ÷ time

**Work** –
Transfer of energy by a force acting to displace a body of mass; is equal to the product of a force and the distance through which it produces movement

**Speed** –
The time rate of change of position of a body without regard to direction

**Agility** –
The accurate performance of a sport-specific movement involving rapid change of direction or velocity in reaction to analysis of the environment

**Quickness** –
Quality that denotes being able to accelerate to a high velocity in a short period of time in a given direction or through a number of movements

**Balance** –
A stable state characterized by the cancellation of all forces by equal and opposing forces

**Coordination** –
The “intelligence” of muscles and their ability to communicate efficiently with central processing for harmonious adjustment or interaction of parts

**Stability** –
The property of a body to resist displacement; a factor of internal forces that attempt to maintain or restore the original condition or position
Power

Power is a key ingredient for performance in most sports. It is the speed of work expressed as (force x distance) ÷ time. This formula suggests that there are three separate factors that can be manipulated to increase power (or consequently decrease it). Considering that force x distance = work, and strength denotes the ability to produce maximum force; when strength measures are high, one might assume the body has the capacity to efficiently perform work and therefore become more powerful. Two paradoxes exist within the strength and conditioning profession; they include the perceptions that 1) strong = powerful, and 2) heavy strength training = improved athletic performance. It can be reasonably argued that neither is always correct. This rocks the foundation of current mainstream philosophy in strength and conditioning, and in a sense, the defined function of the "strength" coach.

Ironically, the term “power-lifting” references the activities associated with the three lifts performed during competition. The lifts included in a power-lifting event include the bench press, deadlift, and back squat. The irony of the term “power-lifting” lies in the fact that none of these lifts utilize high levels of power due to the immense stability required to manage maximal force production across multiple joints. The movements are performed at relatively slow rates; consequently, significant work is performed at the expense of power. The competitors that squat 1,000+ lbs. can take as long as four (4) seconds to work through the descent phase alone. Considering these lifts are performed at slow, controlled speeds and demand very high force output, they are strength-based activities, and consequently have the potential to reduce athletic performance compared to explosive training due to preferential muscle fiber recruitment patterns [9,10,11,12,13,14,15,16,17,18]. An additional concern related to the use of heavy strength training for sports performance lies in the fact that the body becomes more efficient in the application of force within the lifting environment. Therefore, the perception that an exercise like the bench press improves upper body power and transfers to sport-specific upper body actions is not well supported [12,17]. Case in point: how often does an athlete replicate a bench press during a game? Football players perform pressing actions while in a closed-chain standing position (at varied angles and through asymmetrical force vectors). These actions clearly fail to reflect the stresses seen during a barbell bench press. Any inference that a high bench or leg press predicts football capabilities is not well supported. To confuse matters further, strength exercises including the back squat can be employed to aid in power development [10]. The key is knowing how and when to use the applications in a thoughtful and purposeful manner to improve performance. Increasing bench press strength without planned applications into power can be counterintuitive in the same way inadequate strength development can have negative implications.
Olympic weightlifting, unlike power-lifting, is actually power-based. In weightlifting competitions, the clean and jerk and the snatch are demonstrative of power exercises. The obvious differences in these lifts, when compared to those used in a power-lifting competition include: the rate of the positional change of the center of mass, the number of joints used in each lift, and the energy transfer necessary to accelerate the resistance beyond gravitational force. Joint segment movement synergy promotes a rapid vertical displacement of the bar, making the movements extremely powerful. However, if the lift was performed at the same pace used in a strength exercise, the bar would not accelerate vertically beyond the position attained once full hip extension is achieved.

Strength training is an important factor in becoming powerful when applied in the proper fashion \[19,20,21,22,23\]. Athletes must have a strength foundation to properly perform work. Secondary to work capacity is the efficiency of bodily segments/systems to work together to spare energy. During sport activities, movements are rarely isolated. Rather, forces tend to start from the ground, accelerate through the hips and trunk and manifest in the hands or feet. Strength applications that improve force couples are therefore important for linking segments of the body together. If the linkage system (or kinetic chain) has a weak link, force is lost at the site of weakness. An athlete is much better off having strength balance across a functional chain of muscles than being able to bench or leg press significant loads. Once an adequate amount of strength (balance) is attained across each joint segment, forces can be further accelerated. If balance is not attained, energy is lost to inefficiency. In proper sports preparation, emphasis is placed on promoting efficient movements specific to the actions and speed of the sport. This is accomplished through the phasic applications of stress, starting with removing resistive joint stress and rehearsing movements to efficiency across kinetic chains – before loading, challenging, and speeding up the action.

### Definitions

**Force couples** –
Coordination between dynamic and static contractions of interacting muscle groups acting upon a joint or joint segment

**Kinetic chain** –
The combination and interrelation of the nervous, muscular, and skeletal systems in an effort to effectively control the body
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Speed

Speed can be another confusing term. Speed represents the distance travelled per unit of time, identifying the clear association with power. For most sports, power and speed are defining factors in performance. For instance, a three-hundred pound defensive end can do very little to a 220-lb quarterback if he lacks the speed to catch him. This is equally obvious when a forward’s speed allows him to get behind the defense to dunk the ball uncontested in basketball. Clearly, speed is the difference maker among athletes, and often determines playing time. In some cases though, speed, velocity and acceleration are erroneously used as synonymous terms. Velocity is the rate of change of position where both speed and direction are used to quantify it. Acceleration is the change in velocity over time, and due to the fact that it is tangibly quantified as a vector, it can change in magnitude and/or direction. These definitions are important in athletic performance because an athlete may be slower by measures of 40-yard speed (essentially quantifying time to cover a distance between point A and point B), but quicker in bursts or in specific movement segments as seen in starts and “first-move” actions. This is where agility and quickness become relevant. An individual that can accelerate to the highest velocity in the shortest period of time is quick, whereas the time the athlete takes to move his body between two given points would define his speed. From a speed perspective, it is often the length of the distance that defines who is faster, but not necessarily who is quicker. The important concept to consider here is that defining components of sports can occur in seconds (or in fractions of a second). This being understood, power, speed, and quickness are extremely valuable components in preparatory training.

Agility and Quickness

Agility and quickness are listed together because quickness is a factor of agility. Agility is the ability to change the body’s position efficiently, requiring the integration of coordinated neural components applied through the musculoskeletal system. Interestingly, agility is affected by many different factors including environment processing, experience, size, stability, muscular fitness, and power. For example, Barry Sanders at 5’8” and 200 lbs was considered by many to be one of the most agile athletes ever to play American football, and his undersized NFL frame likely played an important role. Changing body positions rapidly relies heavily on dynamic stabilization. Therefore, it is easier to change direction by attaining a lower center of gravity at the point of directional change. When coupled with the ability to keep more of one’s center of mass over the base of support, a person can more easily change position with less effort. Although some athletes demonstrate impressive natural agility; based on the physics of movement, agility can also be taught. The use of repetitive drills in practice, coordinated with improvement in force couples and central stability using resisted exercise will improve dynamic stability. Due to the body’s seemingly limitless movement capabilities and the number of unique environments to which it is exposed, agility training can have significant diversity when used to prepare for sport competition. For this reason, agility and quickness training should be emphasized and well-defined in a sport-specific agenda.
Balance

Balance, like the other performance components, is dependent on several overlapping factors that must function synergistically for an efficient and desired outcome. Balance is comprised of data processing using visionary components such as depth perception, vestibular components, and central and peripheral neuromuscular elements (central nervous system [CNS] and peripheral nervous system [PNS]) applied to muscle activation [24]. In addition, tactile aspects contribute to the afferent data that must be managed by the motor cortex and spinal cord.

Balance is often viewed under two different conditions, static and dynamic, and is evaluated by stabilizing properties. Static equilibrium in sports is most often referenced for postural requirements. When all force sums equal zero, the body is stable and therefore will not be influenced to move in any direction unless the muscles creating the forces fatigue, allowing counter forces to overcome the body’s mass. Dynamic equilibrium (in sports) on the other hand, is more reflective of managed chaos. The force sums do not necessarily equal zero, but the closer an athlete can come to managing forces, the more balanced or stable they become during any multitude of sport actions. Dynamic equilibrium is needed for adequate energy transfer across a moving object as seen during a fade away jump shot, lateral “juke” move by a running back, or agile slashing with the ball in soccer. In some cases, dynamic forces must be immediately controlled as seen in a gymnast’s landing or a diver’s splash-minimizing entrance into the water.

When the factors of ground reaction force shift, so will the requirements for stability. Ice, sand, and mud all dramatically affect tactile properties used by the CNS, therefore making balance a more difficult endeavor. When the body exerts lateral forces, or if the downward forces are not applied centrally to the anchors of the base of support, the likelihood of lateral displacement of the base
increases and the athlete can slip. Both central and peripheral stabilizing aspects must further contribute to prevent loss of balance. In these cases, the resultant difference in the sum of forces determines if an athlete will falter or if they will fall. Due to the number of contributing factors to balance and the role balance plays in sports, it must be appropriately accounted for in the exercise programming.

**Coordination**

Coordination is likely one of the most difficult performance components to develop. It is essentially defined by the “intelligence” of the muscles (PNS) and their ability to communicate efficiently with central processing (CNS). Intellectually speaking, you are born with both a learning capacity and a learning rate by the brain. Similarly, the neuromuscular system is driven by the same concept. Athletes physically learn and adapt faster than non-athletes, which is demonstrative of the term coordination. Certainly everyone can improve in task-specific actions by repeatedly practicing them until more efficient movement patterns occur. The efficiency of the learning process is often considered what makes someone athletic. Each sport requires some level of athleticism, and arguments have been made regarding which sport demands the highest level. This explains why success in one sport does not necessarily predict success in another. Anyone who has watched professional athletes participate in a celebrity golf tournament has witnessed elite NFL wide receivers and NBA basketball players swing and miss a static golf ball during the long drive competition (and the scenario can become even uglier when they actually hit the ball). This underscores the need for sport-specific skill and aptitude in addition to athleticism.

*Note:* In some cases, repetition can mask athleticism. For instance, improving in routine drills does not significantly benefit the nervous system’s educational development. Repetition certainly can improve coordination in a specific act, but it does not necessarily make the nervous system inherently smarter in other environments. Conceptually, this can be compared to line dancing, which anyone can easily pick up; change the dance or increase the speed, and neural adoption rates become obvious between dancers.

As alluded to previously, coordination represents the efficiency of the nervous system to identify a specific movement action or pattern through afferent pathways (evaluative data) and signal efferent directives (response data) to accomplish a task in the most efficient manner. Of course, all this occurs while taking into account the velocity of the movement and other contributing factors, such as loading and adjustments to the center of the mass. A dictionary may define coordination as the skillful and effective interaction of movements, or articulated in a more scholarly manner, the regulation of diverse elements into an integrated and harmonious operation. Both definitions identify that coordination is requisite to an action, but maybe even more importantly, the manner in which the body integrates factors harmoniously to accomplish complicated movements in a fluid fashion. Coordination from a physiological standpoint relies heavily on neural intelligence and proprioceptive pathways of communication. Those athletes whose nervous systems can best manage high amounts of information at the fastest pace in the spinal cords inner neurons are the one’s who demonstrate outcomes that are often the highlights seen on ESPN.”

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**DEFINITIONS**

**Efferent**

*Nerve impulses from the central nervous system to effector sites*

**Proprioceptive pathways**

*Relating to stimuli that are produced and perceived within an organism, especially those connected with the position and movement of the body*
Meeting the Physiological Demands of Sport

Each sport offers unique challenges to successful performance, so rarely does a single demand determine success or failure. A better prediction is based on how an athlete’s physical capabilities overlap with the “blueprint” for the sport. For instance, a sport may have several essential skills that must all be met to perform at an elite level. These skills may be related to strength, power, agility, and balance in varying degrees. Due to the requirements of physical proficiency in each component, having a surplus in any one category will not necessarily give an athlete a performance edge. It is the athlete that physically maintains the greatest uniformity with the sport’s “blueprint” that will have a greater chance of success. Essentially, the more an athlete can mirror the demands with physical capabilities, the better their sport aptitude and opportunity to dominate in the sport. Once the sport has been dissected into its requisite parts, each part can be trained for to improve athletic ability. Simply matching activities to the demands is shortsighted however. In reality, it is the interaction of these parts that determines performance outcomes on the field or court. This explains the need for periodizing programs in a developmental fashion to unite the physical qualities produced during training.
Periodization is a matrix concept. It places emphasis on different areas of performance to create important attributes, which in part remain independent but evolve into an assembly of characteristics that form an overall athletic quality. Strength becomes power and power can translate into speed. Strength is not lost as an independent variable, but it is much more viable in sports when contributing to power. Agility functions in a similar fashion, combining strength with power and then adding coordination and balance in respective contributions. The additional criteria needed to ultimately create the ideal physical condition for a particular sport accounts for the force-velocity relationship and the metabolic pathways that fuel the work.

Exposure to Sport at an Early Age

It was mentioned earlier that athletes do not pick their sport, but rather the dynamics of sport demands weed out those who fail to maintain the attributes needed to overcome challenges presented during competition. Interestingly, the earlier a body is exposed to the energy and force demands of a sport, the greater the probability the athlete will succeed. Not only does this occur because of the time-exposure relationship on neural properties and skill development, but also as a result of muscle system maturation. These changes are referred to as a process of plasticity or chronic alterations in the tissue. Plasticity, as an intrinsic characteristic of muscle during the human life cycle is undeniable, explaining why training causes improvements in tissue at all stages of life. However, due to the fact that muscle mass increases about 20-fold during childhood and puberty, it is believed to be more receptive during this life phase to chronic adaptations. This is likely due to both neural and tissue characteristics. For instance, satellite cells account for only 2–3% of nuclei in adults compared to 10% in children, so the potential for muscle regeneration and fiber type adaptations appears to be far greater at younger ages. A caveat to this statement is that children exposed to intense focus in a single sport rarely succeed as adults in that activity due to mental and physical burnout. Rather, it is recommended that a child engage in many overlapping sports, or in a broad, well-rounded conditioning program to optimize development, and focus later on a selected sport [25].

The reason these factors are so relevant goes back to the sports blueprint analogy. Muscle fiber efficiency is a function of force demands and energy system specificity. Undoubtedly, each muscle fiber can be fueled through anaerobic and aerobic energy pathways, and specific training influences individual efficiency, but fast-twitch fibers have anaerobic preferences. Therefore, if one promotes greater utilization of fast-twitch fibers during the developmental phases of maturation, they would also encourage a greater affinity for immediate and intermediate energy system optimization as adults. This is every track, football, tennis, hockey, lacrosse, baseball, and basketball player’s dream – to be fast-twitch fiber dominant. Aerobic pathways are much easier to develop than anaerobic aspects because it is a more efficient system. Training can make you bigger, faster, and stronger, but the magnitude of the change and the ultimate potential are genetic and developmentally determined. Aerobic pathways, while also genetically dependent, present fewer limitations as absolute force output and the rate of tension are less relevant in endurance-based performance.
Interactive Demands in Sports

Demands for maximal force and the rate of force development differ by sport, but are consistent in the support of competition success. The defining elements in most sports occur at the highest velocity and require the most powerful forces. This suggests that anaerobic sports rely heavily on the recruitment of fast twitch muscle fibers and the most potent fuel (stored phosphagen energy) during game changing actions. The phosphagen system provides the fuel for burst actions and the fast twitch fibers are optimally designed to facilitate its use for higher velocity movements. This underscores the need for sport specific training at the intensity that changes the game’s outcome. Secondly, the training must reflect the environment and multitude of forces which can disrupt an athlete’s ability to move at the highest speeds while under control. The nervous system plays an integral role in the management of full-speed sport activities. Activities such as rebounding in basketball, lateral cutting in football, and heading a ball in soccer all demand synergistic contributions from several physiological mechanisms for successful outcomes.

To help manage the intricacies of the neuromuscular system, the body uses specialized components such as proprioceptors and mechanoreceptors which work with the nervous system in an attempt to capture energy and optimize forces. The nervous system must also relay this information to the muscles acting to stabilize the body during these high speed actions. When harmonized the stabilizers and guiding neutralizers can corral the force transferred across the joints to prevent energy from leaking in a wasteful manner. In sports the emphasis is in sparing energy, not burning calories because most games are won in the final period. Certainly each of these components will be explained in detail in later chapters but the concept to understand is the importance of recognizing the key physiological demands of the sport and how they interact to create the best athlete.

Although the conceptual focus in the aforementioned text centered on anaerobic-based sports, aerobic sports necessitate similar considerations. Fiber-type dynamics, energy-system efficiency and force management all play a role in the relative success of distance-based athletes. With aerobic sports, the need for power and agility is dramatically reduced, but anaerobic components are still relevant. In fact, anaerobic conditioning is a major determining factor in endurance-based competition; underscoring the need for resistance training. Athletes that possess the greatest capacity to utilize anaerobic energy systems during an event while controlling for fatigue often yield the fastest time.

Aerobic-based sports are heavily rooted in two areas: energy system efficiency and economy. Muscle biopsies provide information as to the density of particular fiber types within a muscle belly. Comparisons show individuals with greater fast-twitch fiber density are predisposed for conventional sports. This can also be seen on the track between Olympic athletes that compete at different distances. One hundred meter sprinters present higher fast-twitch fiber density in quadriceps biopsies than the distance runners. Distance runners demonstrate higher concentrations of type I or slow-twitch fibers, predisposing them for endurance sports. Common endurance sports include the marathon, triathlon, and cycling events like the Tour de France. These events do not require consistent, short bursts of

DEFINITIONS

Phosphagen system –
Also known as the ATP-PCr system, supplies immediate anaerobic energy that can support maximal-intensity exercise lasting up to 15 seconds

Phosphocreatine –
A phosphate ester of creatine found in muscle; serves to store phosphates to provide immediate energy for muscular contraction

Mechanoreceptors –
Sensory receptors responsible for sensing various forms of distortion in body tissues

Guiding neutralizers –
Function to counteract instability or unwarranted movements created by the synergistic actions of the prime mover, assistive movers and the antagonist muscle group involved in a given movement
maximal power. When expressed in watts, the average tension requirements are relatively lower, but surges of high output can occur during intermittent sprinting segments in the event. Therefore, type I fibers predominate the force production requirements, allowing the body to capitalize on all energy-sparing pathways. They do so by becoming more efficient through several mechanisms, including efficiency in both fat and carbohydrate utilization; the development of asynchronized neural firing patterns; improved oxygen delivery and heat dissipation; and improved hormone-related augmentation and buffering responses to better manage systemic pH.[30]

Interestingly, of all the adaptations that make an endurance athlete notably successful, a high level of oxygen consumption with energy-sparing attributes is really the only aerobic component. Reduced restriction and improvements in lactate threshold are actually promoted via anaerobic means; and become equally important at the competitive level. Therefore, the demands of aerobic-based sports require anaerobic training. Any athlete that does not consider musculoskeletal balance, range of motion, dynamic stabilization, and/or anaerobic power and capacity will never reach their relative potential. In reality, most aerobic athletes realize a performance epiphany once they start incorporating anaerobic work including flexibility, power, and strength training.

Anaerobic athletes should consider the previous concepts as well. Concurrent energy system interaction is crucial for reaching the highest levels of performance. Many anaerobic athletes avoid conditioning activities that improve endurance for fear of decreasing their force output capabilities; however, the use of oxygen is necessary in buffering the byproducts of anaerobic metabolism. Therefore, athletes with relatively high cardiopulmonary efficiency can train harder due to shortened rest periods between sprints, weightlifting endeavors, and glycolytic-driven plyometric activities. At this point it should become clear that human performance cannot be facilitated from isolated variables; all training should focus on the synchronization of the complex interaction of systems.

◆ The Role of Athletic Conditioning for Sports

It is often surmised that good athletes are born, but great athletes are made. Certain individuals embody this concept and stand out not only for their athletic accomplishments but also for their commitment to physical conditioning. In each case, they reached the pinnacle of their sport, and even more notably excelled for prolonged periods far beyond the statistical norm. Lance Armstrong (regardless of implications) is likely the best example of this commitment, utilizing cutting edge science and a multimillion dollar annual budget to manage his physiological systems and team-based training for unbelievable returns. Jerry Rice was well known as one of the best conditioned athletes in the NFL, with a level of commitment and work ethic considered second to none. He played professional football into his forties, impressively in a speed position (receiver). In recent years both Tiger Woods and Michael Phelps have been recognized for successfully aligning their physical conditioning with their sport-specific work. Woods used resistance training to improve his strength, power, and flexibility; Phelps’ coaches implemented a special periodized approach to add intensity and hours to his training without compromising his recovery. The obvious commonality here is the combination of best in class with a commitment to a comprehensive training program. For athletes to reach their full potential they must have a quality strength and conditioning program as well as confidence and commitment to its implementation.
Preventing Injury is the Primary Role of Strength and Conditioning

The physicality and demands of most competitive sports are so significant that long-term durability may be a more impressive measure than any single, in-competition accomplishment. Ironman careers like Cal Ripken Jr., Brett Favre, and Lance Armstrong are very rare for a reason: injuries hurt. This pun holds serious implications for all athletes because injury presents numerous negative outcomes. Most athletes would welcome the pain if they were ensured the injury would go away in a timely manner and not impact future performance. But injuries aren’t like a loan; paybacks do not follow amortization schedules and often far outweigh the initial price. One of the most important concepts for a strength coach to comprehend is that the basic job task for their position is to put the best product on the court or field. If an athlete is injured, the rudimentary task is unfulfilled.

An athlete is useless on the bench, regardless of their condition prior to injury. Multiple injuries may decimate a team’s chances for success in a full season of competition. The Vegas sports book relies heavily on weekly injury reports for this reason. This is particularly true for star players. If an NFL starting quarterback is knocked out of the game most teams lose their expectation of winning. Sports have and always will be dominated by “franchise players,” so when these individuals get hurt, the impact on the team’s success is always significant. Attempting to make key players faster or stronger without accounting for injury prevention represents error at the rudimentary level. This is true for an athlete in any given sport. Again, professionals must understand that the number one role of the strength coach is to put the best product on the field, a process which starts with injury prevention.

Sports (Movement) Economy

Injury prevention techniques often overlap with those directed at improving movement economy for enhanced athletic performance. In this case, economy does not mean VO2max (which is often a defining element of movement economy), but rather the physical ease of movement. As previously stated, independent fitness variables do not seamlessly transfer into improvements in sports. Strength and conditioning efforts should emphasize preventing factors that limit fluid sport movements before attempting to focus on the factors that can accelerate them. In most cases, when a detrimental factor is removed, accelerated performance occurs as a desirable side effect. For example, a golfer with tight hips would experience significant improvements in power by rectifying hip movement limitations rather than simply employing additional power exercises. Essentially, sports economy starts with skeletal efficiency.

If the skeleton experiences any limitations in movement around a joint, the actions facilitated through that joint are compromised. Muscle imbalances and flexibility issues exist in most athletes, and act as major relevant limitations to performance. In fact, many athletes demonstrate pre-injury conditions at multiple joints and present with levels of inflexibility consistent among non-athletic populations. Any resistance to movement creates performance limitations. In addition, muscle imbalances lead to injury and further retard movement capabilities. When imbalances are combined with flexibility issues, athletic detriment and injury becomes a predictable outcome.

Sports economy also speaks to efficiency in sport-specific activity. Therefore, in addition to an emphasis on a functional skeleton, the principle actions of the sport must be rehearsed in part
or in whole within the training program. The strength coach must identify key components to applicable athletic movements and facilitate training methods that promote the desired response. In many cases, the interaction of range of motion, dynamic stabilization, and strength can be united to account for multiple factors. The first step though, is identifying the primary areas of need, prioritizing training components, and then utilizing a sport-specific approach that prepares the athlete for on-field improvements.

**Nerves versus Muscle Mass**

The nervous system is indisputably the most responsive system of the body. It should be clear that the nervous system is an extension of the brain, and therefore has the capacity to learn. Although sports performance is neural in nature, the nervous system can be further trained to maximize muscle tissue’s output beyond that which is needed for efficient movement. Muscle tissue has a significant capacity for force output; it is simply limited by neural recruitment patterns and available energy. Based on this fact, muscle can make remarkable performance improvements through motor unit management without significant changes in size or protein architecture. In Olympic weightlifting, athletes compete in weight classes, which means improvements between competitions that occur in their relative strength and power are made via neural changes with negligible changes in muscle fiber hypertrophy. Clearly, it is not necessary to increase mass for power and/or speed improvements. This being said, increases in fiber circumference infer greater force capabilities, which is heavily promoted in the thick myosin chains and framework of fast-twitch fibers. Fiber size factors are important to varying degrees depending on the sport however, so an emphasis on morphological changes must be considered with purpose.

The media reported that Andre Agassi fired his strength coach in exchange for a personal trainer. The change in training led to notable increases in muscle size; consequently he dropped from third in the world to seemingly out of contention. When he re-employed a strength coach, he reduced his muscle mass and gained back his speed and agility to make a successful return. Obviously, training for muscle mass can be contrary to the goals of the sport. Bodybuilding as an activity is not athletic. It requires slow, isolated movements performed in an effort to overload muscle groups under periods of specific tension. Sports require the training of movements and are neurally-dominated rather than muscle-dominated. Certainly a larger muscle is a stronger muscle in relative terms, but a larger muscle does not infer a faster contraction. Larger muscles do increase oxygen demands and overall work during practice and competition however. Additionally, the ability to utilize several muscles to perform a task spares localized glycogen and reduces fatigue when compared to the same action controlled by a single dominant muscle group. Muscles must therefore be taught to work together rather than independently. Size considerations and the practices to reach them must be intelligently managed with strength and power development to account for all forward improvements. Proper programming can promote neural enhancements for force and velocity improvements with simultaneous morphological changes. The ability to manage these variables in a simultaneous fashion is an integral factor in strength and conditioning programs.

**Movement Range**

The ability to move fluidly through a full range of motion (ROM) is dependent upon the skeleton, connective tissues, and associated musculature. While bones do not stretch, they are subject to positional shifts based on the effects of nearby connective tissues. Deviations in skeletal alignment provide significant resistive stress to movement, often resulting in notable dysfunc-
tion. Structural adjustments promote changes in tissue length and can consequently reduce both its plastic and elastic properties. Additionally, performing tasks using a limited movement range or failing to select or adjunct activity that encourages improvements in joint ROM can hinder performance and increase an athlete’s risk for injury. Strength and conditioning professionals must recognize the relevance of ROM to athletic performance and the ability to perform quality movements. Limits to tissue lengthening capabilities will prevent proper movement, resist joint actions, potentially reduce the optimal length of muscle for producing peak tension, and negatively change movement mechanics. A lack of flexibility in the trunk, hip extensors and flexors, shoulder flexors, and knee flexors will all impact key movements. Bilateral leg work (squats and deadlifts) and Olympic exercise participation is often inappropriate for many athletes with flexibility issues. This occurs as movement impairment creates undesirable biomechanics during common activities employed for training and practice. Therefore, flexibility training oftentimes requires additional consideration during training protocols for athletic performance enhancement when compared to that seen among fitness enthusiasts.

**Metabolic Conditioning**

Announcers have used the terms “game shape” or “game legs” to describe when an athlete has attained necessary sports conditioning to complete an event without premature fatigue and performance decline. When Michael Vick signed with the Philadelphia Eagles to become their starting quarterback following his prison sentence, the early concerns verbalized by sports analysts centered on his ability to get his game legs back after being out of the league for two years. This concept is really about the neurophysiological aspects of force output. Strength coaches must have a sound understanding of the sport-specific metabolism associated with competition, as well as the factors that affect repeat performance in competitive events. Much like an injury, fatigue limits performance and can make a star athlete perform at sub-capacity. The ability of an athlete to play the fourth quarter like the first is a cornerstone of the strength and conditioning coach and must be properly emphasized in a program developed for athletic performance. The loss of force negatively affects the PRCF and consequently determines event outcomes. While strength and power are relevant aspects of training for sports, preparing both the nervous and metabolic aspects of muscle to sustain force is equally important. The attention to sports conditioning for optimal performance should be properly emphasized in the athletic development equation.

Developing the skills and knowledge to combine the aforementioned in a premeditated and thoughtful program aimed at athletic development distinguishes the quality professional from those of lesser competency. The aim of the following chapters is to identify the predominant elements and respective applications that lead to athletic success. The methods to creating the appropriate matrix of stress with consideration for progressive athletic development will be explored with a sport-specific emphasis. Incorporating a balanced approach based on a thorough needs analysis will allow for the development of effective program strategies, and ultimately goal attainment.
REFERENCES:


