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SPECIAL FOOTBALL ISSUE

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ABOUT THIS PUBLICATION

The *NSCA Coach* publishes basic educational information for Associate and Professional Members of the NSCA specifically focusing on novice strength and conditioning coaches. As a quarterly publication, this journal's mission is to publish peer-reviewed articles that provide basic, practical information that is evidence-based and applicable to a wide variety of athlete and training needs.

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LETTER FROM THE **GUEST EDITOR**

SPECIAL FOOTBALL ISSUE

Football is considered by many to be America's game. It is also one of the most popular and wealthiest sports in the world. In the United States, it is played by millions of youth and high school participants. Of this developmental "pipeline," about 7% of high school seniors will play National Collegiate Athletic Association (NCAA) football. Overall, there are about 70,000 college football players. The journey for about 300 potential prospects will continue as they prepare during the first few months of each year for the National Football League (NFL) Combine in late February with the hopes of having their name called in late April at the NFL Draft. In the end, only about 2% of all college players will advance to the professional level.

The physical development and preparation of the American football player is of utmost importance given the physical demands of the game. Our field of strength and conditioning has its roots in the game of football and was largely influenced by the founder of the NSCA, Boyd Epley, who was the first full-time strength and conditioning coach overseeing the powerhouse football program at the University of Nebraska-Lincoln in the 1970s and throughout much of the latter part of the 20th century.

The general physical demands of the game require specific body size and muscle mass, muscular strength and power, speed, multi-directional agility, and the ability to energetically sustain intermittent short bursts (5 – 8 s per play) of high-intensity movement. The collection of articles in this special issue cover all aspects of the physical preparation of the football player and are written by scholars and practitioners with experience studying and training youth, high school, collegiate, and professional football players.

The issue begins at the start of the journey towards the scholastic and professional levels with an overview of long-term athlete development as it applies to American football at the youth level. As mentioned, football is a game of repeated bouts of acceleration and high-intensity efforts; therefore, the next two articles deal with speed and energy system development. Following these articles, the tools for and importance of monitoring training loads is covered. This is followed by three sets of articles paired on a theme—one on the position-specific training of quarterbacks and linemen, the second on body composition and nutrition, and third set on injury prevention and return to play. The issue concludes with an article on enhancing movement skill and an account of preparing for the NFL Combine.

In closing, I want to personally thank each author for their time, energy, and passion in sharing their expertise, insight, and experience with all of us who test, train, and energize the American football player.

—Joe Eisenmann, PhD

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FROM FLAG TO FRIDAY NIGHT—LONG-TERM ATHLETE DEVELOPMENT IN YOUTH AMERICAN FOOTBALL

JOE EISENMANN, PHD, CLIVE BREWER, MSC, CSCI, CSCS

INTRODUCTION

Football is considered by many to be America's game. During the fall and into the winter months, the game captivates millions of Americans for the entire weekend—Friday (high school), Saturday (college), and Sunday (professional). At the same time, approximately 2 million youth 6 - 12 years of age participate in football every year (13). Although youth numbers are more difficult to ascertain, the National Federation of State High School Associations reported that there were nearly 1.1 million high school football participants in 2016 (15). Of this youth and high school "pipeline," 6.8% of high school seniors will play National Collegiate Athletic Association (NCAA) football and from there only 1.9% will advance to the professional level (14). To date, it has not been systematically studied how elite football players develop and advance through the system. The purpose of this article is to provide an overview of long-term athlete development (LTAD) principles as they could be applied to American football at the youth level. This article will also discuss the important role strength and conditioning coaches can have in the implementation of this model in their community.

LONG-TERM ATHLETE DEVELOPMENT

Currently, there has been increased attention on youth sports in general, and more specifically LTAD. A recent report from the Aspen Institute's Project Play Report Card on Youth Sports gave youth sports in the United States an overall grade of "C" (21). These concerns are considered in LTAD models, or what the United States Olympic Committee (USOC) calls the American Development Model (ADM) (24).

In brief, LTAD has been defined in the National Strength and Conditioning Association (NSCA) LTAD Position Statement as "the habitual development of athleticism over time to improve health and fitness, enhance physical performance, reduce the relative risk of injury, and develop the confidence and competence of all youth," (10). In turn, athleticism is defined as "the ability to repeatedly perform a range of movements with precision and confidence in a variety of environments, which require competent levels of motor skills, strength, power, speed, agility, balance, coordination, and endurance,"(10). Additionally, if these athletic traits are to be optimally developed and executed during competition, basic principles of sound nutrition and sport psychology also need to be considered. Furthermore, these athletic traits need to transfer to sport-specific technical skills that are executed within the tactical environment of the sport. Thus, when truly considering LTAD, the holistic development of the athlete in the four main domains of athletic performance—technical, tactical, physical, and mental—need to be taken into account. In addition, the game structure and how it can be evolved to deliver the principles of development and safety also need to be considered and is addressed elsewhere in this article.

A BRIEF HISTORY AND KEY TENETS OF LTAD

Before the application of LTAD principles are applied to the sport of American football, a brief discussion of the key tenets is warranted. The reader is referred to the specific resources of both the NSCA position paper (10) and the USOC ADM website (24) for details.

The concept of LTAD stems from practices of Eastern European sports science and athletic development during the Cold War era. Many Eastern Bloc countries developed youngsters for national competition through a sport school system where they were tested and selected into schools for specialized sports training that included a regimented daily routine of athletic preparation (18). Most recently, the concept of LTAD has been popularized by Istvan Balyi, a native of Hungary who moved to the National Coaching Institute in British Columbia, Canada. Balyi, working with Richard Way, developed a seven-stage model with age and developmentally appropriate activities within each stage. There was a major impetus for LTAD in Canada at this time due to a poor performance in the 2004 Olympics, which was attributed to a decaying national sports system (19). Throughout the last decade, LTAD was adapted by Canadian national sport organizations, including Football Canada (6), and several other national sport bodies across the world. To learn more about the Balyi LTAD model refer to the book for a full account (2) or visit the Canadian Sport for Life website (20).

The United States was relatively late in adopting LTAD. Disturbing statistics on falling sport participation rates (22), childhood obesity (16), physical inactivity (23), and a projected shorter lifespan of the current generation (17) prompted the USOC and its National Governing Bodies (NGBs) to create the ADM in 2014. The ADM is comprised of four key elements: 1) a statement, 2) a visual model, 3) NGB programming, and 4) resources that are available at the website for interested stakeholders (24).

The five key principles of the ADM include:

1. Universal access to create opportunity for all athletes
2. Developmentally-appropriate activities that emphasize motor and foundational skills
3. Multi-sport participation
4. Fun, engaging, and progressively challenging atmosphere
5. Quality coaching at all age levels

These key principles are based on research-based recommendations (3). Universal access for all athletes regardless of gender, race, physical disability, economic status, and ability allows everyone to reap the myriad of benefits from participating in sport. For the youth athlete, focusing on the development of fundamental movement and motor skills in a fun and engaging environment develops competency and confidence, which in turn increases the likelihood of continued participation in sport. Of course, the preceding statement is highly dependent on the quality of coaching. The Aspen Institute's Project Play (21) identified that only about 30% of coaches reported receiving training in health and safety (cardiopulmonary resuscitation, basic first aid, concussion management), sport-specific skills and tactics, effective motivation techniques, and physical conditioning and injury prevention. Finally, the recommendation of multi-sport participation has recently been addressed in a consensus statement outlining limited evidence of the benefits of early sports specialization and the increased risk of overuse injury and burnout (9).

Currently, several NGBs report to have adopted the ADM with USA Hockey leading the efforts (see admkids.com). Recently, USA Football has focused more attention on the ADM as a possible solution to declining participation rates and concerns for the safety of the game. This will be the focus of the following section.

A FRAMEWORK FOR LTAD IN AMERICAN FOOTBALL

Per the USOC ADM, the ultimate goal is to create positive experiences for American athletes at every level by helping them realize their full athletic potential and utilize sport as a path toward an active and healthy lifestyle. With this in mind, consider a framework for LTAD in American football.

A few overarching themes based on general LTAD principles include:

- The goal is to ensure that young athletes are doing the right things at the right time for their long-term development instead of their immediate development. It is at the high school level that the complete development of a player really accelerates, and the high school coach and program continues to be at the heart of fostering individual development, competitiveness, and commitment to succeeding within the game.
- Learning progressively more demanding versions of football along with technical and tactical skill progressions along the game pathway.
- This pathway and strategy should foster a life-long enjoyment of the game with its fitness and social benefits, providing an opportunity and an appropriate environment for all American children (and adults) to play a form of football that challenges them and provides an outlet for physical activity.
- All aspects of the pathway are athlete-centered, coach-led, development-driven, and administrator-supported.

THE GAME PATHWAY

For most, but not all youngsters who participate in organized youth football, they enter directly into traditional full-field 11-player per side or they may enter into flag football for a few years and then advance into traditional football. Unlike other sports, like baseball or soccer, football does not have a clear progression of game formats. In baseball, youngsters often progress from t-ball to coach pitch to player pitch. And, even once player pitch baseball begins there are modifications to field size whereby the pitching distance and distance between bases progressively increases across age groups. Thus, a potential solution for football is using a modified game. The authors have learned through personal communications and work with USA Football that small-sided, modified versions of the game exist throughout the United States. USA Football gathered such information and developed "Rookie Tackle" to serve as a bridge-game between flag football and 11-player tackle and to become part of USA Football's adoption of the ADM (25). The 2017 pilot season included 10 leagues across the United States with plans to expand efforts in Rookie Tackle in 2018. Key aspects of Rookie Tackle include:

- 6 - 8 players per side and reduced roster sizes
- Improved coach:player ratio, and focus on skill development and participation
- Smaller playing field
- Position sampling
- No special teams
- 2-point stance for linemen
- Center uncovered and no blitzing

During the fall of 2017, the game of football was also confronted with a media surge warning about the safety of the game and specific concerns about short- and long-term consequences of concussions and sub-concussive head impacts, primarily in former professional football players (1,12). This led to calls for a ban on tackle football before the age 12 or until high school (11) thus calling for a greater emphasis on flag football. It is beyond the scope of this article to discuss the pros and cons of this debate. However, safety and adoption of LTAD principles should not be mutually exclusive. For example from a physical developmental perspective, the need to start linemen in the 2-point stance reflects the levels of strength and postural development of a younger player: placing a helmet on a long lever (spine) in a 3-point stance encourages falling forward (leading with the head) to come out of stance. Conversely, the 2-point stance allows for the center of mass to be centered above the base of support, from where it is easier to teach forward and lateral movement. Importantly, this gives better control of the helmet (neck and head), especially in the presence of fatigue.

There are also some innovative football coaches who have been exploring another modified version of the game called padded flag football that may also fit into the game pathway (8). Padded flag football is played after flag football and can be seen as an introduction to contact skills. Regular equipment or soft shell equipment can be worn in padded flag football. Similar rules to Rookie Tackle are enforced but instead of a tackle, the ball carrier is downed by a flag pull similar to flag football. Some leagues also use this year to focus on instruction in blocking and tackling techniques which include drills that can include dummies and padded shields to develop correct techniques. Thus, players have a full year of instruction in blocking and tackling before they enter into full contact and tackle football.

Progressive ideas that build from this include eliminating contact outside of the line of scrimmage, such that higher velocity moves

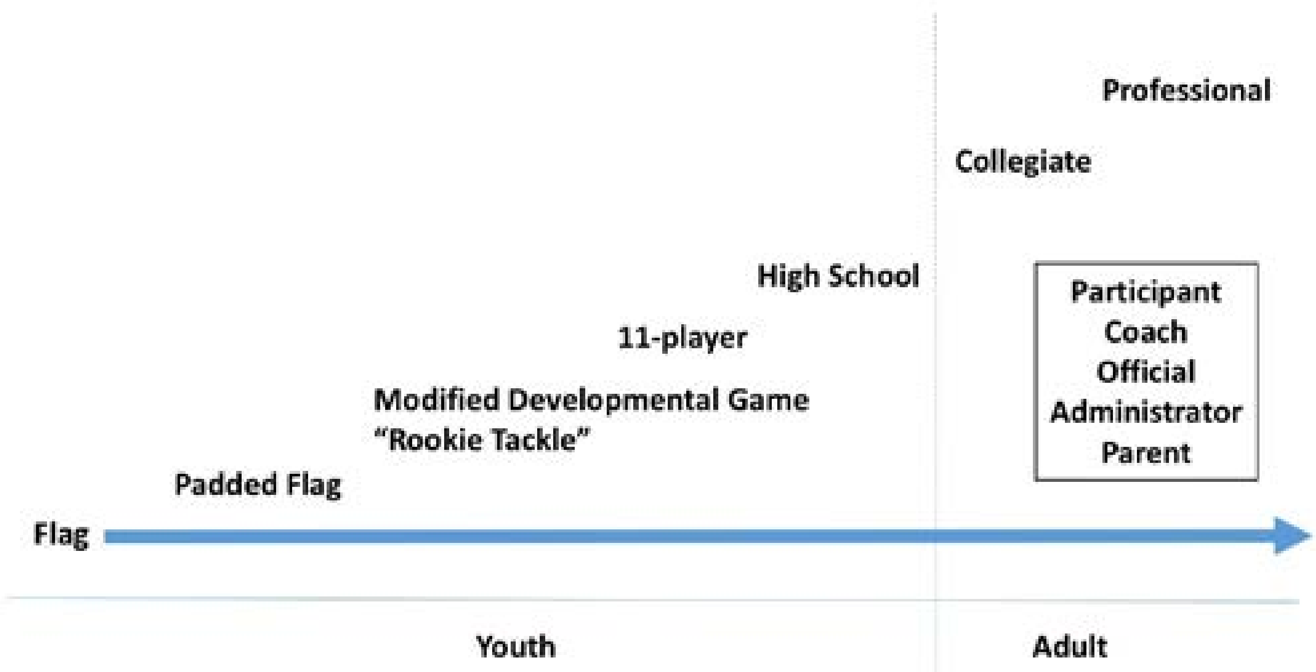

FIGURE 1. A MODEL FOR A GAME PATHWAY FROM FLAG TO FRIDAY NIGHT FOR YOUTH AND HIGH SCHOOL FOOTBALL WITH ENCOURAGED PARTICIPATION AS AN ADULT

do not lead to impacts, and ground collision (an underestimated impact force) is avoided. Removing the kicking game similarly eliminates kick-return collisions and emphasizes the focus on offense/defense. Similarly, eliminating low blocks and low tackles increases the focus on quality contact between the hips and numbers, with optimal body posture at the point of impact being the desired outcome. Considerations should also be made to remove the game clock and use total possessions or possessions per series that would facilitate player focus and engagement—a key aspect of youth sports.

The proposed pathway and strategy builds foundational game experiences, provides environments where techniques can become skills and puts these into practice by gradually introducing the player to contact prior to high school. In addition, a flag football for life approach (represented by the arrow in Figure 1) can be considered for those who do not wish to engage in tackle football or for adults who enjoy the game. Furthermore, adults exposed to the ADM pathway would have the knowledge, skills, and attitudes appropriate to participate in youth football as a coach, official, league administrator, or sport parent.

THE PLAYER DEVELOPMENT PATHWAY

As previously mentioned, the player development pathway should take into account the technical, tactical, physical, and mental development of the athlete in an age- and developmentally-appropriate manner. Indeed, a key aspect of a LTAD program is to make sure that the correct skills are emphasized in the right sequence. The key tenets of athletic development have been thoroughly addressed elsewhere and are addressed below (4).

Several analogies can be used here to highlight the learning of movement skills including learning how to write (e.g., words, sentences, paragraphs, etc.) and mathematics. At the youth level, fundamental movement skills are the basis of athletic development. These fundamental skills can be considered within the following categories:

- **Stability**: posture, static balance, dynamic balance, falling and landing (forward, backward, sideways, and on feet), rotating (forward, backward, and sideways).
- **(Bi-lateral) Object Control**: underarm throwing, overarm throwing, catching (various heights and speeds), kicking, bouncing, striking static objects, striking moving objects, intercepting.
- **(Multidirectional) Movement**: walking, running, vertical jumping, horizontal jumping, hopping, galloping, skipping, leaping, and bounding.

In essence, one needs to master fundamentals before advancing to more advanced skills. In football, this means teaching fundamental movement skills like balance, coordination, and fundamental blocking before complex skills like combo blocking to offensive linemen or bull and jerk, bull and rip, bull and swim, or other linked pass rush skills to defensive linemen. As well as the appropriate sequencing of skill progressions, it is also important to link skill expectations to neuromuscular and musculoskeletal development, in that skills should not be introduced before players are typically physically developed enough to undertake them.

Specific to football, the development of contact skills, specifically tackling, has drawn concern given recent attention to head impacts and concussion (1). Thus, the teaching of fundamental skills such as fundamental athletic position, bodyweight squat, hip hinge, lunge, and triple extension are vital to executing blocking and tackling. Furthermore, teaching proper deceleration technique is also important to tackling. The fundamental movement skills of hopping, skipping, running, backpedaling, shuffling, decelerating, and cutting are important for multidirectional movement on the football field, such as running passing routes and playing pass defense.

These fundamental movement skills can easily be incorporated into a dynamic warm-up or movement preparation period at the beginning of practice or throughout practice as microdosing sessions. Microdosing is a concept taken from the drug industry, where low, "sub-therapeutic" doses are administered to examine the response during the development of the drug. Applied to sports training, it can be seen as using a distribution of weekly training across several short sessions as opposed to fewer longer sessions to enhance athletic traits, often times because coaches are focused on technical and tactical aspects of the sport (7).

It is also important to note that the movement skills do not always need to be conducted with athletes standing in lines or in isolation. They can be performed in a fun and well-designed obstacle course or using a games-based approach, particularly in younger athletes. The latter concept means that the generic and positional technical/tactical skills along with the player's ability to determine when and how to use these in a game to his or her best advantage can be developed in conjunction with physical capacities, and we can also fully prepare a child to graduate to the next level of play (4).

Of course, formal strength and conditioning practices are common in high school football players, and some of the athletes are exposed to formal training at younger ages. For the youth football player, it is important to lay a foundation for these formal strength and conditioning activities by teaching the appropriate postures and patterns for squats, hip hinges, push-ups, planks, etc. that can be transferred between the field and the weight room. Initially, these foundational strength training movements can be taught using bodyweight or light external loads.

NURTURING PHYSICAL DEVELOPMENT

Planning is important in a program for developmental athletes, especially since the objective is to deliver the appropriate biomotor abilities in the correct sequential order to promote the long-term development of the athlete. If a program is planned and progressed properly, it will enable a young athlete to be physically

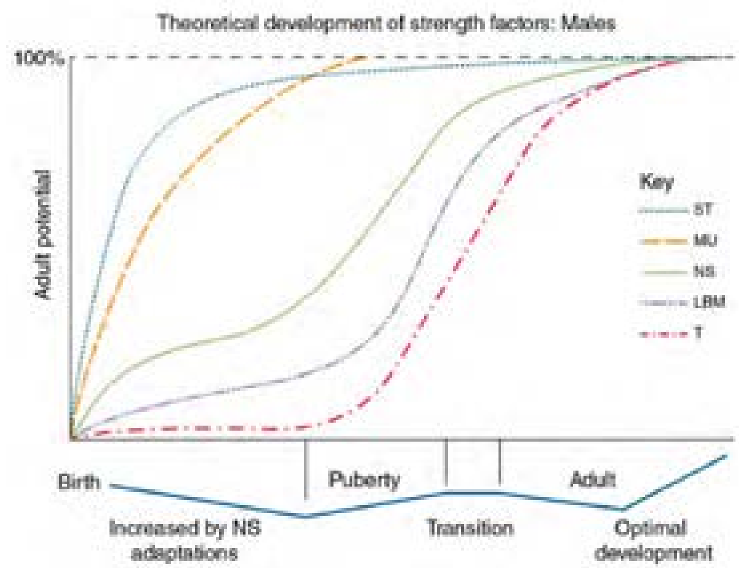

FIGURE 2. THEORETICAL DEVELOPMENT OF STRENGTH OUTPUT AS A CONSEQUENCE OF PHYSIOMECHANICAL DEVELOPMENT OF THE MALE MOTOR SYSTEM
Adapted with permission from Pierce, K, Brewer, C, Ramsey, M, Byrd, R, Sands, WE, Stone, ME, and Stone, MH. Opinion paper & literature review: *Youth Resistance Training Professional Strength and Conditioning Journal* July: 9-22, 2008.

prepared for transitions between stages (e.g., from middle school to freshman to junior varsity to varsity high school). This requires knowledge of the trainability of the youth and adolescent until the point of adulthood (biologically), where all physiological systems become fully trainable and adaptive to specific training stimuli (4).

Given the above, it is also important to note that all aspect of fitness (strength, speed, endurance, mobility, and combinations and derivatives of these) can be developed within children at every stage—not just during the popularized yet unfounded "sensitive periods" or "windows of opportunity." However, as indicated in Figure 2, the components of the motor system that influence muscular strength do not develop at a uniform rate. Understanding this developmental curve allows for the focus to be on two important determinants for the physical development program. Firstly, it provides a guideline for the physiological constraints on program delivery in terms of the methodology and volume/intensity loading. Secondly, it provides a framework for identifying how training programs should be devised to optimally support and reinforce the development of the motor system. Because so many of the components of football skills are reliant on an athlete's ability to rapidly produce multidirectional forces (a function of strength, speed and postural control) it is no surprise that the neuromuscular and musculoskeletal system development are central tenants to the athlete development model (Figure 2). In particular, the importance of the neuromuscular system as a pre-cursor to strength, power, and speed cannot be overemphasized. Therefore, prioritizing appropriate strength, power, and motor skill competency are the major priorities for a strength and conditioning coach working with young athletes (4).

The neuromuscular system is governed by the central nervous system, which is optimally stimulated by both load and velocity. This is important information for coaches to relate to in skill development (e.g., throwing or kicking farther in the early years rather than more accurately will optimally benefit the development of the action). However, it is important to note that in physical development terms, the output objective (e.g., strength, speed, power) must not come at the expense of optimal postures, as this would be contraindicative to the long-term development of the player. The ability to link effective movement postures with effective loading postures will provide a sound basis for the development of the football athlete over time.

SYSTEM INTEGRATION

A final consideration for the implementation of an effective LTAD model in a school or community is system alignment and integration (2). For LTAD to truly work, coaches need to be on same page within a league or community. Too often, there are incongruent practices from one team to another, let alone between sports. If there is no systematic progression or curriculum, then it becomes difficult to carry out progressions in skill development from one season or year to the next. Using the school analogy again, just think if there was no curriculum from grade to grade and teachers did not communicate with each other.

Finally, football is one sport—or one subject. System alignment and integration should also consider physical education and other sports, whether they be school or club sport. To have a developmentally appropriate model where everyone talks to each other and is on the same page across ages and sports is certainly easier said than done.

SUMMARY AND CONCLUSION

Despite recent concerns for the safety of the game and specifically short- and long-term brain injury, high school football remains the top participation sport among boys (15) and collegiate and professional football are widely popular. However, recent trends also indicate a decrease in participation at the youth (13) and high school levels (15) and in viewership at the professional level (5). Thus, many believe that it is a critical time for the game, and thus re-envisioning a long-term football development pathway, particularly at the youth level, is timely. This pathway should consider age- and developmentally-appropriate strategies for the technical, tactical, physical, and mental domains within game types that also fit the needs and capabilities of youth. In doing so, the football LTAD model needs to be athlete-centered, coach-driven, and supported by the administration. Finally, a sound LTAD program should foster competent and confident movers who can enjoy football and other physical activities and sports throughout the lifespan.

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ABOUT THE AUTHORS

Joe Eisenmann is a diverse scholar-practitioner with 25 years of experience as a professor, researcher, sport scientist, coach education, strength and conditioning coach, and youth sports coach. He completed his PhD at Michigan State University in 2000 and has held faculty positions at the University of Wyoming, York University, Iowa State University, and Michigan State University. He has published 180 peer-reviewed scientific papers, lectured nationally and internationally, served on several national-level committees and projects involving pediatric sports medicine, youth fitness, youth sports, and strength and conditioning, and has coached and developed thousands of youth athletes and coaches.

Clive Brewer is the Assistant Director of High Performance (Programs) for the Toronto Blue Jays Major League Baseball (MLB) team. Prior to this, from 2012 – 2014 he was the Head Strength and Conditioning Coach to Widnes Vikings Rugby League Club as they went from a new franchise to a playoff team in three years, and was the National Team Strength and Conditioning Coach for Scotland Rugby League. He was the Strength and Conditioning Coach for the Liverpool Ladies Football Club in the Football Association Women's Super League (FA WSL) in both their championship years. He is the International Association of Athletics Federation (IAAF) strength and conditioning expert for coach education, and has formerly held national lead roles as the Head of Human Performance with the Rugby Football League and SportScotland's National Programme Manager for Athlete Development. Brewer holds a Master's degree from Loughborough University, is accredited by the United Kingdom Strength and Conditioning Association (UKSCA) and the National Strength and Conditioning Association (NSCA), and was awarded a Fellowship of the UKSCA. He is accredited by the British Association of Sport and Exercise Sciences (BASES) as a Support Scientist, as well as being a Chartered Scientist with the United Kingdom Science Council (CSci). His latest book on developing athletic movement skills was published by Human Kinetics in the spring of 2017. A regular speaker at international conferences, Brewer has published two other books, five book chapters, and more than 15 papers in peer-reviewed journals.

THE NEED FOR SPEED—IMPROVING SPRINTING PERFORMANCE IN FOOTBALL PLAYERS

KEN CLARK, PHD, CSCS

INTRODUCTION

It has been said many times that "football is a game of inches," and now more than ever, football is a game of speed. With recent rule changes that favor wide open offensive attacks, such as increased protection of quarterbacks and wide receivers, and the proliferation of spread offenses and nickel defenses from the high school level through the professional ranks, fast athletes are more valuable than ever. Therefore, coaches are increasingly searching for the best methods to improve the speed of their individual athletes and their entire team. This article will review several aspects of sprint mechanics and training to enhance linear (straight-ahead) speed for football players.

First, a needs analysis of football game speed will be covered, to serve as the foundation for speed training protocols. Second, an examination of both acceleration and maximal velocity sprinting will be reviewed, including a review of the underlying biomechanical factors, and effective methods to increase performance. Finally, strategies for implementing speed training will be discussed, so that the reader can apply the concepts being presented in this article (agility and fitness/conditioning will not be discussed, as those topics are outside the scope of this article).

NEEDS ANALYSIS OF FOOTBALL SPEED

To better understand the best methods for improving linear speed for football players, the physiological and movement demands of game play must be understood. Across all levels of football (high school to college to the National Football League [NFL]), the average play from scrimmage lasts approximately 5 – 6 s (21). With regards to special teams plays, the typical punt lasts approximately 9 – 10 s and the typical kickoff lasts 8 – 11 s, depending on the level of play (21). There are approximately 6 – 8 plays per series and between 11 – 14 series per game, with an average of about 31 – 35 s between plays (13,21). Therefore, given a work-to-rest ratio that is close to 1-to-6 for football players at all levels, the energetic demands of football are highly anaerobic in nature (13,21).

The speed and distance covered per play obviously differs depending on position, success of the play, and position on the field. For example, recent Global Positioning System (GPS) data from a National Collegiate Athletic Association (NCAA) Division I team has shown that there are differences between positions for the number of sprints per game and the distance covered while sprinting (28). Skill positions (wide receivers and offensive/defensive backs) complete more high-speed sprints and sprint for longer distances than "big skill" positions (e.g., quarterbacks, tight ends, and linebackers), who in turn complete more high-speed sprints and sprint for longer distances than offensive and defensive lineman (28). Although nearly all players have to execute some form of acceleration on almost every play, most players will rarely approach maximal velocity in a game situation. Given this context, one interesting consideration is the amount of time that should be spent training for acceleration versus maximal velocity. Certainly, acceleration is of paramount importance to on-field performance, and must be trained on a regular basis.

However, although players may infrequently reach maximal velocity, it is indeed a factor in many game-breaking plays. In fact, recent in-game statistics demonstrate that wide receivers and offensive/defensive backs may reach peak velocities of greater than 10.0 m•s-1 (greater than 23 mph) during longer plays (26). Additionally, recent research has shown that maximal velocity is highly correlated with short sprint performance, and may serve as an upper limit to acceleration performance (9). Therefore, improving maximal velocity may indirectly improve acceleration, and thus may be warranted for all positions, although the total volume and training time devoted to maximal velocity sprinting should be less for lineman than for skill and big skill positions.

ACCELERATION

BIOMECHANICS OF ACCELERATION

To accelerate effectively, Newton's laws dictate that an athlete must satisfy two requirements. First, enough vertical force must be applied down into the ground to support and rebound the body upwards into the next step (7). Second, force must be applied backwards, as the horizontal action-reaction forces will propel the body forwards (7). Recent research has shown that athletes who apply more horizontal force in relation to body mass demonstrate greater acceleration performance (14,17,20). From a technique standpoint, this can be accomplished with an aggressive forward body lean, piston-like leg action, and a stiff ground contact on the ball of the foot. The foot should aim to strike underneath the hips, and not in front of the center of mass. The thighs should execute powerful scissor-like flexion and extension through big ranges of motion, with equally forceful arm drive originating from the shoulder joint. Excessive air time should be avoided during the beginning of a sprint, as increases in speed can only occur when the athlete is pushing into the ground. As opposed to maximal velocity sprinting, acceleration typically occurs with relatively flexed hip and knee angles, and muscle actions that have a large concentric component (4). Table 1 lists a technical checklist for both acceleration and maximal velocity.

TRAINING TO IMPROVE ACCELERATION

A number of training strategies have been shown to improve acceleration, including general methods (e.g., strength, power, and plyometric training), specific methods (e.g., sprinting with and without resistance), and combinations of both (22). As previously mentioned, force application is a key determinant of sprinting performance. Therefore, the goal of general training methods should be to increase the amount of force that can be generated and transmitted to the ground. It is important to note that due to Newton's Second Law (force = mass • acceleration or force ÷ mass = acceleration), an athlete's strength relative to body weight (relative strength) is a key factor in speed improvement. Prior research has demonstrated the relationship between relative strength and speed (24). Furthermore, although increasing lower body relative strength does not necessarily guarantee that an athlete will get faster, recent evidence suggests that there is a large transference from increases in relative strength improvements in speed (23).

With respect to strength and power training exercise selection, it may be logical to focus on closed-kinetic chain, multi-joint exercises that span the force-velocity curve. The force-velocity curve indicates that lighter loads can be moved at faster speeds while heavier loads are moved at slower speeds. Therefore, exercises that span this curve could include heavier load, slower velocity exercises such as the full squat and deadlift, and relatively lighter load and higher velocity movements like the Olympic-style lifts and derivatives to improve power (3,25). These exercises are similar to acceleration in that they work through large ranges of motion at the hip/knee/ankle joints and contain a forceful concentric phase to the lift.

With regards to plyometrics, utilizing both vertically- and horizontally-based exercises may be optimal, as this matches the force demands of initial acceleration (15). Therefore, examples of plyometrics aimed at improving acceleration include broad jumps, power skips for distance, and alternate leg sprint bounding. These plyometrics exercises are excellent for improving the acceleration phase of sprinting because they emphasize triple extension through the hip, knee, and ankle while projecting the body up and out, similar to the first few steps in a sprint.

Specific training for improving acceleration can include technical drills and both unresisted and resisted runs. Technical drills can include the wall drill series, which provides the athlete with context for the proper body angles and leg mechanics during acceleration. During these drills, the athlete leans in to a wall at approximately a 45 – 60° angle and executes powerful flexion-extension at the hip while maintaining proper posture from the stance foot through the hips and torso (Figure 1). Partner-resisted marches and skips using a torso-harness can also be effective to help the athlete learn to hold the body in an aggressive forward lean while striking down and back underneath the hips.

Because of the multi-directional nature of football, a variety of starting stances and starts should be utilized with regards to unassisted sprints. These variations can include two-point, three-point, prone, lateral facing, and rolling starts (where the athlete transitions from a jog to a sprint). Partner competitions or chase drills are also excellent for developing acceleration, and can include an "offense versus defense" reactive element which matches the demands of the game (see drill diagrams in Figures 3 and 4).

With regards to resisted sprinting, several different modes may be utilized. Uphill sprints are commonly employed as this appears to share biomechanical similarities to acceleration, and research has demonstrated that training on an incline sprint treadmill can improve acceleration performance (11,18). Additionally, over the last decade, resisted sprints via sled pulling (Figure 2) has become an increasingly popular form of training to enhance acceleration performance (19). Interestingly, recent research indicates that the training effects of resisted sprinting may be optimized with very heavy sled-pulling, incorporating sled loads of 10 – 40% bodyweight, with some researchers suggesting that a load equivalent to about 80% bodyweight may be ideal (10,19). Although more research is required to conclusively determine the ideal resisted sprint load for specific populations, it appears that resisted sprinting is generally as effective as or more effective than unresisted sprinting for improving acceleration (19).

MAXIMAL VELOCITY

BIOMECHANICS OF MAXIMAL VELOCITY

As top speed is approached, the body becomes upright, and most of the force is applied straight down into the ground. Furthermore, as running speeds increase, the amount of time the foot is on the ground decreases. Therefore, research has shown that runners with faster maximal velocities can apply more vertical force (relative to body mass) in shorter ground contact times than slower runners (6,29,30). From a technique standpoint, this can be accomplished in the following manner. The entire body posture should be upright with a neutral pelvis (hips pointed forward, not down). Once the foot toes off the ground, the thigh should not swing too far back behind the body, but rather should immediately swing forward in front of the body into a high knee-lift position. From this position, the foot should attack the ground, aiming to strike underneath the body. Ground contact should occur on the ball of the foot, and the entire body should be stiff and not collapse during ground contact (i.e., minimal compression of the center of mass during contact) (6,16). If this technical checklist can be accomplished, the athlete will deliver large amounts of vertical force into the ground in a short contact time, and maximal velocity can be optimized (6,8). Table 1 lists a technical checklist for both acceleration and maximal velocity.

TRAINING TO IMPROVE MAXIMAL VELOCITY

As with acceleration, a number of training strategies have been shown to improve maximal velocity, including both general methods and specific methods (21). For general training methods, the goal is again to improve force application in relation to bodyweight. However, because force application during top speed running may be more dependent on leg swing mechanics and stiffness upon ground contact as opposed to pure "weight room strength," resistance training for maximal velocity should reflect this (6,8). Exercise selection should include movements that incorporate eccentric muscle actions to match the initial force absorption portion of the ground contact phase. Also, because the posterior chain is important in high-speed running, including exercises such as the Romanian deadlift, one-leg Romanian deadlift, and other versions of straight-leg hip extensions may be especially important for maximal velocity development (3,12). Furthermore, to help prevent hamstring strains during high-speed running, coaches may want to incorporate exercises such as the eccentric Nordic hamstring curl (1). Plyometrics for this phase of sprinting should emphasize relatively shorter ground contact times and stiff ground contact mechanics. Therefore, depending on the level of athlete, simple but effective plyometrics for improving maximal velocity include in-place pogo jumps, one- and two-leg mini-hurdle jumps, and forward one-leg hops.

Specific training for enhancing maximal velocity include technical drills such as step-overs, straight-leg bounding, and mini-hurdle "wicket" runs (Figure 5) (30). Simply sprinting at maximal or near-maximal velocity may also elicit improvements, especially in populations of developmental athletes (5). Maximal velocity sprinting can include several types of drills, including flying sprints, technical build-ups, and sprint-float-sprints. Flying sprints consist of a gradual acceleration of 20 – 30 yd followed by a maximal velocity zone of 10 – 20 yd (Figure 6). Technical build-ups are similar to flying sprints with the addition that the coach provides the athlete with one technical cue to focus on for the duration of the sprint; typically, this cue is related to posture, leg swing mechanics, and/or ground contact. Sprint-float-sprints may extend slightly longer than 40 yd, and can help add short speed endurance to maximal velocity development. These typically consist of a gradual acceleration to approach maximal velocity from 30 – 40 yd, a 10-yard "float" zone from 40 – 50 yd, where the athlete runs at approximately 90% top speed while staying relaxed and focusing on correct mechanics, and then a re-acceleration to run at top speed for another 10 yd from 50 – 60 yd (Figure 7).

IMPLEMENTING SPEED TRAINING

There are several important considerations when designing speed development programs. First, the amount of time available to develop linear speed during the off-season, pre-season, or in-season is highly dependent on the level of play, the rules of the governing body, and the amount of training time allotted toward other physical capacities (e.g., strength, agility, conditioning, etc.). For the purposes of simplicity, this article will present an example program appropriate for an upper level high school or collegiate athlete who is completing speed training during the winter months prior to spring football, or during the summer months leading up to the season. A sample six-week training program is listed in Table 2, with two total hours per week devoted to linear speed training, one day focused on acceleration, and the other day focused on maximal velocity development. This example program assumes the athlete has already completed a dynamic warm-up, and does not include programming for general strength, agility, or fitness as these are outside the scope of this article.

The second important consideration relates to rest time between sprints. Regardless of whether acceleration or maximal velocity training is being performed, it is critical that the emphasis is on full recovery between sprints. Coaches should avoid the urge to rush recovery times and perform maximal effort sprints on incomplete rest, as this may be detrimental to performance since athletes may practice incorrect mechanics when fatigued (2). A good rule of thumb for recovery times is one minute rest for every 10 yd run, or one minute rest for every one second of work. Thus, the rest times should be 1 – 2 min for unassisted acceleration sprints, 2 – 3 min for resisted acceleration sprints, and 3 – 5 min for maximal velocity sprints. The emphasis for both acceleration and maximal velocity training should be low volumes of high quality sprints. With regard to plyometric volume for speed development, although about 80 total ground contacts per session may optimize speed improvement, this number must be carefully considered in context with the other loading demands on the athlete, and fewer ground contacts per session may be warranted (27).

SUMMARY

With enhanced team speed a constant priority, coaches who can conduct effective speed training programs are at a distinct advantage. Although acceleration is the primary form of linear speed demonstrated in football games, it may be worthwhile to address both acceleration and maximal velocity training. Through small volumes of high-intensity sprint efforts, executed with proper technique, athletes should demonstrate enhanced sprinting performance over time. It is hoped that this article provides the foundation for coaches to design and implement their own speed training.

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ABOUT THE AUTHOR

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FIGURE 1. WALL DRILL
Example of a wall drill. The athlete leans into the wall at about a 45 – 60° angle and executes a series of drills aimed at providing context for the posture, body angles, and leg mechanics necessary for proper acceleration mechanics. Examples of these wall drills include marches, runs, and single- or double-exchanges.

FIGURE 2. RESISTED SPRINTING
Resisted sprint training using a weighted sled. The resistance allows the athlete to maintain an aggressive lean while striking underneath the body with a forceful ground contact.

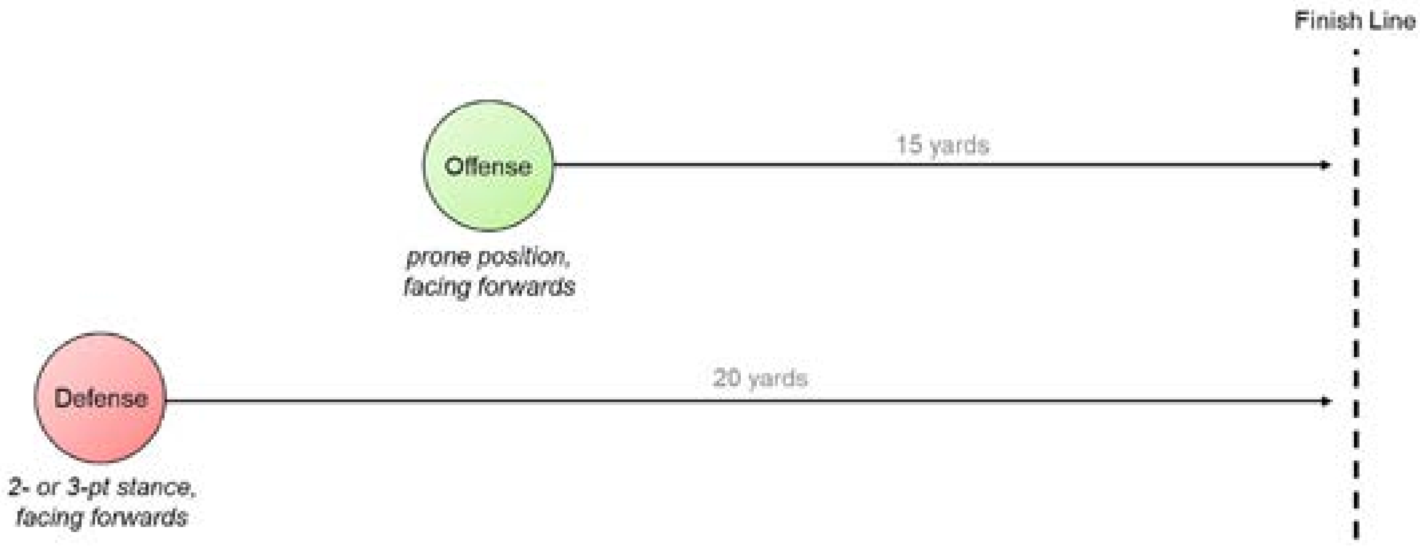


FIGURE 3. OFFENSE-DEFENSE ACCELERATION DRILL—VERSION A

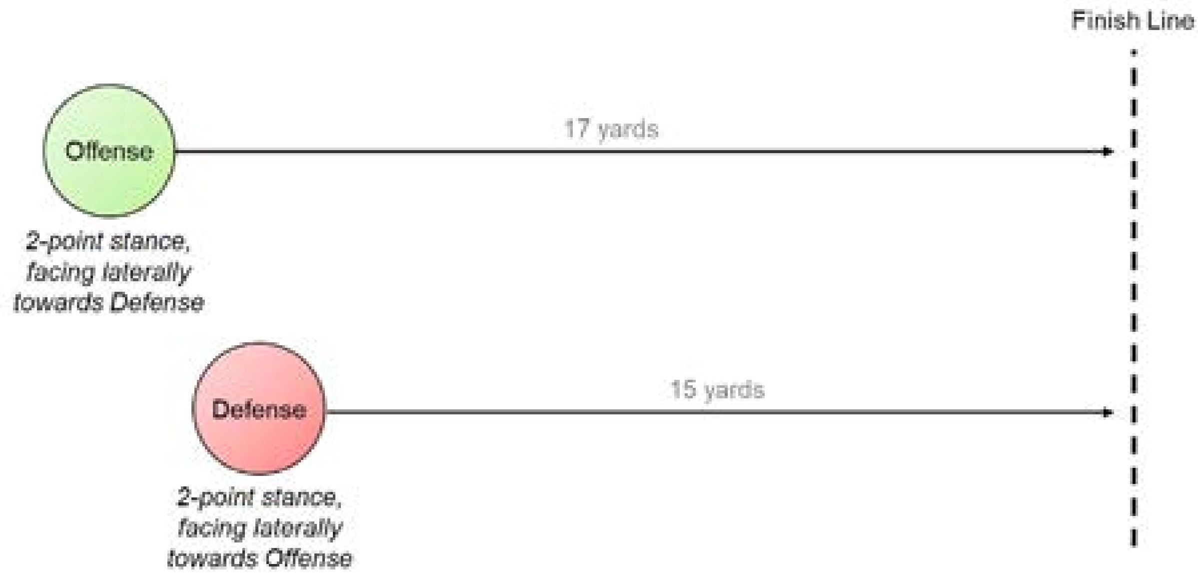


FIGURE 4. OFFENSE-DEFENSE ACCELERATION DRILL—VERSION B

There are two versions of offense-defense competition drills to develop acceleration. (A) The offensive player starts in a prone position, 15 yards from the finish line. The defensive player starts in a two- or three-point stance, 20 yd from the finish line. The offensive player initiates the start whenever he wants and pushes up to sprint, at which point the defensive player reacts and sprints. Both players race through the finish line. (B) The offensive player starts in a lateral position, 17 yd from the finish line (two yards behind the defensive player). The defensive player starts in a lateral position, 15 yd from the finish line. The offensive player initiates the start whenever he wants, at which point the defensive player reacts and sprints. Both players race through the finish line.

FIGURE 5. WICKET DRILL

The mini-hurdle "wicket" drill utilized to improve top speed mechanics. Athletes sprint over a series of six-inch hurdles at measured places on the track or turf. The faster or taller the athlete, the longer the spacing between the mini-hurdles. The mini-hurdles serve as environmental cues to ensure upright posture, minimal backside thigh swing, and powerful knee lift.

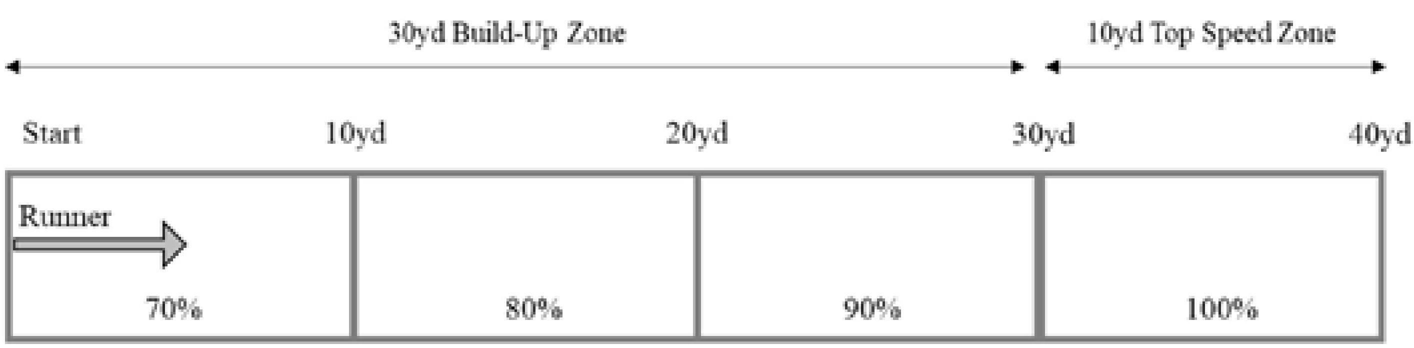


FIGURE 6. FLY DRILL

FIGURE 7. SPRINT-FLOAT-SPRINT DRILL

These are two types of drills to enhance top speed. (A) The 10-yd fly drill: the athlete begins in a two-point starting stance and gradually accelerates from 0 – 30 yd. From the 30 – 40 yd, the athlete sprints at top speed with proper mechanics. These trials may be timed with an automatic timing system for an easy method of monitoring improvements in top speed. (B) The sprint-float-sprint drill: the athlete begins in a two-point starting stance and gradually accelerates from 0 – 30 yd. The athlete sprints maximally from 30 – 40 yd, relaxes and sprints at about 90% from 40 – 50 yd, and then reaccelerates to sprint maximally from 50 – 60 yd.

TABLE 1. COACHING TECHNIQUE CHECKLIST FOR BOTH ACCELERATION AND MAXIMAL VELOCITY SPRINTING

	ACCELERATION	MAXIMAL VELOCITY
Posture and Hips	Leaning forward, with straight line from shoulder to hip to knee to foot	Trunk upright with minimal lean and hips pointed forward
Arm Drive	Big sweeping drive that originates from the shoulder; minimize excessive cross-body arm-swing	Slightly smaller range of motion than acceleration, but arm drive is still powerful and originates from shoulder
Leg Mechanics	Piston-like with thighs executing powerful scissor action (flexion-extension)	More circular; minimize thigh swing behind torso and maximize thigh lift in front of torso
Ground Contact	Stiff strike on ball of foot, contacting ground underneath hips	Attack the ground, stiff strike on ball of foot, aim to contact under hips

TABLE 2. EXAMPLE SIX-WEEK TRAINING PROGRAM FOR DEVELOPING LINEAR SPEED FOR A HIGH SCHOOL OR COLLEGIATE ATHLETE WHO PLAYS A SKILL OR BIG SKILL POSITION

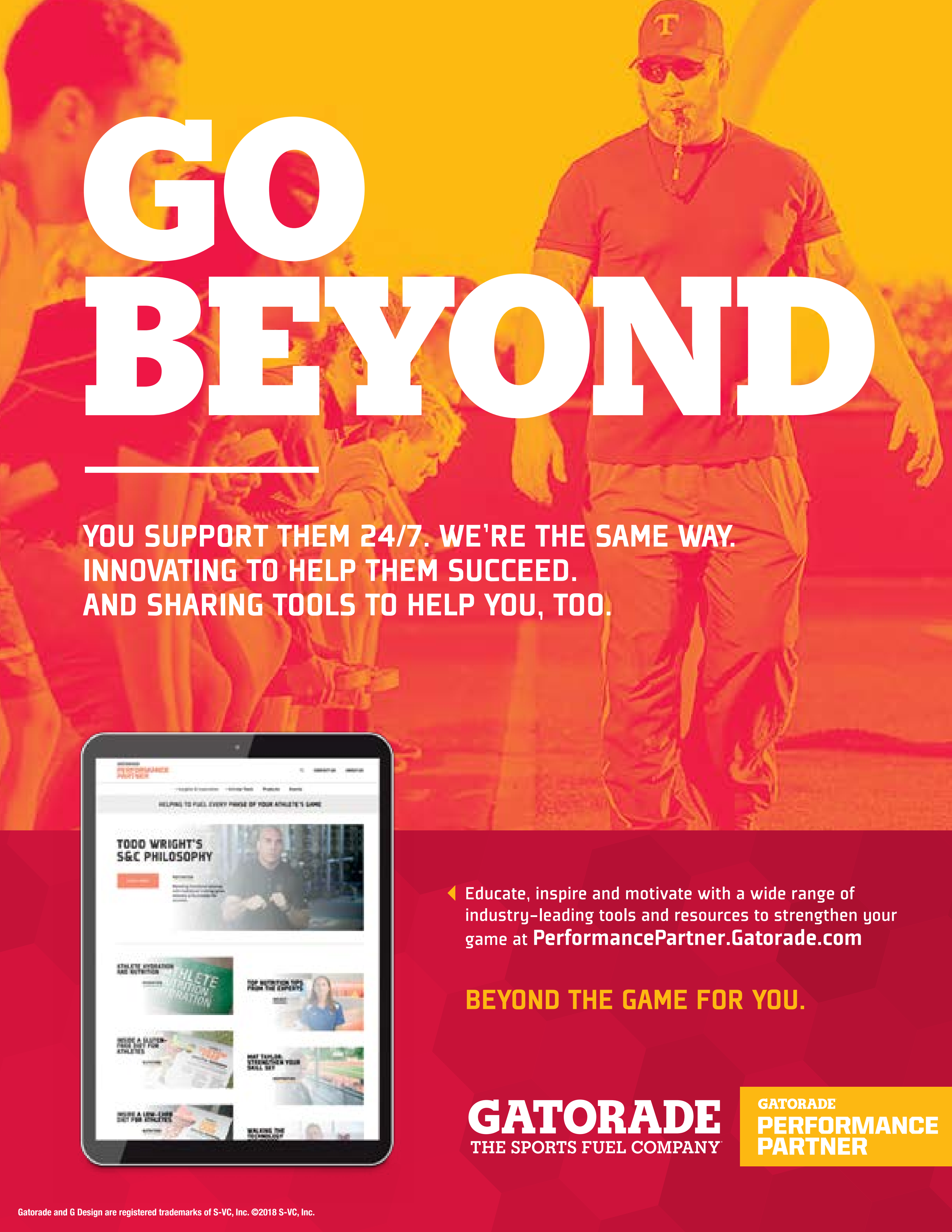
DAY	WORKOUT SEGMENT	WEEK 1	WEEK 2	WEEK 3
Day 1 Acceleration	**Plyometrics**	Single broad jumps 4 x 6 Power skips 4 x 20 yd	Single broad jumps 4 x 6 Power skips 4 x 20 yd	Single broad jumps 4 x 6 Power skips 4 x 20 yd
	Technical drills	Wall drill one-leg (Figure 1) 2 x 5 reps on each leg Partner harness march 2 x 10 yd	Wall one-leg flexion 2 x 5 reps each leg Partner harness march 2 x 10 yd	Wall march 2 x 5 reps on each leg Partner harness skip 2 x 10 yd
	Resisted sprints	Sled pull (Figure 2) with 20% bodyweight 6 x 10 yd	Sled pull with 20% bodyweight 6 x 15 yd	Sled pull with 30% bodyweight 6 x 10 yd
	Reactive or competitive	Partner races from various start positions 4 x 15 yd	Partner off/defense chase drill (Figure 3) 4 reps	Partner off/defense chase drill (Figure 4) 4 reps
Day 2 Max Velocity	**Plyometrics**	Two-leg pogo jumps 4 sets x 6 reps Two-leg forward mini-hurdle jumps 4 sets x 6 reps	Two-leg pogo jumps 4 sets x 6 reps Two-leg forward mini-hurdle jumps 4 sets x 6 reps	One-leg pogo hops 2 sets x 6 reps each leg One-leg forward mini-hurdle hops 2 x 6 reps each leg
	Technical drills	Step-over knee drill 2 x 15 yd Straight-leg run 2 x 15 yd	Step-over knee drill 2 x 20 yd Straight-leg run 2 x 20 yd	Wicket runs (Figure 5) 3 x 9 mini-hurdles (or 20 yd)
	Fly sprints	10-yd with 30-yd build-up (Figure 6) 3 reps	10-yd fly sprint with 30-yd build-up, 3 reps	20-yard fly sprint with 30-yd build-up, 3 reps

Note: Day one is focused on acceleration development and day two is focused on maximal velocity development. Training exercises and volumes may need to be adjusted/individualized based on the athlete and position.

TABLE 2 (CONTINUED). EXAMPLE SIX-WEEK TRAINING PROGRAM FOR DEVELOPING LINEAR SPEED FOR A HIGH SCHOOL OR COLLEGIATE ATHLETE WHO PLAYS A SKILL OR BIG SKILL POSITION

DAY	WORKOUT SEGMENT	WEEK 4	WEEK 5	WEEK 6
Day 1 Acceleration	**Plyometrics**	Repeat broad jump, 4 x 6 Sprint bounds 4 x 20 yd	Repeat broad jump 4 x 6 Sprint bounds 4 x 20 yd	Repeat broad jump 4 x 6 Sprint bounds 4 x 20 yd
	Technical drills	Wall march 2 x 5 reps each leg Partner harness skip 2 x 10 yd	Wall single exchange 2 x 5 reps each leg Partner harness sprint 2 x 10 yd	Wall single exchange 2 x 5 reps each leg Partner harness sprint 2 x 10 yd
	Resisted sprints	Sled pull with 30% bodyweight 6 x 15 yd	Sled pull with 40% bodyweight 6 x 10 yd	Sled pull with 40% bodyweight 6 x 15 yd
	Reactive or competitive	Partner races from various start positions 6 x 15 yd	Partner off/defense chase drill (Figure 3) 6 reps	Partner off/defense chase drill (Figure 4) 6 reps
Day 2 Max Velocity	**Plyometrics**	One-leg pogo hops 2 sets x 6 reps each leg One-leg forward mini-hurdle hops 2 x 6 reps each leg	One-leg pogo hops 2 sets x 6 reps each leg One-leg forward mini-hurdle hops 2 x 6 reps each leg	One-leg pogo hops 2 sets x 6 reps each leg One-leg forward mini-hurdle hops 2 x 6 reps each leg
	Technical drills	Wicket runs (Figure 5) 3 x 9 mini-hurdles (or 20 yd)	Wicket runs 3 x 12 mini-hurdles (or 25 yd)	Wicket runs 3 x 12 mini-hurdles (or 25 yd)
	Fly sprints	20-yd fly sprint with 30-yd build-up 3 reps	Sprint-float-sprint (Figure 7) 3 reps	Sprint-float-sprint (Figure 7) 3 reps

Note: Day one is focused on acceleration development and day two is focused on maximal velocity development. Training exercises and volumes may need to be adjusted/individualized based on the athlete and position.


GO BEYOND
YOU SUPPORT THEM 24/7. WE'RE THE SAME WAY.
INNOVATING TO HELP THEM SUCCEED.
AND SHARING TOOLS TO HELP YOU, TOO.
TODD WRIGHT'S S&C PHILOSOPHY
Educate, inspire and motivate with a wide range of industry-leading tools and resources to strengthen your game at PerformancePartner.Gatorade.com
BEYOND THE GAME FOR YOU.
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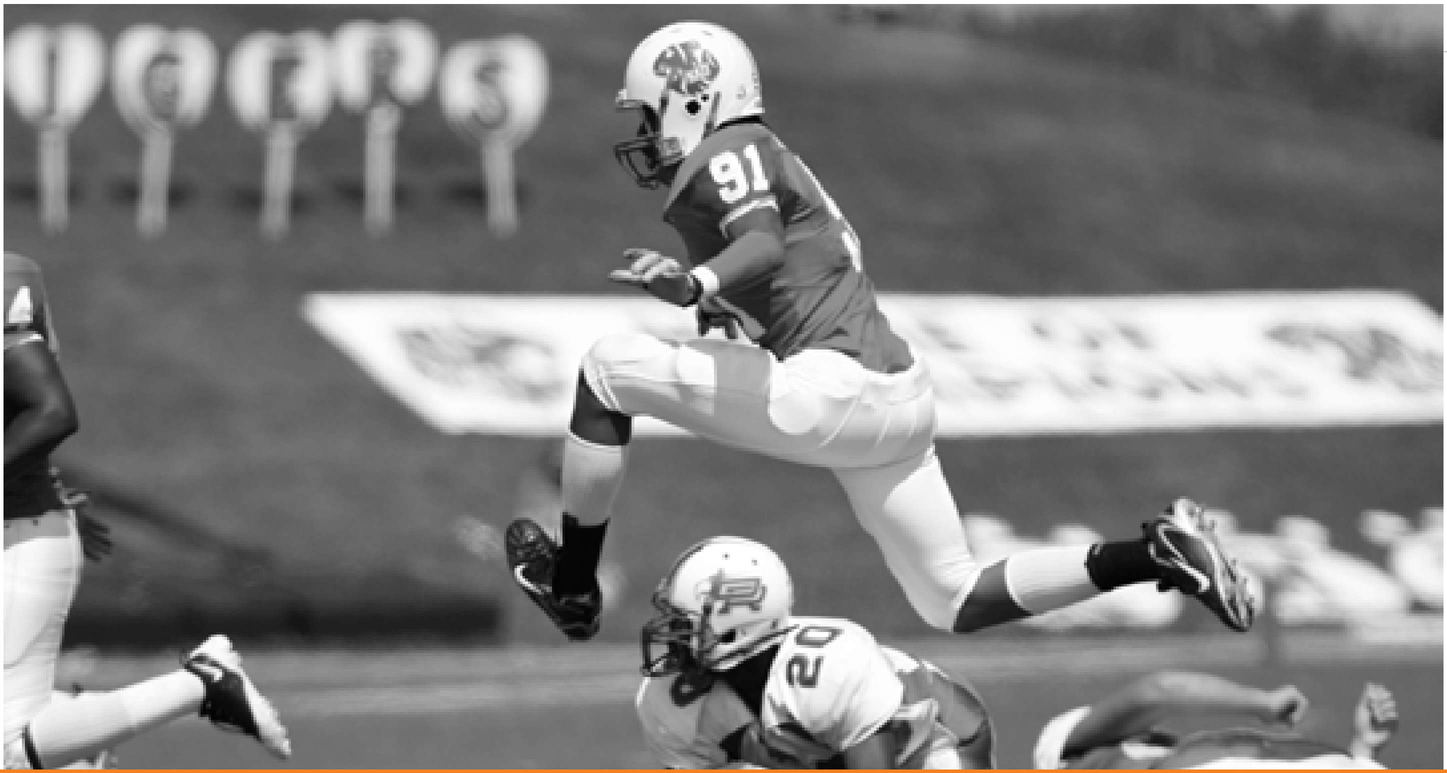

BIOENERGETIC DEMANDS OF AMERICAN FOOTBALL—CONSIDERATIONS FOR DEVELOPING A PREPARATORY CONDITIONING PROGRAM

JACE DERWIN, CSCS, RSCC

Preparation of the American football athlete requires the development of a wide array of physical qualities. Strength, muscular size, and speed all play important roles within the domain of the game. The expansion of bioenergetic efficiency within competition is equally important when it comes to the preparatory needs of the football athlete. Strength and conditioning plans devoid of specific and logical energy system development may not provide the appropriate stimulus to prepare athletes for competition. This article is intended to provide an understanding of the demands of the game from a bioenergetic perspective and provides a framework in which strength and conditioning professionals can design conditioning plans that focus on preparing athletes for competition.

BIOENERGETIC DEMANDS OF AMERICAN FOOTBALL

American football is comprised of short duration, repeated high-intensity efforts interspersed with short rest periods. At the professional and collegiate level, a game is played in four separate 15-min quarters in an exchange of plays (or series of plays) lasting between an average of 5 – 6 s per play (ranging from 2 – 13 s) with approximately 25 – 35 s of rest between plays (8,11,15). The short burst, high-intensity intermittent nature of football places a heavy demand on the alactic-anaerobic system, with reliance on adenosine triphosphate (ATP) and phosphocreatine (PCr) substrates to fuel the majority of muscular activity (8,9,13).

Depending on strategy and tactics, the total number of plays, series, and the total duration of rest intervals between plays will vary (11,15). Time-motion analysis highlights the various sprint speeds, distances, and durations completed by different position groups (16,21). Such observations shed light on the rapid utilization of PCr substrates to fuel short, high-intensity bursts of activity, and the need to resynthesize it between intense efforts. Collegiate athletes have also demonstrated improved muscle oxygen desaturation rates over the course of a season, highlighting an aerobic adaptation that occurs from a season's worth of participation in games and practices (8,9). A football-specific conditioning plan must address an athlete's ability to tolerate and improve their resilience to these specific stressors.

CONDITIONING NEEDS OF FOOTBALL

While football relies predominantly on anaerobic energy pathways to derive ATP, it is the aerobic system that facilitates the recovery of substrates necessary for repetitive anaerobic performance (7,17,20). The ability to perform maximal repeated bouts of exercise is influenced by the durations of both exercise and recovery. The more complete the restorative processes between bouts, the greater the ability to generate force or maintain power on subsequent work intervals (17,20). During brief recovery intervals, partial restoration of ATP, PCr, and oxymyoglobin occur (3,4,17,20). The rate of PCr regenesis seems to be influenced by the rate of oxidative metabolism within the muscle itself; thus, aerobic training can improve the ability of muscle to recover following anaerobic exercise as an athlete with greater aerobic adaptations can improve the repeatability of maximal anaerobic bouts (3,4,7,17,20). Therefore, a conditioning plan should account for both the alactic-anaerobic and aerobic energy system development.

Alactic-anaerobic training methods consist of explosive high-intensity exercises with substantial rest intervals between sets. These training methods involve exercises like sprinting, jumping, throwing, traditional, and explosive resistance training (Olympic-style weightlifting, etc.), and rapid change of direction drills. Work intervals of 6 – 10 s prioritize PCr as the primary energy substrate to derive ATP (4). Rest intervals between 2 – 5 min provides time for the PCr-ATP substrates to resynthesize to near completion without a substantial reliance on glycolysis (4,20). Because the metabolic consequence of increased anaerobic glycolysis is an increase in H+ concentration and depressed pH within the muscle, which may adversely affect performance by disrupting contractile processes, its value as a primary energy pathway should be limited (4,20).

Aerobic training in football is often minimized for the purpose of avoiding potential interference effect with strength training or anaerobic conditioning (4,18). Studies examining concurrent training methods (aerobic and anaerobic training simultaneously) display mixed results when it comes to notable interference of adaptations (19). Some researchers attribute mixed concurrent training results to both training methods independently signaling conflicting intermuscular adaptations (12,19). While aerobic training is not highly touted as a need for football athletes, PCr-resynthesis can be facilitated by a moderately developed aerobic capacity (50 ml/kg/min ± 5 ml/kg/min) and thus, one may argue that aerobic training should belong in a football-specific conditioning plan (9,17,20). Specialized development of the aerobic energy system provides a foundation of fitness that complements the efficiency of repeated alactic-anaerobic exercise.

Aerobic training methods are classically regarded as continuous moderate-intensity exercises or multi-movement circuits. For football athletes, long-distance running should be avoided for the purpose of mitigating an interference effect. An aerobic training response can also be created using high-intensity interval training (HIIT) (4,6,10). To create effective transfer to football gameplay, the aerobic energy system needs only to be trained enough to improve aerobic capacity. Utilizing sub-maximal sprints performed in succession (i.e., repeat sprints) can elicit an increased reliance on the aerobic energy system to resynthesize the PCr-ATP more effectively (17,20). For the purpose of increasing specificity, strength and conditioning coaches can modify work-to-rest ratios to mimic the game demands of football (6 – 15 s:30 – 45 s).

TABLE 1. ENERGY-SYSTEM DOMINANCE AS IT RELATES TO INTENSITY AND DURATION OF ACTIVITY

ACTIVITY DURATION	ACTIVITY INTENSITY	DOMINANT ENERGY SYSTEM(S)
0 – 6 s	Maximal	Alactic
6 – 30 s	Very high	Alactic and lactic
30 s – 2 min	High	Lactic
2 – 3 min	Moderate	Lactic and aerobic
>3 min	Low	Aerobic

Table adapted from Baechle and Earle, 2008 (2)

TABLE 2. HOW PLAY STYLE AFFECTS PLAY DURATION AND REST TIME BETWEEN PLAYS

STYLE	AVERAGE PLAY DURATION	REST MINIMUM	REST MAXIMUM
Run focused	4.84 s	16.59 s	46.93 s
Pass focused	5.41 s	16.59 s	45.92 s
Balanced	5.44 s	16.59 s	5.44 s
Average	5.23 s	16.59 s	46.9 s

Table adapted from Iosia and Bishop, 2008 (11)

TABLE 3. ALACTIC AND AEROBIC TRAINING ADAPTATIONS

ALACTIC TRAINING ADAPTATIONS	AEROBIC TRAINING ADAPTATIONS
Increased ATP and PCr substrate availability	Improved capillary density
Improved neuromuscular firing	Improved oxidative capacity of type II-A fibers
Improved type II-X fiber recruitment	Improved cardiac output
Improved intermuscular coordination	Improved heart rate recovery

Not all conditioning methods require running space or specialized equipment. The use of circuit-based callisthenic exercises (e.g., push-ups, bodyweight squats, burpees, etc.) for a seven-week training exposure can effectively improve aerobic capacity (10). These training methods also provide a general development of basic movement skills that can help to improve football-specific movement patterns. A key factor in implementing effective aerobic training methods is the intensity at which the training is conducted—the intensity must be limited to avoid too great an influence from the glycolytic energy system, which will provide metabolic byproducts that contribute to a greater rate of fatigue (4,20). Athletes should be continually reminded to perform sustainable efforts at an intensity at which they can easily repeat the training protocol. Utilizing too much intensity will inevitably shift the dominant energy-substrate usage to glycolytic pathways, which will dampen the development of the intended adaptations and quicken the time to fatigue.

Aerobic methods should be performed for intervals greater than 2 – 3 min per interval (4). Long recovery between intervals may not be necessary due to the lower intensity demand, and should be kept between 1 – 2 min if needed. More recovery may be warranted if athletes begin to show signs of extreme discomfort or difficulty breathing. The goal of these training methods should be to elevate the heart rate, use a wide range of muscle groups, and increase the breathing rate during submaximal exercise.

An effective alactic-aerobic program must be constructed in conjunction with the off-season resistance training program. Understanding the potential interference effect of concurrent

TABLE 4. ALACTIC AND AEROBIC TRAINING METHODS

ALACTIC CONDITIONING METHODS MAXIMAL EFFORT <6 – 15 S : 2 – 3+ MIN RECOVERY	AEROBIC CONDITIONING METHODS SUB-MAXIMAL/SUSTAINABLE EFFORT <2+ MIN : >1 – 2 MIN RECOVERY
Short sprints at maximal intensity	Extensive bodyweight calisthenics/core isolation
Acceleration/deceleration drills	Medicine ball circuit
Change of direction drills	Sled drag/push/march
Dynamic jumps and bounds	Extensive hops/jumps/skips
Explosive medicine ball throws/slams	Form running/low-velocity sprinting

TABLE 5. POSITION-BASED DISTRIBUTION OF DISTANCE COVERED AT VARIOUS SPEEDS

POSITION NAME	MAXIMUM DISTANCE RANGE (M)	% AT HIGH SPEED + MODERATE-HIGH-SPEED	% AT MODERATE + LOW-SPEED
Offensive Linemen	4,083.5 – 4,702.8	2%	98%
Quarterback	4,982.7 – 5,781.0	10%	90%
Running Back	3,862.9 – 4,912.0	18%	82%
Wide Receiver	5,629.6 – 6,875.9	22%	78%
Tight End	4,217.9 – 5,377.1	2%	98%
Defensive Back	5,288.0 – 7,003.8	26%	74%
Defensive Linemen	4,420.4 – 6,126.9	4%	96%
Linebackers	4,739.8 – 5,403.1	23%	77%

Table adapted from Sanders, 2017 (16)

training goals, the strength and conditioning coach should implement appropriate training methods and program organization to minimize its occurrence (12). Separation of alactic- and aerobic-dominant training sessions is an economical way to organize training methods. This method gives the strength and conditioning coach the ability to organize all training sessions (e.g., resistance training, speed training, power training, conditioning, etc.) in a manner that best complements each individual session.

PROGRESSION OF WORKLOADS

The proper progression of training loads must be followed so that athletes can develop fitness qualities that improve performance and reduce the likelihood of injury. The relative acute training load as it compares to a weekly average training load can reliably assist in monitoring the progression of training loads on a weekly basis (deemed the acute:chronic workload) (5). It should be noted that the determination of an "optimal" workload is not a static measure—it will differ for every athlete and change from day to day depending on sleep, nutrition, and other factors affecting recovery ability (5). Adapting training programs so that athletes can consistently train at a workload that is beneficial to their training readiness takes time, effort, and planning. Strength and conditioning coaches should utilize a measure of internal load (e.g., heart rate, ratings of perceived exertion, and blood lactate), and at least one measure of external load (e.g., training duration, distance covered, and total number of accelerations) when determining the optimal workloads of their athletes (5). Progressing training loads no more than 10% provides an easily implementable heuristic (5). The use of technological resources like Global Positioning System (GPS) and heart rate monitors, as well as subjective wellness or rating of perceived exertion questionnaires that can be administered via technology, are all valuable tools for measuring the cumulative effects of fatigue. For strength and conditioning coaches without financial resources or an aversion to technology, the use of detailed recorded distances and durations of conditioning sessions can provide a measure of external load and can be used in conjunction with self-reported rating of perceived exertion as a measure of internal load (5).

INTEGRATING POSITION-SPECIFIC TRAINING METHODS

The closer that the training environment can replicate game-time demands, the greater the degree of transfer, as stated by the specific adaptations to imposed demands (SAID) principle (2). Integrating alactic-anaerobic and aerobic conditioning stressors specific to the unique movement and energy system requirements of each position group allows for a greater degree of specificity.

Positions are categorically split into offensive- and defensive-focused positions with each position tasked with different game demands. Offensive positional categories include offensive linemen, running backs, quarterbacks, tight ends, and wide receivers. Defensive positions include linebackers, defensive linemen, and defensive backs. Considering the total distance athletes cover and the percent of that distance in which they are at moderate to high speeds provides strength and conditioning coaches a framework to distribute total volume of sprint work per positional needs.

Equipment such as tackle pads or tackle dummies can allow for game-specific motor skills to be utilized during conditioning. Similarly, allowing quarterbacks to finish a conditioning drill with a pass to a target or a receiver on a route run can closely mimic game-time conditions. By modeling metabolic training programs on the competitive demands of the game, football coaches and strength and conditioning coaches can help to prepare athletes for game-time situations in the most effective and efficient manner (15).

CONCLUSION

Proper conditioning plans prepare collegiate and professional football athletes for the stress of competition. Specificity of position-specific skills, work-to-rest ratios, speeds, and distances are aims of improving the transferability of training to competition. Using general conditioning methods earlier in the off-season and transitioning to specific conditioning methods can help to establish a baseline of physiological fitness as well as reduce the risk of overtraining. Progressing athletes with appropriate chronic workloads has been shown to improve athlete resiliency and help prevent soft-tissue injuries (5). The use of technology in

TABLE 6. POSITION-SPECIFIC TRAINING METHODS

POSITION-SPECIFIC ALACTIC/AEROBIC METHODS INTERVALS OF <6 – 15 S : RECOVERY 25 – 45 S 10 – 20 SERIES X 4 SETS X 4 REPS	
Wide Receiver/Defensive Back	Route patterns/coverage or blitz
Linebacker/Tight End/Running Back	Multidirectional shuttles/sprint intervals/route or run patterns
Offensive Lineman/Defensive Lineman	Multidirectional shuttles/sprint intervals
Quarterback/Punter/Kicker	Multidirectional shuttles with pass or kick/sprint intervals

football has allowed for greater levels of analysis that can provide insights to guide the development of the football athlete. GPS technology used in gameplay and practices can help to quantify the total accumulated load of a training session or competition (1,15,16,21). Even without the assistance of technology, strength and conditioning coaches can still implement conditioning plans specific to the position group or individual athlete. Being conscious of play style, positon-specific workloads, and acute and chronic workload ratios can help to make conditioning plans more effective than general running plans.

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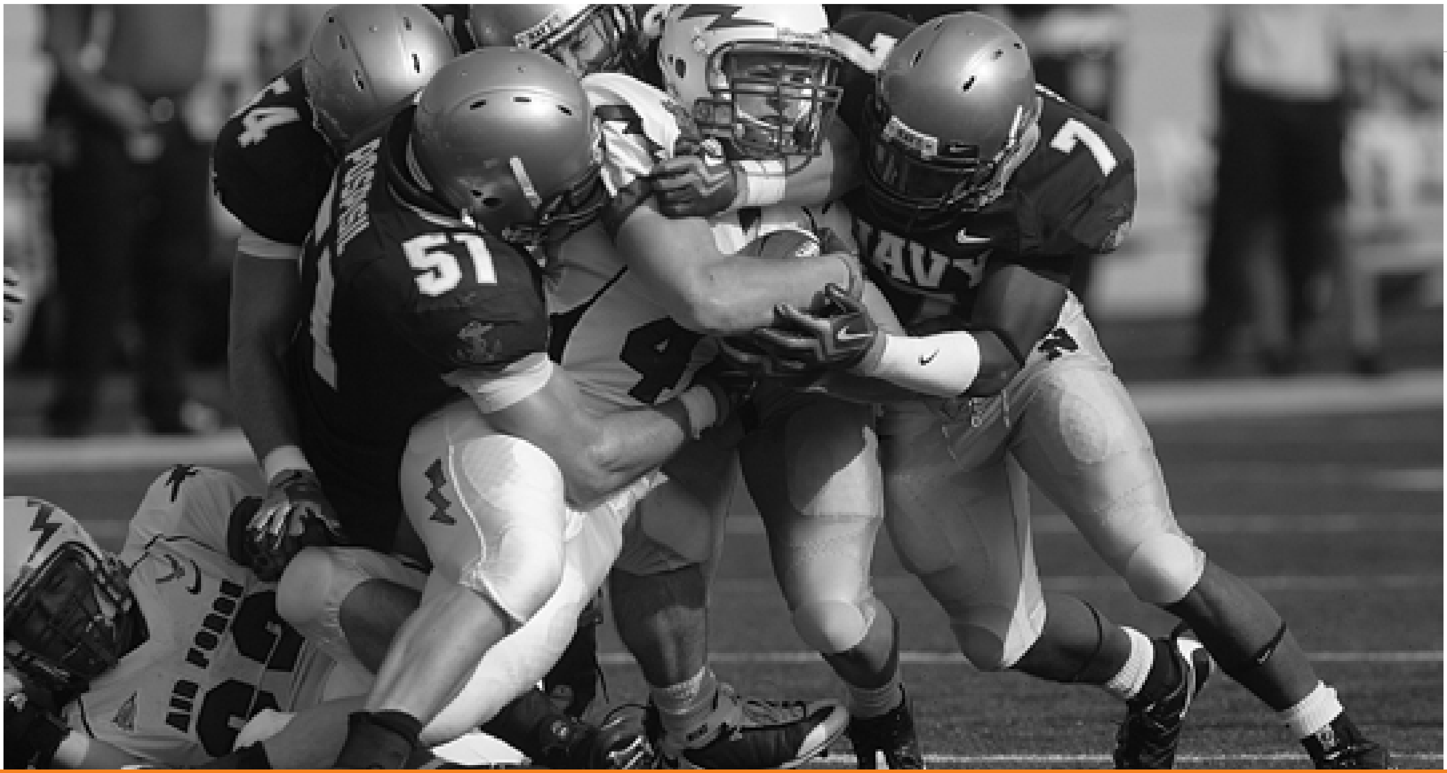

MONITORING TRAINING LOAD IN AMERICAN FOOTBALL

ANDREW MURRAY, MSC, CSCI, CSCS

It is well-accepted that both under- and over-training can increase the risk of injury in sports (21). It is typical that excessive and rapid increases in workload concomitantly result in sharp increases in injury risk regardless of the sport (21). Exceeding 20% of modified training (15) increases the risk of failure, regardless if this occurs due to injury or illness (33). Therefore, finding ways to ensure a consistency of training would seem to be key regardless of the performance level. One way to achieve this is to monitor training load globally (e.g., physiological, biomechanical, structural, and psychological) within the training and competition phases. Typically, monitoring systems within team sports can improve performance while managing the training loads (2).

Monitoring training load is essential for determining if athletes are adapting positively or negatively to their training program. This can be done through internal (biological stressors) or external (objective measures of work done) means. When possible, an integrated approach examining both the internal and external loads yields a more holistic picture. For example an uncoupling in the external and internal response may allow coaches to determine if adaptations to training are positive or negative (23). Such collective information allows discussions to be had with coaches about what is important for them to know to modify training but also what is important for them to develop for success in their sport. Until recently, few scientific investigations objectively quantified the demands of training and games in American Football (AF) (38,39,42).

Once the determinants of performance are established and a performance model agreed upon between the coach and performance support team (Figure 1), opportunities for growth that target gaps in individual's development can be identified. This allows for the development of plans ranging from the annual training plan to the individual session. Once this is established then the progression in load to achieve these objectives and the percentage of time spent in each area can be discussed and subsequently measured against the agreed standard of success. The purpose of this article is to highlight some of the common methods for monitoring training load utilized within AF and how these can be utilized at various levels.

WHY DOES THIS MATTER?

Training load data can be used to assess progress of teams and individuals. For example, for many teams the first week of pre-season camp represents an acute, and often, significant increase in training load (37). This outcome contrasts progressive recommendations for training load needed to minimize the risk of injury (24) and optimize athlete preparation. Depending on the coaches' philosophy, pre-season sessions may reflect a "survival of fittest" approach. Conversely, coaches may be more conservative and believe that increased completion rates of training sessions may increase athlete's robustness. The secondary belief is consistent with some of the literature, which suggests high chronic loads are protective (11). Without monitoring AF athletes, it is difficult to make assumptions on their progression. Monitoring training loads should allow athletes training loads to be managed so that they progress without adverse outcomes.

The goal regardless of the season phase in AF should be to have most athletes available each week. At lower levels, this may be driven by participation and at more elite levels by the desire to win and having the best athletes available. Regardless of the system, if there is not effective communication among staff then the cumulative loads can be too high and may lead to injury (i.e., high school athletes training with multiple teams or elite athletes doing more in the weight room with the strength and conditioning coach). Conversely the AF athlete should also trust the program and only do the programmed sessions to adapt as intended. After all, the purpose of a periodized training program is to cause a positive training adaptation. This is difficult to attain when athletes do not follow the prescribed training program as designed by the strength and conditioning coach.

HOW IS LOAD MONITORED—AVAILABLE METHODS

Some common methods in AF are shown in Table 1. Internal markers deal with the relative biological stressors from training whereas external loads are objective measures of work performed. Outside well-resourced teams, the use of global positioning systems (GPS) can be cost prohibitive and so other markers must be used to monitor load and subsequently adjust programs. The most common of these will be discussed here. Most contemporary monitoring systems should be able to manage "large" amounts of data collected, make meaningful interpretations of these data to inform subsequent training prescription and translate these interpretations into actionable steps for coaches and performance staff (22).

ATTENDANCE

Attendance is very simple and therefore the easiest assessment to measure each week. This requires nothing more than a watch and a pencil to document volume (duration and frequency) on paper and be applied to all AF athletes with minimal costs. This could entail simply looking at the count of sessions completed, relative to sessions missed, as a crude measure of load (e.g., attendance rate = sessions completed / total sessions). This can identify issues and difficult periods for high school or college athletes (i.e., finals). It can add further insight if the session type and or content is also recorded (for example conditioning, lifting, and technical coaching).

SESSION RATING OF PERCEIVED EXERTION (SRPE)

The sRPE was developed to enable simple and reliable estimation of exercise intensity (4). The scale was based on the level of perceived strain experienced during physical activity, as estimated by a specific rating on a scale of 6 (no exertion at all) to 20 (maximal exertion) (4). This scale was chosen for its correlation to heart rate (i.e., average heart rate is sRPE x 10). Since the inception of the original Borg sRPE scale over 40 years ago, the CR-10 RPE scale has become a reference method (0 [nothing at all] to 10 ["maximal"]) to evaluate perceived exertion in a variety of circumstances and has been validated against objective markers of intensity (32). Research by Foster and colleagues (18,19) indicated that the sRPE scale is an effective method of quantifying exercise across a wide variety of modalities. It is now common for a differential RPE rating to be used to look at the load on the

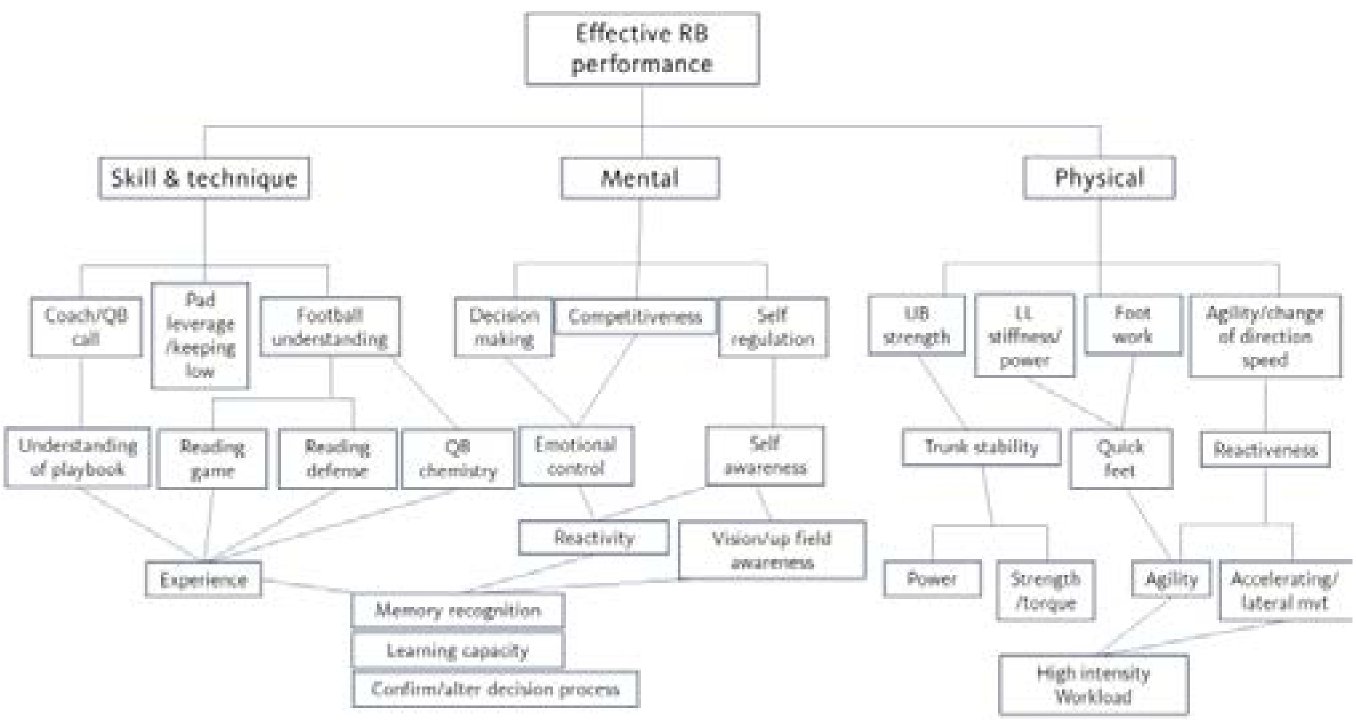

FIGURE 1. PERFORMANCE MODEL FOR RUNNING BACKS WITHIN AF

Key: QB = Quarterback; UB = Upper Body; LL = Lower Limb; Mvt = movement.

TABLE 1. COMMON METHODS USED TO MONITOR ATHLETE TRAINING LOAD IN AMERICAN FOOTBALL

Method	Cost	Equipment Needed	Software Needed	Ease	Validity/Reliability	For interpretation	For prescription	Variables
Internal								
RPE	L	N	Y/N	H	M-H	Y	Y	Single variable in AU
HR	L-M	Y	Y	H	H	Y	Y	HR, time in zone etc
External								
Time	L	Y	Y/N	H	H	Y	Y	Units of time (min:s)
Frequency	L	N	N	H	H	Y	Y	Session Count
Reps	L	Y/N	Y/N	M-H	M-H	Y	Y	Reps taken
GPS measures	M	Y	Y	M	M-H	Y	Y	Velocity, distance, acceleration
Accelerometry measures	M	Y	Y	L-M	M-H	Y	N	x-y-z g force

Abbreviations: L=Low; M=Medium; H=High; Y=Yes;N=No; AU=Arbitrary Units

Key: RPE = Rating of Perceived Exertion; HR=Heart Rate; GPS =Global Positioning System. Adapted from Bourdon et al. (5)

"legs" and "lungs" independently (30,40). Wherever the process is implemented, caution must be applied to ensure that athletes are educated on the use of a validated scale (1). The original method called for collection 30 minutes after a session to ensure a robust and valid sRPE. This temporal factor may be challenged in a practical environment (9,35) and may not be as much of a concern as initially thought (17). Consistency of data collection time and method (i.e., collecting values independently of peers) should be considered before implementing this cost-effective method in AF.

HEART RATE (HR)

The main interest in measuring HR is that it is objective, relatively non-invasive, inexpensive, time-efficient and can be applied to almost all athletes. Within AF there are some challenges with equipment (i.e., pads) that can interfere with chest worn monitors though this minor limitation can be overcome with some basic education (10). HR scores can give an almost instant snapshot of the physiological response to any training stimulus providing feedback on intensity and potentially fitness of the playing group. Expressing these HR scores relative to maximum heart rates (% HRmax) allows comparison across the group and greater training individualization. Within AF certain position groups (e.g., linemen) may be more suited to utilizing HR than others but decisions should be made holistically based on other load monitoring methods utilized and the constraints of individual's situations.

GPS/IMU

The use of GPS and inertial measurement units (IMU) to quantify external training and match load is becoming commonplace in collegiate and professional AF. Despite routine use to monitor training load in college and professional football, there are presently few investigations which have quantified the physical demands of AF gameplay. One study monitored Division I AF athletes across regular season games (39). This research found significant differences between offensive and defensive positional groups with wide receivers and defensive backs completing significantly greater total distance, high-intensity running, sprint distance, and high-intensity accelerations (positive and negative) than other positions. The average total distance ranges between 3,200 – 6,000 yards (170 – 715 yards of high-intensity running) (39).

The differences in high-intensity work are consistent with pre-season periods where non-linemen cover more high-intensity distance than linemen (29). Separate research has analyzed the intensity, number and distribution of impact forces experienced by AF athletes during competition using integrated accelerometery (38). Within the offensive groups, wide receivers sustained more moderate to light impacts than other position groups, whereas running backs were found to endure the most severe impacts, except for the quarterbacks. Defensive backs and linebackers absorbed more light impacts, and interior defensive linemen reported significantly more heavy and very heavy impacts (based on G-forces) than other defensive positions (38). These studies (29,38,39) further our understanding of the individual demands imposed on AF athletes, which may form the basis for position-specific monitoring and training in the preparation for the specific load and impact forces experienced in games.

For the masses, knowledge of the typical positional demands may be the most valuable aspect of GPS technology, rather than owning a system. The cost may make them prohibitive for some programs, especially when the number of athletes within AF is considered (e.g., 105). Another consideration when utilizing GPS is the time dedicated to the analysis of the data to make it meaningful. If these costs can be met, the information can be extremely valuable and consistent across field sessions. It is more common to utilize the IMU portion of the GPS units and the associated accelerometers and gyroscopes to measure "player load," as this is consistently generated across indoor and outdoor training sessions, where the GPS information (e.g., velocity and distance) is not. For a detailed account of factors to consider when implementing GPS technology in team sports, please refer to Malone and colleagues (28), and Cardinale and Varley (8).

ACCELEROMETERY

It is now possible to monitor movement patterns without modifying the athletes normal practice environment. One of these movement patterns is the throwing motion of quarterbacks. Utilizing miniature accelerometers, it is possible to monitor the forces and torque in athletes arms alongside a basic count of throws completed (14). In other sports such as baseball, throw counts are commonplace. For example, among youth pitchers a moderate volume of pitches was protective from injury, a low volume made no difference and a high volume (> 600 pitches in a season) was associated with a high risk of injury (26,27). Outside of quarterbacks, the use of accelerometers could also be extended to kickers and punters as the repetitive volume on the lower limbs can also cause stress (similarly to soccer where the kicking demands vary across positions) (41). Knowledge of the demands and volume trained for quarterbacks and kickers can aid AF coaches in training design by informing them on physical preparation needed for these specific positions.

RESISTANCE EXERCISE

The inherent complexity of the strength and conditioning environment and the number of variables involved (sets, reps, loads, exercise type, etc.) make it difficult to assess the collective load. Standardizing this is also difficult without knowledge of repetition maximums (as may be the case in younger individuals) or accounting for rest periods and velocities of movement (34). Methods to monitor the external total volume load (i.e., total tonnage), alongside the exertion (i.e., an athlete training diary) would create good habits and a format for objective feedback during the periodized program. Given the predominance of resistance exercise in AF as a training modality, efforts need to be made to quantify this portion of training because of its predominance during the year. In addition, there is a need to consider the collective load of strength training along with the on-field training load.

ANALYSIS

Regardless of the load variable measured, the interpretation needs context to evaluate the success of its implementation relative to the plan. Within any sport the efficacy of training is often judged by the scoreboard rather than the performance or fitness level. A systems approach to sports preparation adopts a proposal to model "performance" based on assessments of fitness and fatigue (3). Fitness is considered a positive influence on performance and while slow to develop is also slow to dissipate (7). However, fatigue can occur quickly and dissipate more rapidly. This predicts "performance" by comparing acute (short term; i.e., one week) and chronic (longer term; i.e., one month) workloads (2,3) (i.e., any training session has a short term affect [fatigue] and a longer term benefit [fitness]). The difference between these two influences at any point is the subsequent performance level. In this model where performance is estimated as "fitness" minus "fatigue," the chronic workload represents a marker of "fitness," while the acute workload represents a marker of "fatigue." The difference between the positive function of fitness and the negative function of fatigue provides either a positive (i.e., chronic workload is above the acute workload) or negative (i.e., acute workload is above the chronic workload) outcome.

In the recent literature this balance has been popularized as the acute-to-chronic-workload ratio (ACWR) or the training stress balance. (21) The ACWR is a simplification of the original fitness-fatigue model (2), which uses rolling averages to compare training loads completed in a recent period (acute; usually ~5 – 10 days) with the chronic training load completed over longer period (usually ~4 – 6 weeks) (20,24). This analytical approach has recently been reported to identify injury risk in a variety of athletes (6,24,31). Notwithstanding recent debates over the most appropriate construction of the ratio (25) or the duration of the acute or chronic periods the important part is the assessment of the balance of training, as there is no definitive evidence that one ratio is better than another (16). For the moment, accumulating chronic loads in a safe manner (i.e., avoiding large spikes in training load; < 10% increase) seems to be the primary factor to avoiding injury (21). While guidelines suggest practitioners should aim to maintain the acute and chronic workload ratio within a range of approximately 0.8 – 1.3, different sports will likely have different training load–injury relationships that apply to them. Therefore, applying these recommendations to individual AF athletes should be performed with caution, as it may result in loss of opportunities to improve by modifying sessions needlessly. The ACWR may be viewed in relation to other statistics derived from the training schedule such as monotony or strain (19), as all of these may influence daily variation and purposeful reductions in load to manage fatigue, avoid overtraining and maximize adaptation.

This analysis may not only encompass measures of training load but there may also be a multitude of life stressors that contribute to the overall load depending on the level of AF athletes (i.e., collegiate or school aged athletes experience additional stress and cognitive load around exam time). In most cases the best markers will be holistic. The mode of exercise/training may be characterized by specific physiological and psychological demands which vary not only with the "dose" of the activity (sets, repetitions, duration, etc.) but also with the "vehicle" (e.g., strength training vs. sports specific training) for training. A global measure would allow comparison of the objective intention of the session by the coach (i.e., the planned dose) against the response of the athletes (i.e., measured response). In other sports it has been shown that there is a tendency for athletes to experience higher loads when the session is meant to be "easy" and lower loads when it is intended to be "hard" (36). If these show disparity (i.e., the easy becomes hard and the hard easy) then there may be a need to modify future sessions.

RECOMMENDATIONS

The first step in monitoring training loads is establishing its need with education of the key stakeholders (i.e., athletes and coaches) as to what the benefits are (i.e., increased athlete availability). This allows the message to be communicated that the monitoring program is there to complement and reinforce the intuition (i.e., "gut feel") of the AF coaches rather than replace entirely (22).

The correct amount of load for an athlete is that which is "just right" (13); however, determining this level without specific information about training loads and the benefit of experience is the challenge. The goal should be to establish parsimonious monitoring systems that consider training loads holistically, are both cost- and time-effective (12) and allow informed decisions to be made around athlete management.

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A QUARTERBACK-SPECIFIC MOVEMENT PROGRAM

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INTRODUCTION

The football quarterback (QB) is a unique position in sport. To throw or pass the ball, the QB needs to incorporate nearly every muscle in the body in a very precise sequence to optimally release the ball with the right amount of power, spin, and precision. To accomplish this outcome, QBs need to have efficient movement patterns to drop back and setup in order to release the ball appropriately. It is important to understand the biomechanics of the throwing motion involved and the need to train the QB to perform the movements necessary to move efficiently, position the limbs effectively and load the kinetic chain successfully (8).

As a strength and conditioning professional working with a QB, it is important to understand the offensive philosophy of the offensive coordinator and QB coach. The reason is that many schemes are somewhat different and the need to develop the QB to perform at a high level requires training specific work:rest ratios, angles of release, or timing differences. Other areas of focus should be on timing from the snap and also how many seconds the QB usually spends in the pocket. Although these aspects are on-field parameters, it is important for a strength and conditioning professional to be very aware of these specific game demands and design the training program accordingly. The purpose of this article is to provide a quick review of the movement and throwing motion of the QB with a few specific exercises that can help improve the QB's movement to optimize throwing performance.

MOVEMENT AND THROWING MOTION

One of the major aspects of training the QB from the physical perspective is to ensure that the interplay between movement and throwing are well understood. The reason that movement is important is to allow the QB to better store the potential energy and then subsequently release this energy (kinetic energy) to execute a powerful and successful throwing motion. Besides training, the mechanics of throwing in his on-field drills the QB also needs to develop arm strength, hip strength, core control, and footwork that can help transfer to the on-field training and game days. All of this needs to occur within a minimal time period under significant time pressure (due to the defensive players attempting to tackle or pressure the QB) and ever changing defensive schemes. Being a QB at all levels of football (youth, high school, collegiate, or professional) is challenging because of the factors mentioned above. However, having a structured QB-specific program can aid in the development of the athlete and help them perform on the field by creating and implementing a training program to focus on the specific needs of the position within the larger team-based strength and conditioning program.

Designing a QB-specific movement training program needs to have QB-focused drills and progressions that are specific to the complex interaction between explosiveness and stability. An important aspect in addition to the performance benefits of movement training should also be the focus on reducing the chance of injuries associated with poor neuromuscular control as well as the potential for overuse and the maladaptation seen in the repeated environment of throwing (1,7).

The objective of a QB-specific training program needs to be focused on how to make the QB a better football player for success on the field, not just better in the weight room. Many training devices and implements such as weighted/unweighted tools may be used to the train the QB, but to successfully design a QB-centric program, it is important for a strength and conditioning professional to have a basic understanding of the QB throwing motion and then it is easier to incorporate an appropriate movement training program for the QB. Without understanding the throwing motion, knowing the requirements of movement become difficult. Movement training for the QB ties directly into the throwing motion. The outcome on the throwing motion will be compromised if the QB's movement is not at a level to load and release effectively. Although many models exist highlighting the different stages of the throwing motion, one of the most often used in the scientific literature is the four phase model; which is typically described as 1) early cocking, 2) late cocking, 3) acceleration, and 4) follow through as described below (5):

1. **Early cocking**: The early cocking phase is initiated at rear foot plant and continued to maximal shoulder abduction and internal rotation. Greatest maximal voluntary isometric contraction (MVIC) activity are seen in the infraspinatus (46%) and supraspinatus (45%) muscles (Figure 1—Photo 5) (5).

2. **Late cocking**: The late cocking phase starts at maximal shoulder abduction and internal rotation and ends with maximal shoulder external rotation. Increased global activity except middle deltoid. The MVIC activity in the infraspinatus (69%) and supraspinatus (65%) are highest overall (5).

3. **Acceleration**: The acceleration phase begins with maximal shoulder external rotation and ends with ball release. Overall global increased activation with highest MVIC in pectoralis major (86%) and subscapularis (81%) (Figure 1—Photo 8).

4. **Follow through**: The follow through phase is defined from ball release to maximal horizontal adduction (across the body). This is where an increase in MVIC of infraspinatus (86%) and supraspinatus (87%) to join pectoralis major (79%) and subscapularis (95%) in high levels of activity is seen (Figure 1—Photo 9).

When throwing overhead, there is a proximal to distal sequencing supplied by the kinetic chain (3,4). This refers to the need to summate forces from the body out into the arm and finally this energy is released into the ball to allow for the throw and release of the ball. This sequencing is a vital aspect for both performance and injury prevention. Training the athlete to effectively transfer energy from the ground up through the entire kinetic chain in the most efficient manner is an area that is typically left to the sports (or technical skills) coach. However, appropriate strength and conditioning programs can aid in the overall development of the athlete and play an important role in training throwing mechanics. It is important to remember that most strength and conditioning professionals are not skills coaches, and understanding different roles in the development of the athlete is very important. Current technique can be improved in areas like hip function (to improve stability and rotation), shoulder stability (to aid in injury prevention and shoulder strength), shoulder range of motion (to allow for greater leverage and increase in throwing velocity), transverse plane rotation (to allow for greater rotation and power development through the trunk), thoracic rotation (ability to transfer the ground reaction forces through a greater range of motion to the upper body), lateral flexion, etc. Negative alterations in mechanics due to poor flexibility and stability can result in decreases in ball velocity and increased injury potential (3,4,6).

It is important to note that many of the problems in throwing motions have a direct relationship to how well the athlete can move into the appropriate position. It is important to remember that a football weighs between 14 – 15 oz and is significantly heavier than objects that other overhead athletes manipulate, such as a baseball (5 – 5 ¼ oz) or a tennis racket (weight varies from 7 – 12 oz) (9). This results in different mechanical needs of the body to effectively throw the football. As a result, the same training program for the QB as is used for a pitcher or a tennis athlete will not be optimal. Many similar movements may apply, but it is important to have movements that are QB-specific and involve the need to load the back leg (plant leg) to an even greater degree than other overhead throwing motions due to the increased mass of the football.

The football throwing motion has some similarities with other overhead throwing activities (baseball pitching, tennis serving, volleyball spiking, etc.); however, differences exist in the biomechanics of the entire kinetic chain during the various throwing motions (2). Some of these differences include lower body loading mechanics, the external and internal rotation ranges of motion at the hip, shoulder and elbow loads and torques, as well as the contact points/release points of the different movements. Figure 1 depicts a visual description of the football throw and the different aspects of the motion (8).

THE MOVEMENT OF THE QB

Most QBs are taught to drop back three or five steps in order to pass (9). The first movement backward from the center snap is a very important aspect of the QB's ability to create time in the pocket. The ability to effectively and efficiently perform this first movement requires specific training. All ground-based power movements (i.e., power cleans, power snatches, explosive jumps etc.) that are typically performed in the weight room have specific relevance to power development. The transferability to first step movement needs some greater linkage with the QB throw and the need for the athlete to effectively utilize the ground during each throwing motion; however, a major focus needs to be on the first step in this movement. The challenge with most Olympic-based lifts is that they occur in a vertical plane of motion, whereas as a QB's movement is usually in a lateral movement or various derivatives of a lateral movement pattern (multidirectional movement). The QB first step drill with resistance is an exercises that is specifically designed to aid the QB in this movement

(Figure 2). This movement involves a resistance band secured to a stable anchor at torso level. The belt attached to the band is then secured around the athlete's waist. The athlete then sets up like he would to receive the snap from the center (or this could also be done with someone handing the QB the ball to recreate the snap sequence). On a visual signal, the athlete will explosively push against the resistance working on good lower body mechanics (8).

Another important aspect of the first step in the QB throwing motion is the ability for the athlete to transition from the "under center" position and drop back into the pocket to appropriately position the body for either a hand-off to the running back or to reposition the body the be able to effectively throw the ball down the field. To work on the movement the QB first step loading drill with a band is a beneficial exercise to work on explosively transitioning the body from a low position to a more upright position with slight rotation (Figure 3). This exercise is performed with the tubing connected at a low anchor position in line with the front foot of the athlete. From this low position, the athlete explosively pushes backward with hip rotation and elevation. The purpose of the drill is to move as quickly as possible against the resistance and go from a low body position and an anterior lean position into an upright position mimicking the motion that is required to move the body into a throwing position.

FINAL STEP MOVEMENT

Although the first few steps are always vital for a QB, the final step is one movement parameter that usually receives less focus. The final step during the drop back movement sequence is followed by a step forward to help position the feet directly under the hips. To develop this movement the athlete should perform the single-leg stability pad quarter squat QB drill (Figure 4) (8). This movement is a QB-specific movement that works on hip and core control while the athlete is positioning themselves in the early arm cocking stage of the throwing motion. The goal of this exercise is accomplished through synchronous single-leg and transverse plane movement that improves proprioception (7). Stability is vital during this stage to be able throw effectively. The resistance tubing is anchored in front and to the side of the athlete. The athlete grasps the tubing and then positions their back leg (right leg in a right handed thrower) on the stability pad. From this position the athlete performs a quarter squat movement while keeping tension on the resistance tubing and having a strong early arm cocking stage position of the upper body while maintaining good core and hip control during each repetition (Figure 4).

ADDING A QB-SPECIFIC MOVEMENT PROGRAM

Adding a few additional exercises to the athlete's general strength training program can provide value and specificity to training. Table 1 provides a sample two-day per week program that can be

FIGURE 1. FOOTBALL QB THROWING MOTION

incorporated at the beginning of a strength training session. The exercises should be completed within 15 min and are designed to provide enough resistance to stress the athlete. However, the repetitions and sets should be in a moderate range to not fatigue the athlete completely, and should not impact the ability for power and strength development in a strength training program that can be incorporated at the conclusion of the QB-specific movement program (Table 1).

SUMMARY

Training the QB requires general movement training to improve the overall athleticism and throwing ability. It is very important to incorporate QB-specific movement training techniques to be able to better transfer much of the general movement training that most strength and conditioning coaches currently implement. It is also very important to recognize where in the overall long-term athlete development cycle the QB falls. At a young age, general

FIGURE 2. QB FIRST STEP DRILL WITH RESISTANCE

FIGURE 3. QB FIRST STEP LOADING DRILL WITH A BAND

FIGURE 4. SINGLE-LEG STABILITY PAD QUARTER SQUAT QB DRILL

TABLE 1. SAMPLE TWO-DAY PER WEEK QB-SPECIFIC MOVEMENT PROGRAM

EXERCISE	REPS	SETS
Dynamic warm-up (15 min progression)		
QB first step drill with resistance (Figure 2)	8	3
QB first step loading drill with band (Figure 3)	12	3
Single-leg stability pad quarter squat QB drill (Figure 4)	10	3

**This program can be performed before either a weight room session or a conditioning session*

movement drills and progressions are required to develop good overall athleticism. As an athlete ages and becomes more specific (high school or college level), the QB-specific movement training is required to optimize the movement dynamics of the position.

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HAMMER
STRENGTH
30
20

DEVELOPING LINEMEN FROM THE GROUND UP

PATRICK MCHENRY, MA, CSCS,*D, RSCC

INTRODUCTION

There are more linemen on the field at one time than any other position during a football game, yet they receive less attention than the "skill position" players when it comes time for developing physical skills. Skill position players are usually offensive players responsible for handling the ball and scoring points; typically quarterbacks, running backs, and wide receivers. Quarterback camps, seven-on-seven leagues, and skill position camps are commonly offered, whereas specialty camps for linemen are relatively limited. Offensively, the linemen allow time and protection for the quarterback to throw passes down the field as well as create space and holes for the running back to carry the ball. Defensively, linemen can take on double teams from offensive linemen so linebackers can fill the running lanes as well as rush the quarterback so defensive backs can cover the receivers. All of which are vital to a team's success. It is a common axiom that games are won "in the trenches," which refers to the battle between offensive and defensive lines. A team may have exceptional offensive and defensive schemes but without the linemen to execute properly, even the best schemes will not work. For instance, a running back cannot hit the hole if it is not opened up. A quarterback cannot read defensive coverages or throw accurate passes to the receivers if they are constantly being pressured. Conversely, if linebackers are consistently blocked, it allows running backs plenty of room to maneuver. When the quarterback has time in the pocket, it allows time for the receivers to elude the defensive backs and get open.

Offensive and defensive linemen have opposing objectives on the field, yet they require similar physical development, including range of motion (ROM), footwork, balance, trunk strength, power, and hand speed. All of these attributes are interconnected and when developed correctly will improve the football skills of offensive and defensive linemen. This article will address each of these physical attributes specific to the needs and demands of linemen.

RANGE OF MOTION

Football is played with the feet on the ground and a common theme in articles written about developing linemen is their flexibility. Juan Castillo is an offensive line coach who has worked with linemen from high school to the professional level. To develop a lineman's athleticism, he would put an emphasis "on improving that athleticism by emphasizing flexibility," (7).

Without adequate ROM in the ankle, knee, and hips, linemen will not be able to get into the correct stance, which in turn, will affect power and the ability to move from the starting position (1). A poor stance can limit their initial steps which are critical to accomplishing their task. Lineman who can get into a correct stance using the hip hinge while keeping a neutral spine will be able to generate more power, thus allowing to play at pad level in the athletic position. As stated by long-time University of Oregon strength and conditioning coach Jimmy Radcliffe, "big, long-limbed, top-heavy athletes also tend to have postural problems and limitations when it comes to 'hinging' at the hip, so they often bend over from the lower back, rather than truly bending downward by flexing at the hip, knee, and ankle," (4). If linemen bend at the back, then they will not be able to generate power from the large muscles of the legs. The torso will be parallel to the ground and their legs not flexed at the knees and hips; thus, they will not be able to "fire out" or perform triple joint extension. This will cause them to use their upper body strength and the opponent will be able to get under their pads, which allows for a mechanical pushing advantage.

Flexibility at the ankle, knee, and hip allows linemen to get into the proper stance (Figure 1) and quickly achieve full triple extension. Many younger athletes have a misconception that flexing at the waist will position their chest parallel to the ground (Figure 2). However, the ankle, knee, and hip are not flexed in this position. Consequently, linemen will not be in the correct position to make the first movement. Coaches can utilize a basic bodyweight squat test to determine if a lineman can get into a proper squatting position. Further details on the testing protocol and how to correct mistakes are provided in the article "The Bodyweight Squat: A Movement Screen for the Squat Pattern," (2).

One way to improve ROM at the hip is by holding onto a band attached to a rack and squatting below parallel (Figure 3). When the lineman is able to perform this movement pattern, then they can put the band around their waist (Figure 4), sitting back into the band to emphasize trunk and leg strength, while maintaining an upright torso.

FIGURE 1. PROPER STANCE NEEDED FOR TRIPLE JOINT EXTENSION - THREE-POINT STANCE

FIGURE 2. CHEST PARALLEL TO GROUND - BAD TECHNIQUE

FIGURE 3. SQUATTING WITH BAND

FIGURE 4. SQUATTING WITH BAND AROUND WAIST

FOOTWORK

Once linemen begin to develop ROM, the next area of concentration should be footwork. The ability to move with either foot in any direction will set up the lineman to perform successfully. A poor first step can cause the lineman to be off balance or may cause the lineman not get to an area in time to perform their role. During an average play, linemen may cover about 10 yards in about 5 – 7 s (5). Obviously, this movement is fast and explosive, relying on quickness of the first step; therefore, any wasted steps may allow the opponent to get the advantage. A lineman should be able to lift their leg so they can step in the correct direction, step over anyone lying on the ground, and be able to open up the hips to turn and run. Many line coaches like using bags because it keeps the lineman's base of support under them and forces them to pick up their feet to get over the bag.

It is important to note that developing footwork in linemen is more than having them step over bags and perform ladder or cone drills. Coaches should watch the footwork of the linemen when performing short sprints, dot drills, or cone drills with a focus on the first step. If a lineman is moving forward to the right then the right leg should be moving first in positive yardage. In a pass drop with the left foot moving backward, the lineman should be able to step back without first standing up. Linemen are in close proximity to each other, usually within one or two steps before contact is made, so the first step needs to be correct or their opponent will have the advantage. A misstep or unnecessary backward step allows the opponent to get into their pads, giving them the advantage. One drill that can be useful for linemen is the octagon drill because it allows them to step with either foot in all directions (Figure 5). Linemen must be able to move from a stable stance (Figure 6) or a staggered stance (Figure 7).

FIGURE 5. OCTAGON DRILL

Octagon drill: step forward, cut off left or right, lateral step, diagonal backward, and drop step. All drills should be performed stepping both left and right equally to develop overall movement.

FIGURE 6. STABLE STANCE

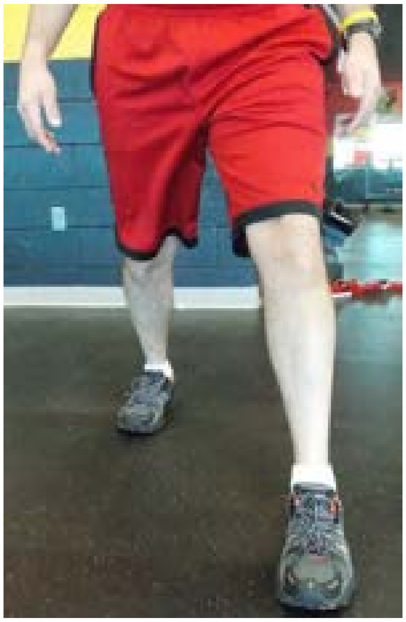

FIGURE 7. STAGGERED STANCE

WELL ROUNDED STRENGTH TRAINING PROGRAM

When designing a training program, emphasis needs to be put on top/bottom and front/back exercises, as well ensuring the use of a variety of exercises. The strength training program must have exercises for the back and front of the body. Many times, high school athletes want to bench press and work the muscles in the front of their body. However, the rear deltoids, latissimus dorsi, rhomboids, triceps, spinal erectors, glutes, and hamstrings should not be overlooked. The strength and conditioning program for linemen should include at least two upper body posterior lifts for every one upper body anterior exercise, and two lower body posterior lifts for every one anterior lower body lift.

Many high school males want to focus on the pectoralis major and biceps, or the so called "mirror muscles." Athletes are only as strong as their weakest link, which in most cases is their backs, specifically rear deltoids, rhomboids, trapezius, and latissimus dorsi. When training the deltoids, linemen should retract the shoulder blades to allow for all parts of the muscle to be developed. Standing chest press with a resistance band (Figures 8 and 9) or using a cable machine allows linemen to develop their upper body while simultaneously learning to stabilize the lower body (6). Other upper body chest press exercises that help develop stabilization include plate chest press and step, medicine ball chest press, and throw or sandbag chest press and throw. Table 1 provides some exercise options for standing exercises with a band.

FIGURE 8. STANDING CHEST PRESS USING A 41-IN. BAND - START

FIGURE 9. STANDING CHEST PRESS USING A 41-IN. BAND - END

TABLE 1. STANDING EXERCISES

Band around rack	Two-arm chest press
	Single-arm
	Piston
Band around rack stand inside	Two-arm chest press
Band around back	Two-arm bench (both arms pushing at the same time)
	Single-arm (one arm moving at a time)
	Piston (both arms moving, one is extending while the other is flexing so they move in different directions at the same time)
Push-ups	Band on back, loop around body
Scoops	Stand in an athletic position with the arms next to the sides and flexed at the elbows, holding the band in front of the body. Flex at the shoulders and extend at the elbows so the arms are parallel with the floor.

TRUNK STRENGTH

The trunk involves many muscles from the thighs to the torso. This musculature is sometimes called the "power zone" because it is where power is produced from the coordinated effort of the joints and large muscles of this region. Consider the following analogy: the body is like a nail, if it is straight the power will go from the toes to the head resulting in proper movement. If it is bent (or the trunk is weak) the power will be dissipated resulting in poor movement.

Developing trunk strength goes beyond the traditional exercises of sit-ups and crunches. Research has shown that performing trunk exercises on a stable surface where the glutes and/or back are supported (e.g., sit-up) is not as effective as an exercise where the torso must be controlled (e.g., plank) (3). When a lift (or on-field contact skill) is performed correctly, the lineman should engage the core and stabilize the trunk throughout the entire set or bout of activity. Younger linemen should be shown how to engage muscles of the trunk during lifts as well as on the football field. Proper trunk activation when lifting must be taught; holding your breath while lifting is not the same as activation. When taught correctly, the lineman can have a solid trunk while still being able to breathe and talk. For novice linemen, coaches should start out by teaching them how to hold the "dead bug" position. Next, have the linemen move their arms or legs while in the dead bug position to help develop trunk stabilization. Progressions and variations from the dead bug include exercises such as bridges, bird dogs, planks, toes on medicine balls in plank position, and pillar series.

Overhead lifts change the body's center of gravity. When this happens, the center of gravity will rise, which means that it will require more muscles to perform the activity. Performing lifts, either overhead or horizontal, with feet on the ground will require the lineman to stabilize the body to add to development of trunk strength.

HAND SPEED

Getting off the ball quickly is one component of lineman play. Fast hands allow linemen to get under the pads of the oppositions and push them off balance or dictate which direction to move them. Close-grip bench, scoops, and sandbag training can teach the linemen to keep their arms close to their body. Upper body dot drills, the octagon drill (performed by hitting the dots with the hands instead of the feet), and medicine ball exercises can teach the linemen to quickly place their hands in specific places. This can be created by simply taping or painting the dots (or octagon shape) onto a mat and mounting it on a wall.

SUMMARY

Each of the attributes discussed in this article should be developed year-round. It can be accomplished by having the linemen wrestle in the winter and participate in field events in the spring. For instance, incorporating strongman training into the summer program allows linemen to take part in activities as a team while the rest of the team is participating in a seven-on-seven tournament. The multi-sport approach can help to develop well-rounded linemen. Motor patterns developed by participating in other sports can help prevent burnout, fits into the long-term athletic development model that is promoted by United States of America Football, as well and many National Collegiate Athletic Association (NCAA) Division I coaches, and will improve their overall athleticism. These motor skills cannot be developed solely during the competitive season (August – November). Another advantage of working on these areas is that it gives linemen a sense of purpose during the off-season. A sample calendar of different drills, movement patterns, and strongman training shows how variety can be added to off-season workouts (Tables 2 and 3).

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TABLE 2. SAMPLE 10-WEEK PROGRAM

WEEK	POWER EXERCISES	AGILITY EXERCISES
1	Medicine ball 1 – 3	Ladders 1 – 3 (upper body)
2	Medicine ball 1 – 3	Ladders 1 – 3 (upper body)
	Octagon drill	Dot punch pad
3	Medicine ball 4 – 6	Ladders 4 – 6 (upper body)
	Octagon drill	Dot punch pad
4	Medicine ball 4 – 6	Ladders 4 – 6 (upper body)
	Octagon drill	Dot punch pad
5	Medicine ball 7 – 10	Ladders 7 – 9 (upper body)
		Sandbag 1 – 3
6	Medicine ball 7 – 10	Ladders 7 – 9 (upper body)
		Sandbag 1 – 3
7	Strongman 1 – 4	Ladders 10 – 12 (upper body)
	Cone 1 – 4	Sandbag 4 – 6
8	Strongman 1 – 4	Ladders 10 – 12 (upper body)
	Cone 1 – 4	Sandbag 4 – 6
9	Strongman 4 – 6	Medicine ball with partner 1 – 3
	Cone 5 – 9	
10	Strongman 4 – 6	Medicine ball with partner 1 – 3
	Cone 5 – 9	

TABLE 3. EXERCISE DESCRIPTIONS

EXERCISE	VARIATION #	DESCRIPTION
Medicine ball	1	Prone partner throw
	2	Sitting on knees wall throw
	3	Sitting on knees hip up wall throw
	4	Sitting on knees wall throw to drop
	5	Sitting on knees wall throw to push-up
	6	Athletic stance wall throw
	7	Athletic stance wall throw with step
	8	Three-point stance wall throw
	9	Three-point stance to partner across gym
	10	Single throw with run-down and catch after one bounce
Octagon drill	1	Coach calls out direction
Strongman	1	Yoke turn
	2	Hercules hold for time, start with 30 s (holding a sandbag/weight in each arm with both arms elevated to be parallel to the ground)
	3	Fingal fingers (with landmine or tire, press/throw weight overhead with arms extended and walk the hands up the implement until it flips over; repeat on other side)
	4	Sled pull (with harness, if no attachment go around sled)
	5	Overhead press for repetitions
	6	Deadlift for repetitions
Ladders	1	Hopscotch
	2	Jumping jack
	3	Lateral shuffle
	4	Run through
	5	Scissors
	6	Carioca
	7	Mountain weave (single-leg in-out weave; repeat with other leg)
	8	Hand in/hand out
	9	Crossover
	10	Tree (start with feet out in front of ladder, step so both feet are outside of first box, then both feet in second box; repeat)
	11	Both out/both in
	12	Icky shuffle
Sandbag	1	Scoops
	2	Rotational throw
	3	Wood chops
	4	Rotation throw over the shoulder for distance (low to high throw)
	5	Three-point stance throw
	6	Over the back throw (over goal post)

TABLE 3. EXERCISE DESCRIPTIONS (CONTINUED)

EXERCISE	VARIATION #	DESCRIPTION
Medicine ball with partner (can be done with bands on legs)	1	Athletic stance lateral partner pass (five steps down/back)
	2	Holding a small ball in each hand so that both people are pressing on the ball in opposite directions at the same time, push the ball back and forth giving each other resistance and they move laterally
	3	Weighted ball push (five steps down/back)
Cone drills with and without medicine ball	1	Lateral shuffle
	2	T-test
	3	Rainbow (start at middle cone, shuffle to cones on either side, then sprint to and backpedal from cones at 45°, 90°, and 135°)
	4	Star (full circle medicine ball throw)
	5	Four corner
	6	Forward/backward weave
	7	N-drill
	8	W-drill
	9	X-drill

BODY COMPOSITION IN FOOTBALL PLAYERS

TYLER BOSCH, PHD

INTRODUCTION

Physical size is an important attribute in American football. The use of body composition (or percent body fat [%BF]) has been a common physical assessment in football for a long time (22). Body composition can be measured in several ways with each method having underlying assumptions that impact the accuracy and reliability of the measurement. The purpose of this article is to review the concept and measurement of body composition in football players and discuss future advances in body composition that move beyond the measurement of total percent fat and focus on regional (what is in the leg/abdominal regions) and proportional (upper to lower body ratios) measurements of body composition.

WHAT IS BODY COMPOSITION?

Body composition refers to the type of tissue (bone, fat, and muscle) as well as distribution (how much of each in each part of the body) of mass. The %BF is commonly used as the measure of body composition. However, %BF is simply the ratio of fat mass/total mass and fails to account for the distribution of mass in different parts of the body (e.g., trunk, extremities, etc.). An example of this can be found in Figure 1 A – D, panels A and C represent the total mass and the distribution (percent) of total for lean, bone, and fat masses. However, panels B and D represent the totals and distribution of lean and fat mass across the body. Importantly, the largest variation in fat mass distribution seems to be in the trunk (torso) between position groups. Understanding these distribution patterns allows us to compare players to themselves over time, or between players at the same position. Additionally, it allows us to start asking questions like, "how do body composition distribution patterns change during the season?" Or, "how does a training cycle effect lean mass accumulation?"

MEASUREMENT OF BODY COMPOSITION

There are numerous excellent reviews on body composition methodologies that outline the details of each (1,2). Therefore, only a brief overview will be provided herein. Body composition methods are defined by the number of components (i.e., bone, muscle, fat) measured. A good reference for a complete overview of body composition methods can also be found in a book edited by Lukaski et al. (18). In addition, Dengel et al. detail several methods for measuring body composition and other chapters within the book provide comparisons between methods (12). The sections below will provide a brief summary of the methods most commonly used in football. Table 1 compares important considerations when determining which method to use.

TWO-COMPONENT METHODS

Most methods commonly used to assess football players are two-component methods that estimate fat and fat-free mass (muscle and bone). Two common two-component methods used in football are skinfold measurement using calipers and air displacement plethysmography. Skinfold assessment is done using a hand held caliper to measure the thickness of skinfolds at various sites across the body (e.g., abdomen, thigh, subscapular). Anywhere from 3 – 12 sites can be measured and the values are used in prediction equations to calculate an estimate of total fat mass and fat-free mass. Oliver et al. developed an estimation equation for body composition using skinfold assessment in 157 college football players against dual x-ray absorptiometry (DXA), seen as the current gold standard (17). This prediction equation can be recommended in a football population when skinfold assessment is used to measure body composition (17).

Air displacement plethysmography (ADP) is a method similar in principle to hydrostatic (or underwater) weighing, but it is based on the displacement of air instead of water. The method involves the athlete entering a chamber or egg-shaped device (e.g., BodPod™), and uses prediction equations to estimate fat mass and fat-free mass. The hydrostatic weighing method is not as common anymore because of the feasibility of measuring athletes and requires individuals to expel all of the air out of their lungs while underwater.

Bioelectrical impedance analyses (BIA) is another method used in some cases. BIA sends a single- or multi-frequency electrical current through the body to determine the resistance of the flow of the current and in turn used to estimate fat mass and fat-free mass. BIA also measures total body water and estimates intracellular and extracellular water within the athletes.

THREE-COMPONENT METHODS

DXA is a newer technology used in athletes and is a three-component method because it measures fat, muscle, and bone density separately (5,10,15,17). DXA requires an athlete to lay flat on a table as a scanning arm passes over the athlete. DXA measures the muscle, fat, and bone based on the amount of

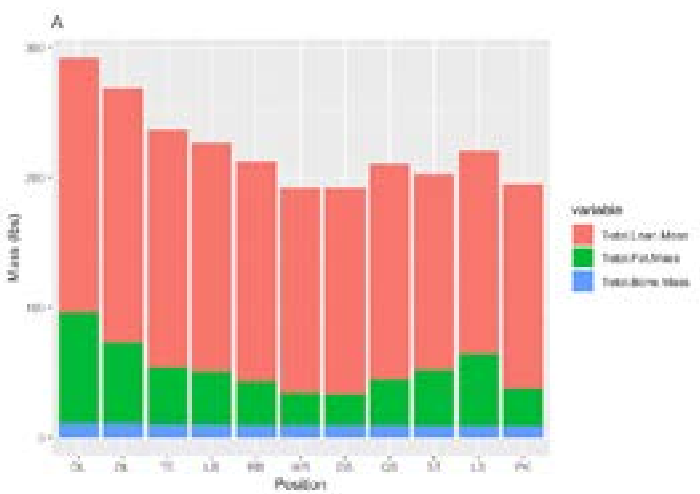

FIGURE 1A. AVERAGE TOTAL LEAN, FAT, AND BONE MASS FOR EACH POSITION

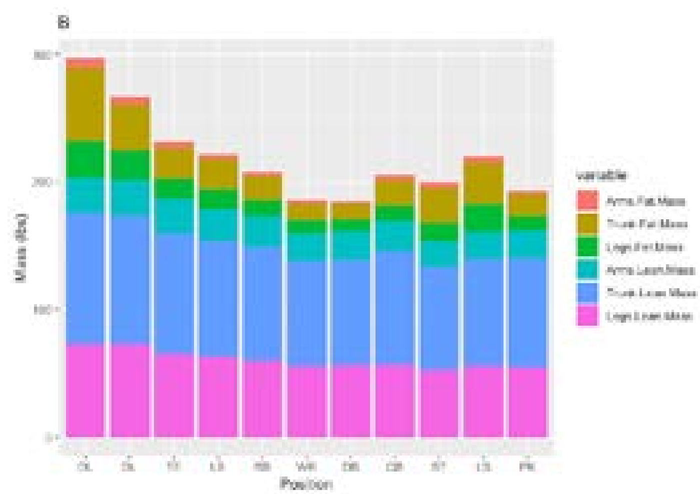

FIGURE 1B. AVERAGE REGIONAL FAT AND LEAN MASSES FOR EACH POSITION

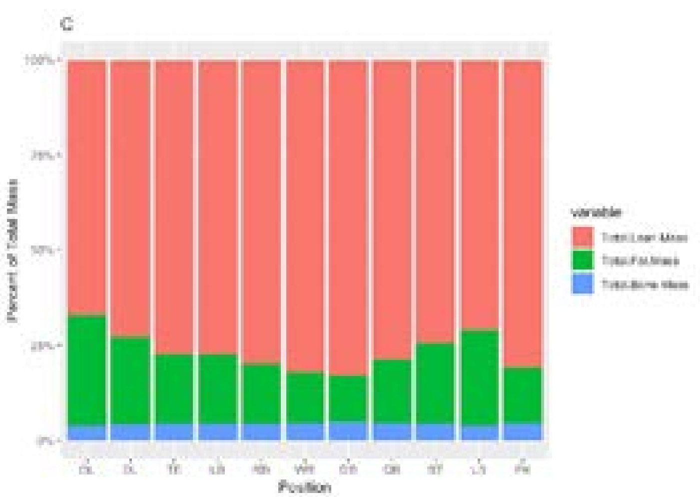

FIGURE 1C. AVERAGE PERCENT OF TOTAL MASS FOR EACH POSITION

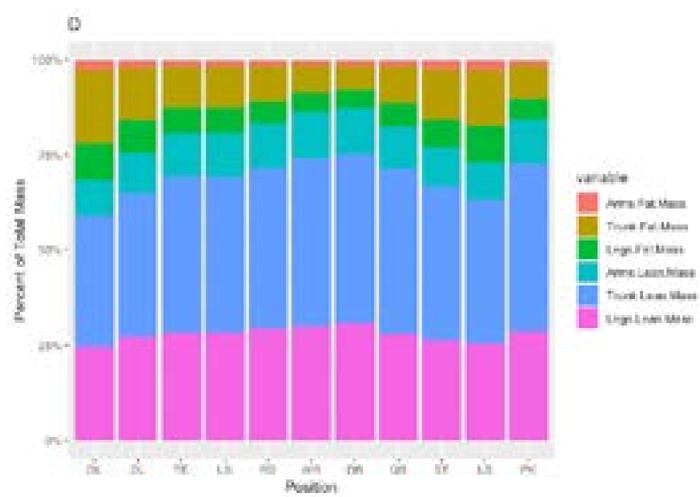

FIGURE 1D. AVERAGE PERCENT REGIONAL DISTRIBUTION OF FAT AND LEAN MASSES BY POSITION

These figures represent: A) average total lean, fat, and bone mass for each position; B) average regional fat and lean masses for each position; C) Average percent of total mass for each position; and D) average percent regional distribution of fat and lean masses by position. Body composition measured by dual x-ray absorptiometry. Data from Bosch et al. 2017 and modified from 2017 ACSM Scientific Sessions (5).

energy absorbed from the photon beams emitted by the DXA as the scanning arm passes over the athlete. Although hydrostatic weighing was long considered the "gold standard" technique for body composition assessment, DXA is now considered the gold standard assessment since it measures the tissue directly rather than estimating via extrapolations (15). Four- and six-component methods exist, but are both expensive and not feasible for regular use in athletes.

COMPARING DATA BETWEEN METHODS

Does it matter which method you use to measure body composition? It depends on how you want to use the information. If you are trying to assess body type or compare players that play the same position, you will want to use DXA for the accuracy and between person (tester/technician and athlete) reliability. However, if you are just trying to estimate change in total fat over time, you can use any method with a fairly high degree of reliability.

The most important factor is standardizing the method you choose, as even DXA becomes less accurate and reliable without a standard measurement process. It is important to note that these methods are different and numbers cannot be compared between methods. If you see information from another team that used a skin-fold assessment, you should not compare those numbers to the BodPod numbers. On average, two-compartment methods (i.e., skinfold, ADP, and BIA) differ by an average of 4 – 8% for %BF compared to DXA, depending on the method and population (9,11,17,18). However, the range of that difference is quite large (4 – 20%), and it usually increases for larger individuals (9,11,17,18).

To summarize, comparing measurements between different populations and different methods is challenging and likely inaccurate. It is recommended to identify the method that will work for your situation and then clearly define the "hows" and "whens" of that measurement.

ADVANCES IN BODY COMPOSITION

The next advancement in body composition will be the ability to determine body type/frame size accurately and reliably. Frame sizing and somatotyping has been around since William Sheldon developed the method in the 1940s (21). Somatotyping involves taking anthropometric measurements such as seated height, chest depth, and other measurements to estimate the body type (i.e., ectomorphic, mesomorphic, endomorphic) and frame size of a player (19). This information is useful in understanding how much mass a player can hold and how that mass might be distributed across the body. To date, this work has focused on total body mass (weight) and not the type and distribution of weight. We have shown the non-linear relationship between both the type and distribution of mass with increasing weight (6,13). These data suggest that individuals may be limited in how they store their muscle and fat mass. Beyond their ideal, their body starts to have non-optimal distribution of fat mass (i.e., increased fat in the stomach) (4). Being able to estimate how much total and regional fat and muscle mass change during weight gain would be an advancement in training and athlete development. Rather than saying a player needed to be a certain weight because of his position, we can identify the ideal weight based on body type.

Dengel et al. recently published a method using DXA that provides an accurate assessment of ideal weight and lean mass in football players based on frame size (11). The method used the body composition data combined with selected anthropometric sites from the skeletal images obtained from the scan to develop and test the model. Figure 2 shows the skeletal image output from

TABLE 1. SUMMARIZING THE DIFFERENCES BETWEEN METHODS

METHOD	ACCURACY	WITHIN PERSON RELIABILITY	BETWEEN PERSON RELIABILITY	COST	TIME
Skinfold Range of Diff from Actual	Moderate (4 – 15%)	High (if method is consistently measured by the same person)	Low (comparisons between people is not recommended)	Low	Short ~ 2 min per person (dependent on number of sites and people)
ADP (from BodPod™) Range of Diff from Actual	Moderate (4 – 10%)	Moderate Must be consistently calibrated	Low (comparisons between people is not recommended)	Moderate	Short ~ 5 min
BIA Range of Diff from Actual	Moderate (higher for totals) (4 – 10%)	High (but only for total fat mass and fat-free mass (regional is low))	Low (comparisons between people is not recommended)	Moderate	Short ~ 2 min
DXA Range of Diff from Actual	High (1 – 3%)	High (hydration status will cause variation)	High people can be reliably compared	High	Moderate ~ 4 – 20 min (dependent on device)

**Parentheses indicates the range of variation. Modified from Lukaski (18)*

DXA, and how customized regions of interest can be created to measure the width and depth of different anthropometric sites (e.g., ankle width, knee width, shoulder breadth). Using these measurements frame size can be estimated for each athlete. Figures 3A and 3B show the measured mass versus the predicted mass for both weight and total lean (i.e., muscle) mass. Interestingly, there are a group of individuals between 250 – 280 lb that have about 20 lb less mass than predicted by their frame. Interestingly, almost all of these players are defensive ends, and comparing their predicted lean mass (Figure 3B), those same players have similar predicted and measured lean mass. These data suggest they have less fat mass than expected and likely lends to the explosiveness and quickness required by that position. Identifying an optimal mass for an athlete's frame and position can help improve performance by optimizing the mass to force/strength ratios.

We are currently working on the ability to estimate how changes in weight effect changes in regional fat and lean mass. Being able to estimate how much total and regional fat and muscle mass change during weight gain would be an advancement in training and athlete development. Rather than saying a player needed to be a certain weight because of his position, we can identify the ideal weight based on frame size and positional needs. It has been observed that at about 250 lb and 20% body fat there is evidence of an increased distribution of fat to the abdominal and visceral (deep fat surrounding organs) areas (4). Additional work needs to be done in this area to provide improved accuracy in how much weight a player can put on before they reach a point where they are adding a higher percentage of fat mass relative to lean mass. While body mass is important in the game of football, adding more fat relative to lean mass may impair performance and current and future health.

BODY COMPOSITION IN FOOTBALL PLAYERS

Several papers have described the body composition of football players (6,8,9,10,11,12,13). The majority of these papers have been cross-sectional studies comparing position groups (e.g., bigs, big skill, skill). Recently a few papers have examined longitudinal trends across a collegiate career (3,22). In 2016, DXA data from five National Collegiate Athletic Association (NCAA) Division I schools was pooled from a variety of sports, including football.

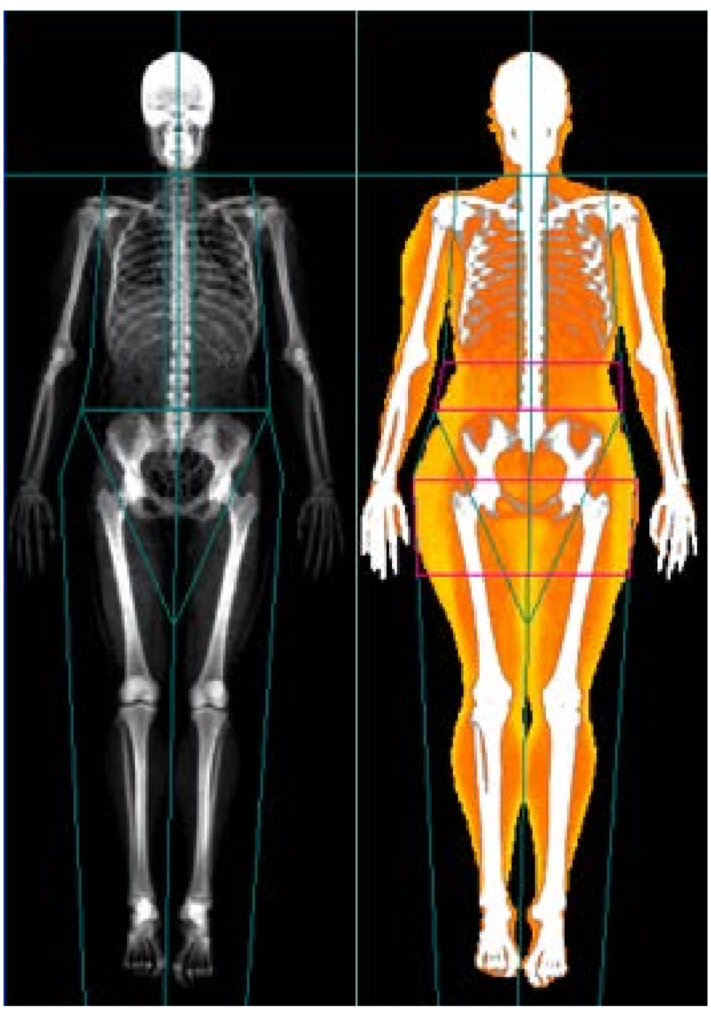

FIGURE 2. EXAMPLE DXA BONE MAP IMAGE

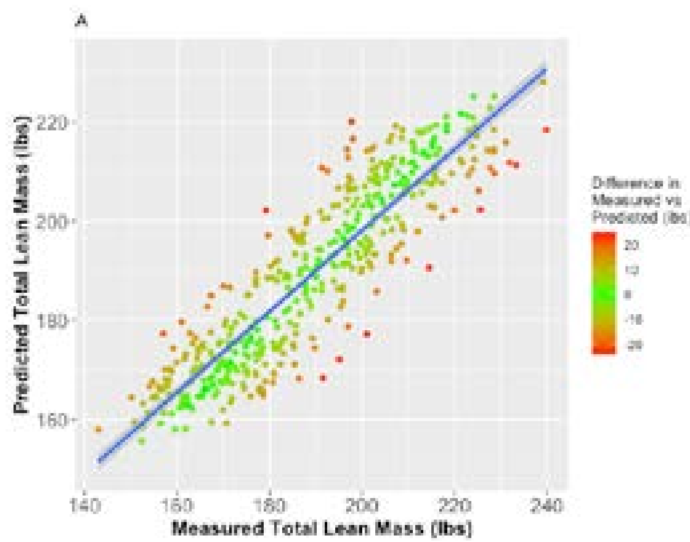

FIGURE 3A. PREDICTED VS. MEASURED WEIGHT BASED ON SKELETAL FRAME

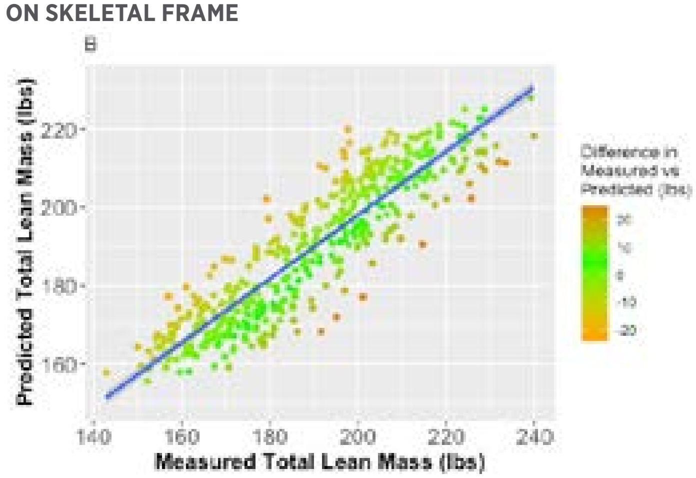

FIGURE 3B. PREDICTED VS. MEASURED LEAN MASS BASED ON SKELETAL FRAME

The first publication included over 450 college football players and detailed total and regional body composition of different positions (6). This study, combined with our research in professional football players provides a comprehensive evaluation of player body type (height, shape, and ratios of upper and lower mass) and composition (how much muscle, fat, and bone mass is distributed in the legs, trunk, etc.) across NCAA Division I (6) and professional football (11).

A summary of the key findings across college and professional football players is provided here:

1. Positions that mirror each other have similar body types and composition (e.g., wide receiver/defensive back or offensive lineman/defensive lineman) (6,11).
2. Tight ends have a unique body type with similar fat mass to running backs and linebackers, but lean mass that is more similar to offensive linemen, particularly in the upper body (6,11).
3. Linemen are able to gain significant lean mass even as upper classmen (12).
4. Above 250 lb, lean (muscle) mass starts to plateau and fat mass begins to increase at a much faster rate (5).
5. Above about 20 – 22%BF (measured via DXA) there is a significant increase in the amount of fat store in the abdominal and visceral (internal) regions of the body (5).
6. During the competitive season, the majority of all weight change, increase or decrease, is fat mass (about 80% for all positions except running back) (7).
7. During the competitive season, a 1% increase in total fat mass is associated with a 3% increase in abdominal fat mass (7).
8. The ratio of mass distribution (upper to lower mass) is similar across all positions, with linemen being the lowest (i.e., higher proportion of lower to upper mass) (7).
9. On average, college offensive linemen have 40 lb of fat in their trunk (torso) which is more than all other positions (except defensive linemen) have in their entire body (Figure 1B) (6).
10. Linemen (both active and retired) are at higher risk for cardio-metabolic disease (e.g., insulin resistance, high triglycerides, high blood pressure) (2,4,8,9,22).
11. Mass, %BF, and mass ratios influence an athlete's response to a practice load (13).

THE RELATIONSHIP BETWEEN MUSCLE AND FAT MASS WITH INCREASING WEIGHT

Ideally, all changes in weight of a football player are either increased lean (muscle) mass and/or decreased fat mass. However, this is rarely the case, it is extremely difficult to only gain muscle during weight gain and similarly it is rare to only lose fat mass during weight loss. One reason is because fat is a fuel source for muscles, and trained athletes actually store fat within their muscles. Thus, there is a distinct relationship between the proportion of fat and lean mass that changes with increasing/decreasing weight. A few years ago, we published a study that found a unique relationship showing the accumulation of fat and muscle mass differences above and below 250 lb (6). In athletes that weigh less than 250 lb, it was found that for every 10 lb of weight gained about seven pounds is muscle and three pounds is fat (6). Whereas in athletes greater than 250 lb this proportion switched to seven pounds of fat and only three pounds of muscle for every 10 lb gained (6). We are still trying to identify the exact reasoning behind this shift, but the current hypothesis is tied to a limitation in muscle mass accumulation; however, it is possible that it may also be tied to energy requirements.

In summary, gaining muscle mass independent of fat mass is increasingly harder as athletes gain more weight. For some football positions (e.g., OL, DT), increased mass, regardless of whether it is fat or muscle, can be beneficial, but at the thresholds identified above, increasing mass may become detrimental to health and performance.

GETTING THE MOST OUT OF BODY COMPOSITION

As alluded to previously, body composition is often used interchangeably with %BF. However, it is much more than just %BF as outlined herein. Similar to training, body composition should be about identifying the optimal body type that allows them to meet the demands of their position. The question can be asked, "Is their body type the limiting factor? If it is not, than will making them bigger make them a better player?" The key is to understand how and where each athlete stores their mass and how that changes in response training and nutrition. Body compositions assessments should be used to determine how athletes are responding to different parts of the training cycle (off-season, pre-season, and competitive). It is important to know if athletes are gaining lean mass, but it is even more important to know where they are gaining lean mass. Integrating body composition with strength and power testing can be done by taking regional measurements. Are the changes in lean mass translating to relative increases in strength, speed, and power? Finally, most teams track weight daily, but what is the composition of the bodyweight fluctuation? There are examples of players gaining 10 – 15 lb of fat or losing 10 – 12 lb of muscle during the competitive season. On a scale, a three-pound change is negligible, but this may be 20 – 27 lb of functional mass change. Given these examples, the assessment and evaluation of body composition needs to be reconsidered including a better understanding of realistic changes that occur in football players.

FINAL THOUGHTS

Football is a sport where body mass is carefully considered; however, there is a need to move beyond position-specific ideals, which are often based on an average value, and shift to individual consideration based on each player's unique genetic makeup and body frame to inform their optimal body mass. There is also a limit to how much mass a player can add before it impairs health and performance. Standardized, consistent assessments provide feedback to how players are progressing. Regional assessment methods using state-of-the-art methods, such as DXA, provide a more complete picture to how the athlete is responding to nutrition, training, and competitive stresses. Regardless of the methodology, body composition is more than %BF and the information is an opportunity to adjust training or nutrition strategies based on the results.

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OPPORTUNITIES AND CHALLENGES IN THE CURRENT NUTRITION LANDSCAPE OF COLLEGIATE AND PROFESSIONAL FOOTBALL

PRATIK PATEL, MS, RD, CSSD, CSCS

INTRODUCTION

Nutrition plays a crucial role in athletic performance. Over the past decade, there has been an increase in the amount of published research related to sports performance and nutrition. This body of evidence supports and adds to the credibility of nutrition being a dynamic area of practice in the sports performance equation. Its application for athletes and to team sports such as American football have been shown to provide numerous benefits. A sound, individualized nutrition plan can improve training adaptations (14,25), help prevent injuries (26), expedite recovery from injuries and illnesses (30), improve performance (14,17,33), and help prolong health (2,31). In recent years, a growing number of NFL teams and colleges have realized a sports nutrition program or department can be an integral part of their player performance team.

The purpose of this article is to discuss the landscape of nutrition in collegiate and professional football. It will address the following areas: 1) the current landscape, 2) current practices, 3) opportunities, and 4) challenges faced in collegiate and professional football.

THE CURRENT LANDSCAPE

WHERE WE CURRENTLY ARE

Multi-million dollar facilities, substantial nutrition budgets, and experienced staffs running sports nutrition programs and departments make up the current nutritional landscape in the National Collegiate Athletic Association (NCAA) and National Football League (NFL). Teams and schools are dedicating more funds and resources to ensure their players are fueled, recovered, and ready to perform throughout the year. NCAA Power Five schools (from the Big Ten, Big 12, Atlantic Coast Conference [ACC], Southeastern Conference [SEC], and Pac 12 Conferences) are spending millions of dollars building or renovating facilities to feature athlete-only feeding areas (dining halls and fueling stations). Some NFL teams are operating on an annual $2 – 3+ million per year foodservice budget which equals that of a number of Power Five schools, and 23% (15/64) of Power Five schools are budgeting at least $300,000 annually for nutritional items outside of provided meals (7,24). Along with overseeing nutrition departments and collaborating with foodservice operations, sports Registered Dietitians (RDs) have become an integral part of the player performance team working in conjunction with sports medicine, strength and conditioning, and sport science and performance. Applying the science of sports nutrition to a variety of non-lab situations takes knowledge and experience, which can be handled by qualified sports RDs.

HOW DID WE GET HERE?

With advancements in nutrition research and more information readily available on its importance, more opportunities (e.g., nutrient timing and nutrition periodization) have been identified to address what players need to perform at their best (29). Nutrition can have a positive effect on not only the performance, but also the health and career of players. The field of sports nutrition has grown rapidly in recent years due to the hard work and visibility of sports RDs and groups such as the Collegiate and Professional

Sports Dietitians Association (CPSDA), which have advocated for the advancement of applied sports nutrition and growth of sports nutrition infrastructure. Many head coaches and administrators (e.g., athletic directors, general managers, and other front office staff) recognize the critical role that sports RDs play as part of the performance team (5,10). NCAA recruiting tends to be a race to see who can provide athletes with the best facilities and greatest resources. Sports RDs are a valuable asset that can be leveraged to potentially attract student-athletes and their families to a university, or a free agent to an NFL team.

WHO IS STEERING THE SHIP?

Along with the increase in food allowance and football facility investing, there has also been a significant boost to investment in nutrition resources and staffing for college football teams. In 2004, only eight full-time sports RD positions were filled in the NCAA with only one full-time in the NFL (9). In 2017, 67% of Power Five schools employed at least one full-time sports RD and had for at least three years (with many having a heavy role with football) (9,23). A handful of these schools have hired a full-time sports RD solely dedicated to football. Almost all Power Five collegiate football players now have access to a sports RD (7,8).

Even though the field has seen its most rapid growth in recent years, sports RDs have been around for much longer. In general, veteran sports RDs have more than seven years of experience, experienced sports RDs have 2 – 7 years, and qualified sports RDs have less than two. It is common to find a veteran sports RD as the head or director of a department, as an assistant or associate athletic director, or on a coaching staff. The most recent NFL Collective Bargaining Agreement mandates that teams provide players access to at least a consultant nutritionist (RD or Certified Nutritionist). Currently, 59% (19/32) of teams have responded by hiring a full-time sports RD to oversee the nutritional program and needs of its players (8). Most of the remaining teams have sports RDs in consultant roles. Among consulting RDs, at least two teams have had sports dietitians for over 20 years.

WHAT WAS ATHLETE FEEDING LIKE BEFORE?

Prior to 2014, NCAA scholarship football players only had access to basic snacks, such as bagels, nuts, fruit, and calorie replacement beverages along with a single training table meal for a player on scholarship. Walk-ons were not allowed to partake in the training table meal. The 2014 deregulation of feeding rules opened the door to what players now have access to in terms of sports nutrition. Schools are now able to provide unlimited snacks along with meals incidental to participation for the entire team (24). Once the ruling went into effect, schools began building and renovating facilities and implementing and creating independent nutrition departments within the athletic department.

THE EVOLUTION OF NUTRITION ROLES AND PRACTICE

Years ago it was common for a nutrition interaction with a player to be limited to meeting individually for a nutrition consult related to weight gain, weight loss, recovery needs, or medical nutrition therapy (MNT) for clinically diagnosed conditions such as celiac disease, Type 1 diabetes, dyslipidemia, or low Vitamin D. The influence and practices of what nutrition can do for a team has paralleled that for nutrition spending and investing in facilities, resources, and staffing. Nutrition is a complex puzzle with many different pieces. Sports RDs now are required to be well-versed in a variety of different areas (e.g., nutrition, exercise physiology, sports science, athletic performance, strength and conditioning, and foodservice) depending on the circumstances and requirements from their respective teams. There are now football sports RDs being hired in a dual-role capacity (RD plus strength coach, sport science coordinator, or chef) with more being hired at the NFL level.

Primary duties and responsibilities for current sports RDs can include but are not limited to (28,29):

- Individual nutritional assessments and counseling
- MNT
- Team nutrition educational sessions
- Dietary supplement evaluation
- Body composition assessment and plans
- Muscle glycogen assessment
- Reviewing a wide range of blood tests for parameters that impact performance and health
- Hydration assessment and plans
- Foodservice and inventory management
- Fueling station management
- Menu development
- Travel nutrition and logistics
- Nutrition for training and competition
- Working as a sports performance team member
- Life skills development

All of these pieces can have a positive effect on athletes when directed and implemented appropriately by an experienced sports RD. It is now common to have a sports RD plan and oversee everything a team eats and drinks on a given day because of the unique and taxing physiological demands of football (16).

TAKEAWAY MESSAGES

- Sports nutrition is an integral part of athletic performance and a field experiencing rapid growth.
- The benefit of nutrition is more widely understood, and teams and schools are investing to maximize its benefits.
- More money is being invested in nutrition programs, facilities, resources, and staffing than ever before.
- Sports RDs are being hired in full-time and consultant positions to run these nutrition programs and departments.
- The roles and practices of the nutrition staff have recently advanced to meet the evolving needs of modern football teams.

CURRENT PRACTICES

NOT ALL ROLES ARE CREATED EQUALLY

Every team and organization has a different nutrition situation in regards to staffing, facilities, resources, and responsibilities. These factors influence buy-in from coaches and administrators based on what they want for their team and what they deem as important. Coaches that value their players being prepared, energized, hydrated, recovered, and resilient day after day will be very vocal and supportive of nutrition, and will empower those involved in its execution. If it is important to the head coach, it will be important to the players. This can really open the doors to all of the various areas where nutrition can play a role (29).

A SEAT AT THE TABLE

Not only is every situation with a team different, so are the day-to-day interactions with the other staff members who operate "in the trenches." A modern day football performance team typically includes staff members from athletic training, strength and conditioning, sports nutrition, and sports science that are in place to help players prepare and perform their best for as long as possible. Everyone brings something valuable to the table and everyone should have a seat, an equal voice, and be working in unison for optimal performance (12).

While each performance staff member has their own specialty, they also have their own unique relationship with players and what they hope to accomplish with them. Understanding what is important to each discipline and how each discipline can help one another will strengthen the performance team dynamic, build trust, and improve the effectiveness of interventions. The biggest bridge to collaboration is constant communication and respect within the performance team. If staff members are not communicating constantly about what is happening with players or the team then potential actions to assist with resolving issues will be delayed. Problems can also arise when staff members do not respect the job of others or they step on toes and work outside of their scope of practice. Neither helps the performance team function effectively and ultimately impairs the ability of the performance team to help the players.

COLLABORATION

The relationship between strength and conditioning and nutrition has always be an important one (19). Both areas complement each other and can help each other achieve common goals such as strength gains and improvements in body composition. Strength and conditioning coaches who are strong supporters of nutrition can assist with nutrition communication by reinforcing the same nutrition messages with the athlete and team, and help reach non-compliant players. If both staff groups are communicating and on the same page, player issues can be resolved quickly and effectively. Information that can be shared regularly includes player weight and body composition goals, performance during training, wellness scores, training demands, and compliance.

Nutrition and medical staffs also have the common goal of working to not only prevent injuries but also establish protocols to help players get back to full health as quickly as possible. Most injuries have a nutrition component and if there is daily communication about the status of player injuries or illnesses, then a nutrition protocol can be administered immediately to help assist with return to play (30).

The information gathered and compiled from the sport science staff can help tailor individual nutritional recommendations based on what is actually happening during training and competition using objective data. Specific variables, such as estimated calories burned, total workload, distance covered, high-intensity running, force and contact, decelerations, and heart rate (among others), can be used as a tool to help educate athletes about how to fuel and recover optimally based on training demands. The sport science staff can help identify which players need more attention from a recovery standpoint based on physical output.

TAKEAWAY MESSAGES

- Every situation is different and support from decision makers can boost the effectiveness of a nutrition program.
- Nutrition programs and sports RDs are not a luxury but a necessary and integral piece to the football performance team.
- Constant communication and collaboration from all staff members is essential for all groups to be successful.
- To maximize effectiveness to support players and coaches, everyone should be on the same page and speaking the same language.

OPPORTUNITIES

THE SCHEDULE

Before considering how to set up a nutrition program or what to have available for the team, an understanding of the yearly and daily schedule needs to be clear. The schedule will dictate where the players will be, at what time, and what they are doing based on the time of year (e.g., in-season, off-season). It also reveals where resources should be allocated and situated, where educational sessions may take place, and where the nutrition staff should be present (1,3).

OPPORTUNITIES

- Scheduled lifts, training, and conditioning sessions pose opportunities to have the team fueled, hydrated, and energized to maximize output during activity and to have the appropriate items available after activity for recovery (14,17,33).
- Scheduled meal times (home and away) offer several opportunities to follow-up with players, provide live meal coaching, answer questions, and teach and educate players on what they need in order to meet their goals and perform at a high level.

- Scheduled games serve as the most important single event on the schedule (home and away), where all nutrition resources should be implemented for optimal player performance at pregame, during the game on the sideline and on the field, halftime, and postgame (1,3,27).
- Scheduled treatment and recovery sessions are great times to follow-up with players to gauge daily wellness, communicate with medical staff about player status, sort out any issues, and perform individual informal educational sessions.

THE PROGRAM

A good nutrition program is well planned and tailored to meet the individual needs of players. It should also be structured based on the time of year as to factor in nutrition periodization. The program should plan for optimal and best practices (based on current research and experience) but accounts for players not always being 100 percent compliant. Meeting them in the middle and being open to compromises is necessary. Being open and flexible can help build trust, buy-in, boost morale, and develop a positive relationship with the nutrition program.

A good program takes into account:

- Opportunities
- Proximity and location of facilities and players
- Available resources
- Team culture
- Motivation
- Player habits
- Ability to be compliant

Developing good habits is essential for players to play at a high level for a long time. Good habits done repeatedly will produce desired outcomes. This holds true with nutrition, but it must be consistent and enforced daily. Due to the number of demands placed on players, people involved in their daily lives coupled with the rise of social media, they can quickly forget what to do or even buy-in to a diet or supplement advertised on the internet or through friends unless a well-qualified individual is available to guide and educate them daily.

PROXIMITY AND LOCATIONS

Maximizing locations and availability of nutritional items can raise player awareness and help reinforce good habits. The following areas are where players spend a lot of their time on a daily basis and should have a dedicated setup that includes access to appropriate nutrition and hydration items:

- Weight room
- Cafeteria
- Meeting rooms
- Player's lounge
- Training room
- Academic center
- Entrance and exit to facility

Many schools and organizations have fueling stations around these areas to fulfill that purpose. If a fueling station is not available or feasible, then a simple table, cart, or portable cooler can mimic and serve the same purpose. A setup does not have to be fancy or elaborate to be effective.

TAKEAWAY MESSAGES

- The schedule dictates everything.
- It is important to identify what the team needs based on what they will encounter. Identifying those opportunities and implementing a nutrition program around them is key.
- For a nutrition program to be effective, it has to have a vision, be implemented every single day, and be adaptable to meet the ever-evolving needs of the team.

CHALLENGES

There is no one size fits all nutrition application in the field because nutrition is always changing and should be individualized. The implementation of an effective nutrition program is an art based on science, and the goal is to meet each player's individual needs. However, the following challenges need to be considered.

TIME DEMANDS

Meeting each player's needs regularly and consistently is a challenge based on lack of available time. The goal is to make sure each player has what they individually need, get an equal amount of player face time, and gauge compliance and player satisfaction daily. This can be challenging due to the daily responsibilities and the fact that all the other staff members are vying for their time and attention too.

PLAYER CHALLENGES

Nutrition buy-in is the most important aspect, yet biggest challenge, when trying to implement a program. The challenge comes with getting players to do what you want them to do when they may have limited experiences with nutrition and different levels of motivation and habits. What food and nutrition means to players can be complex because everyone's nutritional knowledge level is different. There are a number of factors that influence players' food choices. Food choice is dynamic, complex, and constantly changing (4).

BARRIERS TO PLAYER BUY-IN

- A long history of poor nutritional habits that they either have not addressed to improve or are unaware of (6,22).
- The unknown of what players actually do when they are outside the facility and on their own time (potential for lack of compliance compounded with bad habits and poor choices).
- Players wanting results and improvements instantly and not following a nutrition plan consistently.
- Lack of formal nutrition knowledge and education from qualified practitioners (13,18).

- Lack of resources to purchase or access food (11,22).
- Lack of nutrition life skills (e.g., cooking, grocery shopping, cleaning, etc.).
- Not wanting to try new foods or nutritional habits, getting out of their comfort zone, or acknowledging available help.
- Being stuck in the pre-contemplation stage of the transtheoretical model of behavior change leading to constant non-compliant behavior.
- Listening to those who are not nutrition experts (e.g., "gurus").

UNCONTROLLABLE OR HARD TO CONTROL CHALLENGES

Below are external issues that do not have to deal with player buy-in but still pose significant challenges with implementing a consistent nutrition program.

- Lack of necessary resources in regards to facilities, resources, and staff.
- Unrealistic expectations from coaches and players on how quickly or how much weight a player should gain or lose (e.g., gain or lose 20 lb in minimal weeks) or unrealistic body composition goals (all linemen should be less than 20% body fat).
- Too many people outside of the nutrition staff thinking they should have input or voicing opinions on how the program should operate and what should be offered to players nutritionally.
- Too much misinformation from non-credible sources being interpreted by players from the media, news outlets, internet, TV, and magazines (32).
- General nutrition misconceptions about what players can or cannot consume (e.g., carbs, gluten, sugar, fast food, sports drinks, etc.).
- Fad diets, ineffective supplements, and detoxification protocols that promise benefits to health and performance but have no supporting evidence (20,21,29,34).
- Lack of communication and collaboration among staff affecting the ability of a staff member to effectively execute their job.
- Issues with coaches revolving around their lack of support about nutrition for their team or their narrow view of what can be done with a nutrition program.
- Staffs that refuse to change their ways and continue to implement practices that are not nutritionally advantageous.
- Unqualified or inexperienced individuals attempting to run a nutrition program but missing opportunities with poor execution and leading to a negative association with nutrition.
- Facility renovations or new builds planned and constructed without input from those that will manage them.
- Unforeseen factors, such as impromptu schedule changes, products out of stock or back-ordered, vendors or caterers not set on time, or wrong items being delivered.

TAKEAWAY MESSAGES

- There are a handful of challenges when implementing a nutrition program for a team and executing a program, especially for the inexperienced sports RD.
- A good nutrition program will not be perfect, but the sports RD should understand barriers to player buy-in and address them accordingly.
- A good nutrition program controls what can be controlled and plans for uncontrollable or hard to control challenges as they happen.
- One missed opportunity or one perceived unhealthy meal, snack, or eating day will not make or break a player's health or performance as long as their habits and compliance are consistent enough day to day.

CONCLUSION

Nutrition is a complex science that is always evolving. A nutrition program that is well thought out, visible, tailored, and has a vision can be a great complement to a team. This is enhanced with an experienced sports RD running the program, as well as buy-in from players, coaches, staff, administration, and management. Collaboration and communication among staff members and having the appropriate resources, facilities, and staffing supporting the nutrition program is vital to its success.

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REDUCING THE RISK OF ACL INJURIES IN AMERICAN FOOTBALL PLAYERS—EARLY INVESTMENT FOR LONG-TERM GAINS

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INTRODUCTION

American football is one of the most popular sports in the world; however, owing to the high-intensity, collision-based nature of the sport, there is an inherent risk of injury either during practice or competition (9). While there are growing concerns surrounding traumatic brain-injury in the sport (14), knee-related injuries are fairly prevalent within the sport (32) and result in significant time lost from activity.

Retrospective epidemiological data showed that 219 injuries to the anterior cruciate ligament (ACL) were experienced by players in the National Football League (NFL) between 2010 and 2013 (6). Additional data from the National Collegiate Athletic Association (NCAA) show that in American football, most injuries were caused by direct contact with another player, and that soft tissue injuries to the knee, including partial or complete tears to the ACL or menisci, were the most prevalent (5,16). Similarly, previous research has shown that among 20 different sports, American football had the highest injury rate (6.29 knee injuries per 10,000 hours of athlete exposure) among high school athletes (37). Cumulatively, existing evidence indicates that knee-related injuries, especially those involving the ACL, are a problem for American football players of all ages. Given that recovery from ACL injury typically lasts up to 9 months (8,11), the risk of re-injury is increased by as much as 25% (26,40), and the NFL players who suffer an ACL injury earn less money than salary-matched controls (33), concerted efforts should be made to minimize the risk of an initial ACL injury.

Research has consistently shown the ability of neuromuscular training to reduce the risk of ACL injuries in both male and female athletes (2), with data (albeit, primarily in females) indicating greater risk reduction when athletes are exposed to neuromuscular training earlier in their pre- or early adolescent years compared to late adolescence (24). Given the heightened ability of the neuromuscular system to adapt to developmentally appropriate training during childhood and adolescence, it would appear highly important for young American football players to engage in neuromuscular training as early as possible to optimize movement competency and develop a resilient and robust system to better tolerate the demands of the sport throughout their playing careers.

RISK FACTORS FOR ACL INJURY

American football is classified as a high-risk sport due to the elevated speeds of play and high frequency of rapid decelerations, hard cuts, and forceful collisions. For youth athletes, rapid changes in stature and mass, which lead to altered motor control strategies at key stages of growth and development (28), are also contributing factors to injury risk (31). The most common and severe injury in male youth team sports players is a knee ligament sprain (38), and these occur more frequently in the later stages of maturation. The incidence of anterior cruciate ligament (ACL) injuries in American football has been a point of discussion in recent years following a reported spike in ACL injuries in professional players. The traumatic nature and potential for long-term complications of such injuries indicates that attempts should be made to reduce their occurrence.

A paucity of evidence is available that has examined the mechanisms of ACL injury in male youth athletes and American football (1). In collegiate male players, competitions display the greatest risk, followed by practice sessions that are dedicated to scrimmaging (7). Research from other invasion-based sports (i.e., where two teams play against each other on a field with the objective of scoring a goal or point and preventing the opponents from scoring) has noted that pressing, regaining balance after kicking, and landing from a jump as the three main actions associated with non-contact ACL injury (39). It was also shown that ACL trauma occurred most frequently when in a position of dynamic valgus concomitant during a shallow knee flexion angle (< 30°) (39). While a range of anatomical and environmental risk factors have been indicated in male athletes (1), many of these are non-modifiable; thus, a greater focus should be placed on aspects that are responsive to targeted training interventions, namely neuromuscular adaptations.

Neuromuscular control strategies associated with ACL injury include quadriceps dominance, asymmetry, ligament dominance, neuromuscular coordination and sensorimotor control, and dynamic postural stability (22). While it is beyond the scope of this article to cover each of these risk factors in depth, a brief overview of each has been included with appropriate references for the interested reader.

QUADRICEPS DOMINANCE
During tasks that involve rapid deceleration, there is considerable anterior shear of the tibia relative to the femur, and this is counteracted by co-activation of the knee flexors. Imbalances between the quadriceps and hamstrings (quadriceps dominance) indicates an imbalance in force absorption and will increase the strain on the ACL (35).

ASYMMETRY
Asymmetry can be defined as an appreciable difference in force production and control between limbs, and this may place additional stress on the weaker leg, predisposing athletes to injury during cutting and landing activities. Limited evidence is available linking asymmetry with primary ACL injury, but deficits appear to remain following ACL reconstruction and may be linked to risk of re-injury (26).

LIGAMENT DOMINANCE
Ligament dominance involves excessive frontal plane motion with the knee moving inwards into a position of valgus. Similar knee positions indicative of reduced frontal plane control have been reported in male athletes who subsequently experienced an ACL injury (39). Greater loads are placed on the ACL in this position, which may be a predisposing injury risk factor.

NEUROMUSCULAR COORDINATION AND SENSORIMOTOR CONTROL
Neuromuscular coordination and sensorimotor control are required during sport-specific scenarios such as competitive match-play, specifically in sport scenarios where there is limited time for decision making and postural repositioning. Non-contact ACL injuries have been shown to occur between 17 to 50 milliseconds following ground contact (17). This short time frame indicates that neuromuscular coordination and sensorimotor activation patterns such as pre-activation (early recruitment) of the involved musculature prior to loading is an effective force absorption and knee control strategy to potentially reduce joint torques and ligamentous loadings.

DYNAMIC POSTURAL STABILITY
Dynamic postural stability is required to maintain the position of the body's center of mass within the base of support (23). A more lateral trunk position has been shown to heighten knee injury risk (41), likely due to increased joint loads. For youth athletes, increases in body mass and center of mass height following periods of rapid growth will make controlling the trunk more difficult. As jump performance increases due to maturation, this will further magnify the challenge as a result of higher velocities at the point of impact.

There are few studies available that have examined biomechanical and neuromuscular risk factors in male athletes. Reduced total and internal hip range of motion has been identified in soccer players who sustained a non-contact ACL injury (10). A more erect trunk position during single-leg landing maneuvers has also been shown from video footage captured at the time of ACL tear (34). Further research is needed to more clearly elucidate baseline risk factors for ACL injury in this cohort. Preventive exercises targeting neuromuscular and postural control can then be implemented via risk stratification to heighten training effectiveness.

REDUCING DEVELOPMENTAL RISK FACTORS FOR ACL INJURY
ACL injury is exacerbated by numerous neuromuscular and anatomical risk factors (15,30). Consequently, injury prevention programs must be diverse in nature to negate these risks. As with all injuries, prevention is better than treatment and, therefore, a pre-emptive approach through sound long-term athletic development is recommended. ACL injury occurs through exposure to high forces while displaying aberrant movement patterns (15,17). Hence, it is intuitive that prevention programs should address both of these issues by correcting faulty movement patterns and then developing the capacity to safely tolerate large forces.

Dynamic knee valgus involves a combination of hip adduction and internal rotation, knee abduction, tibial external rotation and anterior translation, and ankle eversion (12). Since most ACL injuries occur due to dynamic valgus collapse in cutting or landing tasks (usually unilateral) (17,39), it is necessary to provide an athlete with the skills required to execute these tasks with minimal risk of exposure to injurious positions. Neuromuscular coordination training has consistently been shown to be an effective strategy for reducing ACL injury risk factors such as dynamic valgus collapse (23). Such training programs begin with developing robust movement patterns in simple athletic tasks such as jumping and landing, squatting and lunging (21). This training can be safely implemented at a young age to build the foundations for a structured resistance training program in the future. The importance of which cannot be overstated since children will grow taller and heavier and subsequently be exposed to greater forces in high-risk positions if this is not addressed. It is essential that this neuromuscular training occurs prior to the pubertal growth spurt, since evidence shows that there are greater numbers of ACL injuries in post-pubescent compared to pre-pubescent children and this phenomenon is even more prevalent in females (36).

Once movement competency in these foundation movements has been established, it is necessary to develop the force tolerance capabilities of the athlete, which can be done through a targeted and structured resistance training program. Resistance training has been demonstrated to be effective at reducing ACL injury risk factors such as dynamic knee valgus (12) and a combination of resistance training and plyometrics is optimal to enhance joint stiffness and tendon stiffness (18). The gluteal muscles are hip abductors and external rotators, which play an important role in resisting dynamic knee valgus (30). The hamstring muscles resist the anterior tibial translation that places undesirable strain on the ACL (25). Thus, neuromuscular training programs should place particular emphasis upon these posterior chain muscles since this has been shown to be an effective strategy for reducing the risk of primary ACL injury (23). Attention also needs to be given to strengthening the trunk muscles to prevent undesirable multi-planar movements, as this has also been observed to be a risk factor for injury (41). Due to the greater degree of instability and narrower base of support during unilateral stance, it is advocated to include single leg strengthening exercises to place greater emphasis upon stabilizing musculature and neuromuscular recruitment patterns that maintain appropriate joint alignment.

There is also a need to target feedforward movement control mechanisms and pre-activate the appropriate musculature due to the short time frame following ground contact in which an ACL tear occurs (17,39). Consequently, there is insufficient time for the nervous system to provide feedback if limb alignment is undesirable; therefore, training interventions that develop these qualities are considered beneficial. Plyometric training has been shown to reduce ACL injury risk factors (13). A conservative approach to plyometric training is advised initially, starting with low eccentric load bilateral exercises, eventually progressing to high eccentric load unilateral exercises as strength improves to facilitate such intensities. Since the target of injury prevention strategies is to correct movement patterns and then strengthen the correct positions, there should be a continual emphasis upon optimizing technical execution at all stages of the training program.

PROGRAMMING

PRINCIPLES

Participation in an integrated neuromuscular training program that focuses on developing muscular strength and movement competency from a young age is of vital importance to reduce the risk of injury and increase performance (20). Stronger young athletes will be better prepared to learn complex movements, able to sustain training and competition demands of American football, and are less likely to suffer a sports-related injury. Structured interventions should always include qualified instruction and activities that are developmentally appropriate with a technique driven emphasis. While chronological and biological age may have an influence on the type and volume of training that is prescribed (29), an adolescent with a low training age and poor technical competency should not commence a high-intensity training program without first developing a range of movement skills and base levels of muscular strength. Similarly, a pre-pubertal child who possesses innate athleticism and high levels of technical competency should not be restricted to training modes typically associated with inexperienced children.

EARLY STRENGTH AND CONDITIONING

The focus of physical conditioning programs from early childhood should focus on developing a breadth of athletic motor skill competencies (AMSC, Figure 1), which are a series of foundational motor skills that combine to produce athletic movements and include upper body pushing/pulling and lower body bilateral/unilateral movements, jump and land abilities, and trunk conditioning activities (21). The AMSC are regarded as the building blocks for sport-specific movement patterns that can be established later in a young athlete's development. For young athletes with a low training age, the use of their own bodyweight as a form of resistance provides a suitable training stimulus for the simultaneous development of motor skills and muscular strength. Basing exercise selection around the AMSC should be the priority; allowing young athletes to learn the correct movement patterns for squatting, lunging, pushing, pulling, jumping, landing, and bracing.

FIGURE 1. ATHLETIC MOTOR SKILL COMPETENCIES (21)

PROGRESSION

Considering the collision nature of American football, strength and power are key physical qualities that will often determine success in the sport (9). Additionally, research has revealed close associations between muscular strength and sprinting and jumping performance in young athletes (4,27), which are key qualities that may determine the outcome of a competitive game. Therefore, once a young athlete has achieved a good level of technical competency in the AMSC, strength and conditioning coaches should introduce additional load to the exercises to progressively overload the muscular system and continue to make improvements in strength levels. A variety of training methods includes manual resistance, machine weights, plyometric exercises, medicine balls, and elastic bands. Compound movements such as squatting, deadlifting, lunging, and other single-leg exercises (e.g., step-ups) should be staple exercises for most strength and conditioning programs in order to develop strength in key movement patterns that will translate to success on the football field.

Recommended resistance training guidelines for youth have been proposed as 2 – 3 sets, 8 – 15 repetitions with loads of 60 – 80% of 1-repetition maximum (1RM) (3). However, recently, research focusing on well trained young athletes has concluded that the most effective training prescription for strength gains required the use of heavier loads (80 – 89% of 1RM) and greater training volumes (5 sets of 6 – 8 repetitions) (19). Therefore, as a child becomes more experienced, the volume and intensity of resistance training will need to increase for ongoing improvements in strength and power. This progressive approach to strength and power development will help the athlete continue to meet the physical demands of American football, especially as their level of performance and physical size and strength of opposition increases. However, it should be noted that the prescription of resistance training should always be individualized, based on factors such as technical competency, biological age, and both sport-related injury risk factors and those identified during athlete screening. It is imperative that the prescribed training is part of a holistic training program that is appropriate for the developmental stage of the athlete (20).

SUMMARY

While the complete eradication of sports injuries is impossible, existing research clearly shows that the risk of ACL injury may be reduced when athletes are exposed to, and engage in, neuromuscular training programs. Given the many deleterious, long-term effects of ACL injury, including the increased risk of osteoarthritis and re-injury, strength and conditioning coaches play an essential role in the efforts to minimize the risk of the injury in the first incident. While data on young male athletes requires greater attention, the existing body of research points to the fact that athletes are likely to benefit more from early engagement in neuromuscular training. While this form of training should encompass a range of training modalities, developing movement competency and strength levels appears to be critical.

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RETURN TO PLAY—TRANSITIONING FROM REHABILITATION TO STRENGTH AND CONDITIONING WITH THE FOOTBALL ATHLETE

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A reality of football is that it consists of high-speed, forceful impacts, and thus, injuries are inevitable. Indeed, they show relatively high rates compared to other sports (4). These injuries can range from minor to drastically severe. Once the injury occurs, there are several processes that take place in order to set the athlete back on the path to healing, training, and ultimately, playing in competition again. Strength and conditioning professionals play a vital role in this process. Each step in this process is extremely important and should be approached with careful consideration and planning by the entire staff. This return to play protocol requires careful, detailed, and innovative ways that can safely progress the injury sustained by the player, as well as provide the challenge needed in order to get them ready to return to the gridiron.

The aim of this article is to cover some of the challenges, as well as solutions that are involved with transitioning a football player from rehabilitation to strength and conditioning. A lot of what is done from a rehabilitative perspective is in contrast to the strength and conditioning component of a periodized training program. However, there are some areas of overlap in conditioning/reconditioning the athlete back from injury.

COMMUNICATION AND SYNERGY

Communication is very important and may be the glue that holds the entire return to play process together. Unfortunately, athletes often pay the price for poorly coordinated recovery plans within the return-to-play process (7). A lack of communication between medical providers, strength and conditioning coaches, and team coaches can slow or prevent athletes from returning to peak capability and increase the risk of new injuries and, even more devastating, reinjuries (1).

It would make sense practically that the rehabilitation specialist should dictate the rehabilitation components of the athlete's return to participation, which is under the direction of a qualified physician. In the same sense, the strength and conditioning coach should oversee and progress the strength and performance phase. However, challenges arise when a physical therapist and/or athletic trainer, who may not have adequate knowledge and experience of periodization or efficient ways to structure a strength training program, tries to dictate those components. Along those same lines, strength and conditioning coaches generally do not have in-depth medical knowledge so it would be unwise to have them oversee the rehabilitation components of a return-to-play progression. However, it is important to recognize that the overlap of rehabilitation and strength training is inevitable. One individual should not be expected to possess all of the knowledge and training needed to ensure complete recovery for athletes through all stages of the return-to-play process (8). It is important for these athletes to have professionals that know how their role fits into the big picture of returning the athlete to their pre-injury status. The high level of communication between those individuals concerning their specific areas will facilitate success for that athlete. When working with an injured athlete, whether it be a recent injury or working on developing their transition back into the team population, an open dialog between the medical staff and strength coaches with each room understanding what the other is doing, provides optimal opportunity for the athlete to develop to their maximum potential. It is also important to communicate honestly with the athlete. The player needs to understand the plan and progression as much as anyone else involved. Communication is vital in them achieving the goals on their road to full recovery.

PROGRAM REPLICATION

A cause of concern in terms of overloading the athlete is the overlapping of rehabilitative and strength programming. For example, if the rehabilitation for the day is a heavy focus on general strengthening, it may not be beneficial for the athlete who is partially participating in lifts to do the same thing in the weight room. Also, if the athlete is prescribed certain exercises in rehabilitation, it makes no sense to repeat the same exercises during the lifting program.

For this particular athletic population, a strength and conditioning program utilizing a reduced training volume load may prove more effective for improving performance in the future (9). An awareness of the exercise prescription on any given day will better enable the rehabilitation staff and strength coaches to anticipate, collaborate, and administer treatments (8). This obviously relates to the above point of communication as well.

PARTICIPATION IN PRACTICE

One aspect that is unique to the sport of football is the implementation of the return-to-play program as it pertains to the practice schedule. In a normal football practice, players may be subjected to demands in intensity that could interfere with the normal, safe rehabilitation progression. Full contact football is uniquely dangerous to the athlete due to collisions that are expected and accepted within normal practice days. What the athlete can do at practice and when they will actually do it is a consideration that has to be discussed with the coaching staff. There may be days, particularly when a player is close to clearance, when an athlete's participation at practice is limited and must coincide with the continued return-to-play programming. For example, if a player is to participate in the individual period of practice where they perform repeated repetitions of various position-specific drills that may involve running, the rehabilitation and strength training may need to be adjusted to fit the demands of that particular day. For example, it may not be wise to do a high-volume or high-intensity hamstring lift on the day a wide receiver is going to be running high repetition or long yardage routes. One useful way to monitor this is by using wearable technology. The use of global positioning systems (GPS) is one such technology that is commonly used throughout the National Football League (NFL) to measure movement demands and training load. In this example, the GPS monitoring can be done to make sure the injured player is transitioning back onto the field without exceeding recommended training loads. Although there are many factors that could contribute to injury or reinjury, regardless of the method used, external load should be monitored from an individual perspective (5).

RECOVERY

The monitoring of training loads goes hand in hand with methods of recovery when discussing the progression back on to the field (6). Understanding recovery methods will allow the strength and conditioning professional to safely gauge the proper amount of stress for the particular player without causing setbacks in the progression. If training is done 4 – 5 days per week, a split routine is advocated to allow proper recovery between the muscle groups used (10). Activities on "off days" might include flexibility training, yoga, balance, proprioceptive exercises, or core/abdominal training. An adequate recovery period is crucial in allowing the player to perform on the field while continuing to reach the point of complete clearance from all restrictions.

IMPLEMENTATION CHALLENGES AND SOLUTIONS

The strength and conditioning programming for the injured football player is something that every team will face at some point given the risk of injury in the sport. Many of the solutions to these challenges lie in drawing on experience and understanding the individual athlete, while using a scientifically-guided approach. Some of the challenges from a strength and conditioning coach's perspective include communication between the player and sports medicine staff, understanding the specific player's mindset, mindfulness of their physical ability, as well as continued player development when out for extended periods of time.

ATHLETE MINDSET

The physical demands of a sport like football can be extremely difficult for the elite, healthy athlete. There is even added pressure when that elite football player becomes injured. Negative psychological responses to injury often result in a lack of rehabilitation adherence or prolonged recovery rates, or both (2). As strength and conditioning professionals, we need to understand the athlete's mindset as specific individuals every day. We need to know when to push and when to take a step back and evaluate all that the athlete is dealing with, whether it is on-field pressure or off-field issues. This goes hand-in-hand with communication between the athlete and each staff member involved. There will be good days of training and there will be bad days. The goal is to have more good days than bad days, and to push the athlete to stay the course and fulfill their maximum potential. Variations of exercises are great ways to break the monotony of every day training when coming off injury, which can help the strength and conditioning coach in determining when to push the athlete or when to back off. Routines are great, and the majority of professional athletes have routines, but through the experience of working with injured athletes, unpredictability can be useful for managing athlete's mental state. However, it is important when changing the routine that the athlete understands why their routine is changing and that will help them to be adaptable on and off the field.

TRAINING ABILITY AND PROGRESSION

As strength and conditioning coaches, we want to see ability and progression with all of our athletes. It is imperative to stay mindful of what the injured athlete is able to do, and work the progression off of this timeline. This ties into communication and understanding the player's mindset on a daily basis. A strength and conditioning coach may think a player is ready to advance a lift or progress to what should be next in the progression, but in order to do that, both the player and involved staff have to know what is planned and why. In almost every weight room around the country, there are strength and conditioning coaches that demand more from their athlete's than what they are getting, which is how progression works. When working with injured athletes, every aspect of physical activity is under a microscope. In order to progress and maximize an injured athlete's work output, strength and conditioning coaches need to be mindful of their ability to do the prescribed workload, which requires communicating with the athletic training staff. Strength and conditioning coaches need to take the good with the bad and progress further.

PLAYER DEVELOPMENT AND TEAM INCLUSION

The above points (communication, understanding player mindset, mindfulness of ability, and progression) all tie together for the final point, which is that strength and conditioning coaches should address player development when they are injured for an extended period of time. Injured or not, it is important for an athlete to feel included in the team setting, including during strength training sessions. In younger athletes, friends, family, and the social context are of considerable importance (3). While injured, some athletes describe how they feel excluded, lonely, and concerned about losing their position in the team or training group. Strength and conditioning coaches should attempt to involve the injured athlete with their teammates during team workouts or in less physical demanding activities. Strength and conditioning coaches may need to be creative in planning workouts in order to avoid putting the athlete at risk of further injury, while also being inclusive so that they are aligned with the team objectives. It is easy to send an athlete over to the athletic training room while there is a team lift going on, but in order to challenge the player, the strength and conditioning coach should keep them on board with team objectives and maintain their alignment with their own personal goals. Strength and conditioning coaches must incorporate the injured athlete into the daily plan, but this may require getting out of their comfort zone as a strength and conditioning coach, as well as having some creativity. It is important to keep progressing an injured athlete toward returning to full health, while including them in team workouts, so they are not excluded from normal team activities while injured.

CONCLUSION

It is rare that two athletes with the same injury possess the same mindset. Strength and conditioning coaches need to be aware of all factors at play on an individual basis in order to maximize performance. Through open and effective communication, understanding the athlete's mindset, and mindfulness of inclusion in team activities based on ability, strength and conditioning coaches need to make sure the athlete has bought into their specific individualized return-to-play plan. This will help them to get the most out of individual and team goals. Ultimately, the strength and conditioning coach's job is to help football players achieve all of their desired outcomes when they return from injury to the football field. Strength and conditioning coaches can do this with a player-centered approach, focusing on maximizing individualized performance with all parties involved, including the sports medicine staff, coaching staff, and strength coaches being on the same page. In conclusion, developing and implementing a systematic approach to transitioning a football player from rehabilitation to strength and conditioning includes using a scientifically-guided approach, experience, some creative out-of-the box thinking, and understanding the individual athlete, but most importantly, communication.

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MOVEMENT SKILL ACQUISITION FOR AMERICAN FOOTBALL—USING "REPETITION WITHOUT REPETITION" TO ENHANCE MOVEMENT SKILL

SHAWN MYSZKA, MS, CSCS

INTRODUCTION

At the heart of the performances that occur on a football field exist the movements of the human body; a player's ability to coordinate, control, and organize their movement skill in response to the ever-changing problems presented by events, objects, and opponents within the competitive environment. These movement solutions, while carrying out collective behavioral goals driven by a team's tactical strategies, represent the glue that binds all eleven positions working together in shared manners through the course of a game.

To help understand the emergent movement behaviors which occur in American football, it is often advantageous to employ an approach using an ecological dynamics framework (3,4). This approach, which combines ideas of ecological psychology along with those from the dynamical systems theory, was introduced as a means of viewing the human movement system as a complex adaptive one which interacts with important tasks in the environment through on-going information and energy exchange (3,4). These interactions between the athlete and the environment lead to important perception-action coupling (also known as information-movement coupling) as the athlete attempts to solve the movement problems presented (3,4,5). From a practical application standpoint for coaches, it is important to understand how one should go about crafting these perception-action couplings through the practice means and methods employed within the constructed learning environments.

Considering the ideas of the motor behavior scientist Nikolai Bernstein, who poignantly stated that the process of practice for enhancing movement skill should not consist in mere rote repetition (i.e., repeating a particular solution, repetition after repetition) but instead should be an on-going problem solving process where athletes are required to solve the problem again and again by a solution structure which they are changing and optimizing each time they face the problem (i.e., coined "repetition without repetition") (2,9). Bernstein proposed that this "repetition without repetition" practice structure could promote a search process by the athlete through constant exploration and discovery of more functional coordination solutions. Furthermore, it could serve to enhance the dexterity of an athlete's movement system. For the purposes of this article, dexterity refers to the ability to find a movement solution for any situation in any condition (9). Therefore, dexterity should be a hallmark capacity of movement skill expertise which coaches aim to enhance.

MASTERFUL MOVEMENT FOR FOOTBALL

Dexterity is driven by having a functional match between the athlete and the range of environmental and task constraints that he must aim to satisfy during the organization of his movement solutions. These solutions extend beyond the surface appearance of the executed movement (e.g., the technique, motor patterns, or biomechanics). Instead, the construction of these functional movement solutions become characterized by having heightened perceptual attunement to the specifying sensory data that will direct one to the affordances for action within the problem (8).

Knowing that similar situations can selectively invite, as well as constrain, various movement strategies and patterns from different performers, the masterful mover will understand the ways that he may be able to exploit the strengths of his individual movement toolbox. Based on this sensory-perceptual information, one must make decisions that are accurately formed spatially and temporally to fit the motor problem at-hand by selecting and organizing the appropriate response.

Often times in football, one may need a host of options at the motor level for carrying out the solution. More specifically, the athlete will rarely be able to execute a motor response in the fashion that may be deemed "textbook" and/or fit certain technical movement models. Fortunately, the human movement system inherently possesses the capacity to display a great amount of movement variability in order to give rise to these needed functional options. This has been termed motor abundance or degeneracy (11). These behaviors show that the human movement system has the ability to vary motor behaviors without compromising function or performance outcomes, which is precisely what is required to appropriately handle the information-rich, dynamic environment indicative of a sport like football (11). Overall, the more masterful moving athlete, armed with perceptual attunement and these abundant options, will be able to intimately interact with the environment and sufficiently coordinate, control, and organize an adaptive movement solution which effectively solves the problems at-hand.

CHANGING THE MOVEMENT SKILL ACQUISITION PARADIGM

When focusing on ideas concerning the acquisition of enhanced movement skill, coaches often think of traditional approaches which involve what many would refer to as "perfect practice" or the accumulation of repetitions consisting of a more idealized or stereotyped movement pattern until it theoretically will become automatic. Due to this expectation for automaticity, coaches will offer a sometimes constant barrage of instruction and feedback in practice hoping to change the athlete's representation of how a skill should be executed more "perfectly." Theoretically and traditionally, the way to that automaticity and more perfect execution is found through the accumulation of more repetitions.

This approach, however, is not without its critics who point to a number of realities of motor behavior, control, and learning in sport; namely, no two problems (i.e., situations) in American football are truly ever the same. Thus, if the athlete were to over-practice under more rigid and fixed constraints (where one attempts to repeat a task in a nearly identical fashion in a non-changing environment) it would significantly slow and hinder the acquisition of movement skill expertise. Under practice conditions set up in this way, the athlete will lack opportunities to adapt movement solutions to ongoing changes in the problems being faced (4,12). Furthermore, this could potentially decrease one's ability to display more dexterity when the time comes for the movement to be executed under more extreme physiological and psychological constraints like fatigue, pressure, anxiety, and complexity within the problem. Thus, the process of skill acquisition may be less about acquiring an entity of skill, but instead to enhance the more functional relationship between the athlete and the dynamic environment that they are required to perform within (1).

REPETITION WITHOUT REPETITION IN 2018 AND BEYOND

Movement on a football field occurs in a dynamic, fast-paced environment where there are various organism, environment, and task constraints which coalesce to influence the self-organization of emergent movement behaviors and the ultimate performance that the athlete can achieve. According to the constraints-led model originally outlined by Newell (10), *organism* constraints refers to the individual performer's characteristics or features that are both physical or functional, *environmental* constraints refer to both physical and sociocultural variables in nature like temperature, ambient light, playing surface, or cultural norms and expectations, and *task* constraints usually refer to the actual activity such as rules of the game, equipment used, boundaries, and the opponents to be faced (3,4,5,10). These constraints are always interactive and set the boundaries to create the specific problem that the athlete is facing at that moment in time (otherwise known as the perceptual-motor workspace), whether it is in a practice environment or the competitive performance arena.

Due to the wide range of potential problems that the athlete may be required to face on game day, it is often difficult to determine the level of performance transfer from the training environment to game situations. However, it could be said that failing to replicate the required movement demands in practice will detract from the athlete's potential ability to adapt under the host of constraints it will be presented with in a game. If an athlete is unaccustomed to dealing with the demands required in the game situation, when they are required to face a perceptual-motor workspace with the increased perceptual-cognitive load indicative of these situations, it will likely be difficult to handle accordingly. This could lead to an athlete: 1) missing relevant specifying perceptual information for solving the problem, 2) making inaccurate or mistimed decisions for action, and/or 3) lacking the capability to adjust the biomechanics to meet the needs of the problem.

To help combat the potential negative consequences previously mentioned and drive more effective movement behavior for football performance, coaches should aim to manipulate constraints in the practice environment. Through this type of learning design, athletes will more frequently encounter activities which contain the necessary specifying information that they must become attuned to and adapt their movement in conjunction with (i.e., thereby enhancing the likelihood of the emergence of functional information-movement/perception-action couplings) (1). This type of dynamic performance environment can be simulated by the inclusion of what has been referred to as representative task design which contains activities which behave, look, feel, and act like one's sport (3). This does not necessarily mean that in order to acquire skill that is functional that the athlete needs to be specifically engaged with the sport. Instead, coaches must investigate an athlete's current movement toolbox in-context (i.e., game-film) to determine where weaknesses and gaps may exist within their movement behavior repertoire on the field. Coaches can then use this needs analysis to guide the activities that are prescribed in practices/training by looking for ways to manipulate practice constraints to create problems which are representative and expose the athlete to game-like situations that will require them to adapt during competition.

To further enhance the likelihood of emergent skill adaptation for the athlete, coaches should combine these representative learning ideas while also looking for ways to include Bernstein's thoughts regarding "repetition without repetition." Namely, a problem that is ever-changing will equate to a solution that will need to be adjusted repetition to repetition and include skill capabilities that enhance dexterity. In order for this to occur, the athlete will need the opportunity to couple their movement behaviors to appropriate information variables and, in turn, more practice in perceiving, deciding, and acting. To accomplish this, coaches can design practice tasks where strategic constraint manipulation will lead to the following:

Exploration – Self-organization of the human movement system is encouraged through discovery learning of the perceptual-motor landscape. Through this landscape, the athlete is given the opportunity to search (i.e., explore) their potential movement solutions by controlling for the degrees of freedom in their coordination and control solutions.

Amplification – When the most specific information of the problem is presented (i.e., amplified) in the practice environment, the athlete is given the opportunity to connect to this information, thereby increasing the potential that the human movement system receives an education in perception, intention and action.

Exploitation – When athletes becomes accustomed to facing a wide range of problems, they begin to understand their unique affordances for solving (i.e., exploiting) the problems. From there, athletes will gradually expand their movement toolboxes to allow for enhanced access under a diversity of conditions.

A reality with training in a practice environment that looks, feels, and behaves more like game situations is that they are often "messier" and more mistake-filled, so some coaches feel apprehensive about their athletes' resultant movement execution or outcomes. Within this type of practice structure, the goal is not to strive for an idealized movement pattern or identical execution repetition to repetition but instead to achieve authenticity and ownership under these ever-changing conditions. Because of this goal for practice tasks, when athletes attempt to satisfy these problem constraints, they will often be coming in and out of "grip" with their movement solutions and progressively be pushed further into a learning zone. This type of learning zone is indicative of a perceptual-motor workspace where the athlete can truly expand their skill. This type of space is sometimes known as the optimal challenge point where coaches should acknowledge that: 1) movement tasks represent different challenges for different athletes, 2) as skill level improves, the expectation for increase in performance will revolve around designing a task that becomes progressively more challenging, and 3) when increases in functional task difficulty occur, there may be a decrease in acute performance but an increase in the potential for learning to occur (6). It is here that coaches can begin to respect the nonlinearity and individuality present within learning environments and design appropriate challenges that stretch one's movement capabilities.

Finally, individual ownership for movement performance should become a key objective. In many instances, coaches offer too frequent or too explicit instructions and feedback for individual ownership to truly be enhanced. This over-communication can be a very slippery slope which quickly leads to an athlete's overreliance on the coach for guidance. Instead, it may be preferable to adopt a learner-centered approach where, for example, the coach includes less explicit rules for movement execution, more externally focused instructional cues, and more faded or descriptive feedback (rather than highly explicit rules, internally focused instructional cues, and frequent or prescriptive feedback that is more indicative of a coach-centered approach) (7).

Collectively, the primary outcome of the aforementioned movement practice recommendations is centered on the retention of the nuances of the skill to be learned as well as a higher potential for transference to the performance environment. Ultimately, everything should be done to craft a movement skill that is both stabilized (i.e., consistency within the states the athlete finds himself in) and flexible (i.e., adjustable to the constraints) so that it can be organized accordingly regardless of what conditions it may need to be executed within and how it needs to be adjusted (1,3).

EXAMPLE—REPRESENTATIVE TASK DESIGN TO IMPROVE OFFENSIVE AGILITY SKILL

For example purposes, take a running back (i.e., the organism) with whom a coach is trying to improve the movement skill of evasive agility with the objective to help the athlete feel more comfortable in time and space to evade one or more defenders. As discussed throughout the article, the coach's activities should help enable the discovery of individualized functional movement solutions which will allow the athlete to develop a diverse movement toolbox in order to manipulate available space and time, exploit the movement weaknesses of defenders, and ultimately gain an advantage over the range of problems faced during games.

To accomplish the objective, the coach could design a practice activity which would stand as a representative task where the information present within the problem represents a specific one and the athlete is offered sufficient opportunity to perceive and act in accordance with. It should be noted that that movement solution variability (both inter- and intra-individual) is expected to exist within each level of the human movement system (i.e., perception, intention, and action) both based on the skill level of the athlete and the variability/fluctuations present within the problem. This means that coaches should be expecting an authentic movement solution to emerge for each individual athlete even if they are faced with a relatively similar problem as another athlete. The following are considerations for coaches when designing such a practice activity.

ENVIRONMENT

Choose a space to operate within. Requirements include a start line, a line-to-gain marker/end zone line, as well as potential boundaries to the left and right of the participating athlete.

TASK

Have the athlete sprint to (and from) any number of directions and angles within the space, and attempt to execute directional changes with unpredictable locations and times (changing the spatial and temporal demands problem to problem) in response to an ever-changing opponent.

POSSIBLE PROBLEM/ACTIVITY VARIATIONS (BUT CERTAINLY NOT LIMITED TO)

- Change the size of the space (length or width) and/or shape. This environmental constraint change will challenge the kinesthetic sense and awareness capabilities of the athlete by understanding potential affordances for action with various spatial demands.
- Change the opponent's movement behaviors or the number of opponents. This task constraint will require the athlete to solve various problems by understanding subtle differences between the situations set up by various opponents who will likely possess a range of movement skillsets.
- Change starting conditions or movement strategy of the athlete. This organism constraint will force an athlete into variable/differential motor learning, which will require modifying movement behavior accordingly to self-organize a movement solution in response to various positions and patterns.
- Change the field conditions. This environmental constraint will test adaptability of the movement solution by modifying the interaction that occurs between the foot of the athlete and the field surface (e.g., a movement strategy that works on one style of surface may not work on another).

It is important to note, the number, degree, and magnitude of the constraint manipulations should be strategically designed to "stretch" the dexterity of a player's movement toolbox; however, care should be taken to ensure an appropriate matching of the demands of the problem to the skill level of the athlete. Each of the potential problem variations mentioned above, as well as any additional constraint manipulations, will have a subsequent effect on the athlete's process of constructing a movement solution.

CONCLUSION

The acquisition of functional movement skills for football performance can be improved through the use of a constraints-led approach for designing representative tasks to be carried out in a "repetition without repetition" framework. This type of approach will require an athlete to become more attuned to the specifying information in the environment, make accurate decisions in-line with their desired intentions more frequently, and to adapt their movement patterns to meet the needs of problem demands. The intended outcome from this type of practice environment will be improved perception-action couplings which will allow for more effective problem-solving as well as improved movement skill and movement solutions on the football field.

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LEAVE NO STONE UNTURNED—TRAINING FOR SUCCESS IN THE NFL COMBINE

LOREN LANDOW, CSCS,*D

INTRODUCTION

Every spring, the National Football League (NFL) converges for their Player Selection Meeting, more commonly known as the NFL Draft, in which the 32 franchises take turns picking new potential signees from a pool of draft-eligible college juniors and seniors. The event has become a public media spectacle over the years, broadcasted nationally and inspiring endless online analysis and discussion. In the span of a few months between the final collegiate whistle and a team going "on the clock" for the first overall pick, football fans devour information about potential future NFL stars, and assemble mock drafts to predict potential scenarios.

The front office of each franchise works year-round to evaluate thousands of NFL Draft-eligible prospects from the nearly 800 college football programs across all levels (8). From those eligible players, less than one percent will receive an opportunity at playing in the NFL. The NFL Draft consists of seven rounds, with trades and compensatory picks from free agency determining the number of picks per team. After the event, another 200 or so players will sign undrafted free agent contracts to compete for an NFL roster spot. Thus, earning either selection at the NFL Draft or a free agent contract is a rare achievement; one must truly be the best of the best to have a chance to play in the NFL.

Draft week marks the beginning of a new and exciting career for these athletes, but it is also the finish line for a brief—yet intense—sprint of preparation for various job interviews. In the timespan between a player's final collegiate game and the NFL Draft (about 3 – 4 months), he will face an onslaught of training, studying, bowl games, and all-star games. Nearly every athlete will showcase his athletic abilities at a college Pro Day, and up to 335 of the top prospects will receive an invitation to the NFL Combine with others choosing to attend an NFL-sanctioned regional or super regional combine. Effective and efficient preparation for the demands of these tests is of the utmost importance for maximizing one's earning potential (i.e., contract and bonuses) at the professional level.

DEMANDS OF THE NFL COMBINE

The NFL Combine is a week-long evaluation process that allows NFL scouts, coaches, general managers, and owners to get an up-close and personal evaluation of the talent that comprises the given year's draft class. NFL Combine officials take each player through four days of interviews and testing in large waves, with different positional groups starting the event at staggered intervals.

A NFL Combine invite is a great honor, but also an immensely difficult challenge. The event begins with a three-day gauntlet of physical assessments, during which the medical staff of all 32 teams put players under a figurative microscope to evaluate health and potential injury risk. Among the examined vitals and information are blood panels, electrocardiogram (EKG), X-ray, and magnetic resonance imaging (MRI). Teams will scrutinize players with prior injuries to determine how those injuries have healed, as well as the general level of wear and tear on the athletes' bodies. Scouting departments may examine results of the Cybex leg test for hamstring and quadriceps isokinetic concentric strength to determine the quadriceps to hamstring strength ratio. Researchers have also found this test to be an effective evaluation of peak torque disparity between an athlete's dominant and non-dominant sides (13). NFL Combine officials also administer mental aptitude tests such as the Wonderlic Personnel Test.

The myriad of medical assessments and interviews leads into a fourth day, which is comprised of on-field skills assessments. Given the television broadcast of these drills, fans can watch and critique each player, unaware that the athletes have been staying awake until 1:00 am for the several nights to undergo formal and informal team interviews only to wake up again by 5:00 am for weigh-ins, drug testing, and additional meetings and examinations. Once the testing and interviews are completed, athletes pack their bags and leave the NFL Combine and another group of players from other position groups will arrive, ready to begin their own four-day journey.

Although this bombardment of tests is certainly an immensely challenging trial, it is important for the athletes to remember during preparation that the evaluation process is not a right—it is an opportunity. Simply stated, receiving an invitation to the table is much easier than earning an offer to remain seated there. These athletes must put on their best figurative "suit" to make a strong first impression with potential employers.

PREPARING FOR THE NFL COMBINE

So how does one prepare athletes for this process? The window for preparing and training for the NFL Combine is usually 6 – 8 weeks, and in some cases as little as 2 – 3 weeks. There are various factors determining this period for an individual athlete, including the date when his collegiate season ends and any all-star games he may play in (e.g., Senior Bowl, East-West Shrine Bowl, NFLPA Collegiate Bowl, etc.). The player's chosen agent will also be a key factor in deciding where and when to train. The strength and conditioning professional's role is to maximize results for the number of weeks each athlete is available to train. There are several private facilities that specialize in NFL Combine preparation, but for the sake of this article, what is done specifically at our training facility (Landow Performance in Denver, CO) will be discussed.

ATHLETE INTAKE AND EVALUATION

The typical journey at our facility begins with an intake, including complete medical and physical assessment from our team of athletic trainers, orthopedists, and physical therapists. Typically, the athlete's agent has a good understanding of the athlete's injury history, but they may still be unaware of certain issues. For example, an agent may know that his or her client tore an anterior cruciate ligament (ACL) three years ago, but she may have no idea that the athlete has dealt with a chronic bulging disc, or lumbar or cervical stenosis. This is where our team starts to learn as much as possible about the athlete's medical issues prior to initiating the training program. We need to uncover anything that may inhibit some of our training strategies, such as previous injury history,

TABLE 1. SAMPLE NFL COMBINE SCHEDULE FROM 2018 (SPECIALIST POSITION GROUP)

Tuesday **February 27, 2018**	Travel to location of Combine Registration Hospital pre-exam and X-rays Overflow testing Orientation Interviews
Wednesday **February 28, 2018**	Measurements Medical examinations Overflow testing Interviews
Thursday **March 1, 2018**	Psychological testing NFL Players Association meeting Placekicker/Special Teams workout Media Bench press Interviews
Friday **March 2, 2018**	On-field workout (timing, stations, skill drills) Departure from Combine

undiagnosed tendinopathy the player has managed through the past season, and suboptimal rehabilitation results following a prior injury. To look for these red flags, we utilize a joint-by-joint process to assess passive and active range of motion (ROM) and strength. We also perform a DXA scan for body fat analysis and conduct a nutritional consultation with our Registered Dietitian (RD).

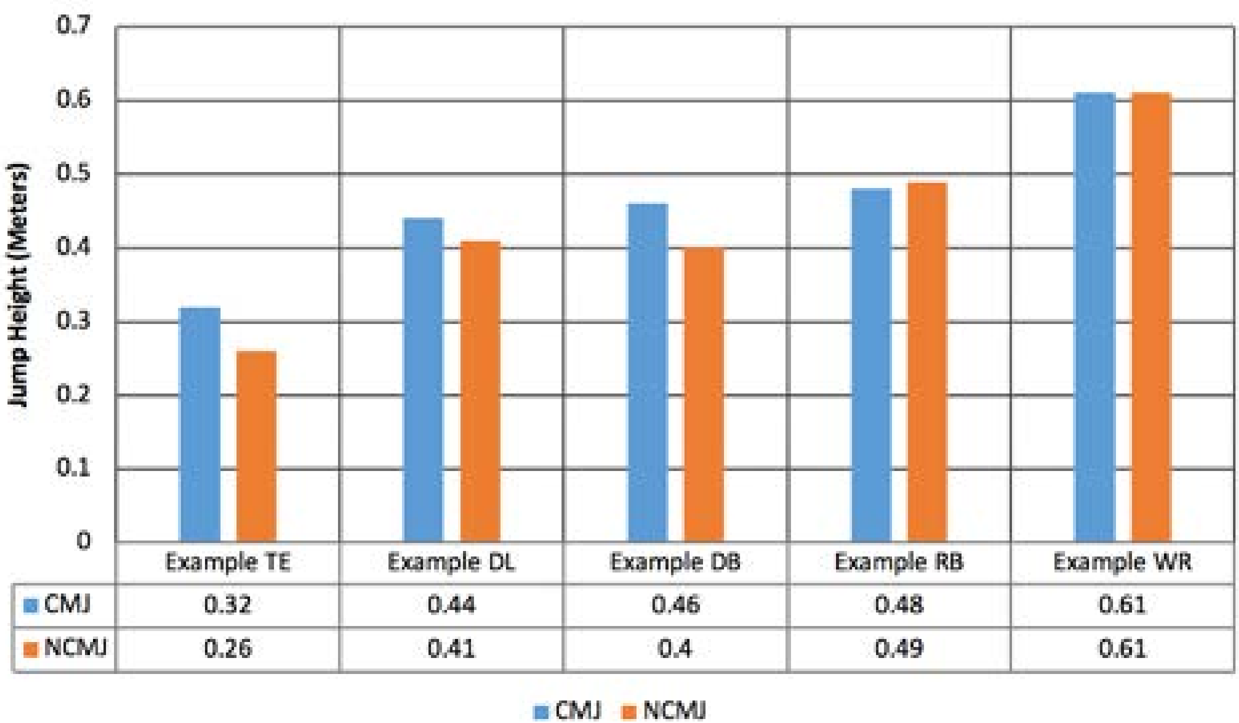
Once medical testing is complete, the athletes perform a battery of tests on the force plate system (Bertec Corporation). We determine force-velocity profiles, including the relationship between countermovement (CMJ) and non-countermovement jumps (NCMJ), also known as eccentric utilization ratio (EUR). Another metric of interest is reactive strength index (RSI), calculated by dividing the height of a depth jump by the ground contact time of that jump (3). Besides providing baseline data, these assessments are also part of weekly monitoring to gauge how athletes are responding to the prescribed training stress. Regardless of individual training needs or position-specific drills, all athletes are required to perform tests of general athleticism including the vertical jump, broad jump, 40-yard dash, pro-agility, L-drill, 225-lb maximum repetition bench press, and 60-yard shuttle (offensive linemen and interior defensive linemen do not perform the latter).

The second day of intake at our training facility entails completing the NFL Combine-specific testing to acquire baseline numbers. Once we acquire this data, a list of key performance indicators (KPI) is created for each player based on his position. For example, a defensive back needs to be fast and explosive with great change of direction, whereas an offensive lineman may require similar qualities but needs more upper body strength and power for his job tasks. The 225-lb bench press test has traditionally been the evaluation of choice to assess upper body strength, while the vertical jump, standing broad jump, 40-yard dash, and 10-yard split are common standards for lower body explosiveness. As such, we express KPI in terms of how we prioritize the level of improvement necessary for each NFL Combine test by examining the athlete's strengths and weaknesses as they relate to his positional KPIs.

Each player receives a needs analysis based on the KPIs in which they currently excel and need improvement. In some cases, restoring an athlete's health from a previous injury may be the priority, to return his speed and power numbers to a good standing. All athletes require proper "saturation," or training volume accumulation, of a specific training stimulus to drive the desired adaptations. Once our team of coaches has examined the data, they will start crafting each athlete's individual training plan, or "road map." As stated earlier, most of these road maps are relatively similar since many of the tests are the same, but we often find that some training methods may need to change based on the individual results of the intake.

INDIVIDUALIZED VELOCITY-BASED TRAINING

Once we correlate vertical jump measures from CMJ and NCMJ to determine EUR, we group athletes based on the indicated training focus and plot their needs along the force-velocity curve. Some athletes may need to enhance maximal strength, whereas others may require training further down the force-velocity curve focusing more on speed-strength. To monitor the exact adaptation that we are driving in an athlete based on the applied training stimulus, bar speed is tracked using GymAware units and software.



	Example TE	Example DL	Example DB	Example RB	Example WR
CMJ	0.32	0.44	0.46	0.48	0.61
NCMJ	0.26	0.41	0.4	0.49	0.61

FIGURE 1. SAMPLE ECCENTRIC UTILIZATION RATIO

We subsequently divide the weight racks in the facility into velocity-based and strength-based racks. Although the athletes may be working with identical set and repetition schemes, their loads and velocities are customized. With advances in technology becoming more widely available to strength and conditioning professionals, velocity-based training (VBT) is becoming more accepted as a superior training modality. Popularized by Dr. Bryan Mann and Dan Baker, among others, VBT allows coaches to autoregulate an athlete's load based on where the athlete is at physically on a given day, creating precise feedback that allows coaches to adjust training load (6). Each type of strength quality has a corresponding velocity, and VBT devices such as GymAware, Push, Tendo, and others allow us to target a specific performance quality by selecting an exercise intensity that matches that velocity. Racks dedicated to higher velocity training may have athletes working in a range of 1.0 – 1.3 m/s, while athletes in the strength racks work at 0.5 – 0.75 m/s. Tracking bar speed based on the initial force plate testing data allows athletes to autoregulate load and adjust to individual needs, thus ensuring they are training the desired quality. Because the training window for the NFL Combine is relatively short, we cannot afford to lose out on potential training gains by merely applying a generic blueprint to each athlete.

During intake, we also identify healthy players with an advanced training age who may warrant more advanced strategies, such as post-activation potentiation (PAP) sets which has been described as "the idea that the performance of a maximal, or near maximal, muscle contraction (i.e., a conditioning activity [CA]) may increase the strength/power production in subsequent exercise(s)," (11). Some of the athletes have a lower training age, so they simply need more pure saturation of strength work to elicit the best possible results in the allotted training window. We look at athletes with a prior injury history on a case by case basis for PAP work, and only opt for more advanced training strategies such as this in situations that call for their implementation.

INSIDE A TYPICAL WEEK OF NFL COMBINE TRAINING AT LANDOW PERFORMANCE

Our program encompasses six days per week of training, preparation, and recovery methods. A typical week includes a general framework allowing for individual variability, intended to place each athlete in the best position to maximize his training time. This schedule has evolved over the years into what I now believe is an ideal system of undulating speed training, multidirectional movement, resistance training, and recovery.

MONDAY

Monday morning is comprised of an acceleration training session, and initially the focus is on technical aspects (i.e., mechanics). All acceleration starts are from a two-point position, as the goal is to teach the athlete proper weight distribution and timing of impulse and limb movement (timing is of the utmost priority). The athletes must receive ideal rest between acceleration efforts to keep quality of bouts high. Although elite athletes typically bring a high level of attentional and intentional focus to these workouts, Blumenstein, a prominent sport psychologist, argues that proper rest and recovery are still vital during a high-quality session to reduce neural fatigue and allow athletes to continue working at a high level (2). As the athletes accumulate more acceleration training volume, we begin transitioning them from two-point starts into three-point starts according to proficiency. The prescribed acceleration distances begin to lengthen, but in most cases are no longer than 20 yards per repetition. Teaching athletes how to properly accelerate is critical during this 6 – 8-week period, since the 40-yard dash is one of the most emphasized and prioritized drills. If an athlete cannot execute the skill of acceleration well, the ability to make up for it and still run a fast 40-yard dash time becomes significantly more challenging.

Monday afternoon is a high-effort lower body speed/power/strength session. To transition athletes properly between the morning and afternoon sessions, our nutritionist will dictate the necessary nutrition and recovery for optimal training. The goal of this session is to match the theme of the morning: high neural stress. We place a priority on managing neural fatigue by balancing high neural effort with large bouts of recovery between sets. Jumps, throws, cleans, and squats are the main exercise choices to best enhance motor unit activation. Initially, these methods are conducted as standalone parts, as we need to teach proper execution first. As training progresses, we start involving more potentiation methods to elicit a greater speed or power stimulus.

TUESDAY

This day focuses on multi-directional movement, including 1) the "closed" NFL Combine drills (e.g., the pro-agility, L-drill, and long shuttle) and 2) the "closed reactive" drills of the NFL Combine that are more position-specific. These closed reactive drills blend simple change of direction ability with reactive components, giving the drills an agility aspect as well. As athletes learn these drills, we involve auditory and visual stimuli to make the drills reactive in nature. Typically, a reactive start and a reactive cut or break to the ball makes the drill more qualitative, as coaches and scouts are interested in observing how athletes solve various movement tasks. If teams find that an athlete moves poorly in a relatively controlled drill, they know that when the stakes and variables become larger, those movements will possibly become worse. As a result, the Tuesday sessions focus on specific breakdowns and rehearsals of these drills at slower speeds to ensure precise movements. Practice time is vital since athletes only get one opportunity to perform these drills at the NFL Combine. Quality practice is a massively important component for the actualization of skills under pressure, and few situations create more pressure than the NFL Combine. For athletes at this level, the environmental context specificity of this rehearsal is of high importance in skill execution during the real event (9). Ultimately, the amount of time spent in quality practice of these drills determines an athlete's level of skill actualization (5,10).

The Tuesday afternoon session is slotted for upper body training with a strong focus on the 225-lb bench press test. This maximum repetition test is the only upper body strength evaluation at the NFL Combine. For some athletes the test will show strength endurance, while for others it may display maximal strength. Though the goal is to complete as many repetitions as possible, there are position-specific standards that a player must achieve for NFL scouts to check off a necessary box in their player evaluations. For example, a defensive back certainly needs to run, jump, and change direction very well. However, if he cannot reach 10 – 15 repetitions on the bench press test, it leaves scouts wondering if upper body strength is an issue. Meanwhile, an offensive lineman should complete at least 22 – 25 repetitions on the test. His ability to reach this threshold is more important than the cornerback's ability to reach his threshold given the higher relative importance of upper body strength for offensive linemen.

We implement various strategies in training for the bench press maximum repetition test, placing emphasis on training horizontal pushing strength, muscular endurance, and scapular stability. We also focus on teaching athletes how to bench press more efficiently, so they can properly pattern the test. Each athlete develops their own testing rhythm and strategy. For example, if I have an athlete who typically can do 20 repetitions on the test, we create a strategy that allows him to starve fatigue and maximize results primarily determined by bar speed. For example, if an athlete can do 20 repetitions on the test, the strategy is typically to begin with 12 straight repetitions. Once bar speed begins slowing from the athlete's normal stroke, we teach them to pause and take a breath with arms locked out, then begin clusters of doubles; once that bar speed slows again, we begin the same process with clusters of singles. This strategy has been useful in our preparation to prolong fatigue and failure with our athletes, but each athlete is different; some may perform better clustering with singles only. Some particularly strong athletes can go immediately to 25 repetitions, then add 10 more, then begin clustering doubles once they are at 35 repetitions. To determine how much time to spend working on a test, it is crucial to remember how much value ought to be placed on that test for each position.

WEDNESDAY

Although recovery is a consistent priority throughout the week, Wednesday is the first dedicated recovery session of the week. All our athletes use the following modalities daily: hot and cold contrast bath, infrared sauna, NormaTec compression, and various soft tissue work. On Wednesdays specifically, we remove the body's typical overall workload and spend time working on self-recovery modalities. This is important not only to help spur recovery during the NFL Combine training window, but also to help players learn how to take care of their bodies for the entirety of their professional career. We structure a recovery circuit for this session that typically includes methods such as myofascial work with a foam rolling series, active isolated stretching patterns, and barefoot stability work, ending with soft tissue therapy.

Wednesdays also serve as a day for extra technical work on starts, drills, or video analysis, so the athletes can get a few more mental repetitions or process issues they may be having on drills. Our athletes take weekly neuromechanical coupling tests with the Dynavision™ D2 Visuomotor Training Device a light-training reaction device, developed to train sensory motor integration through the visual system to best maximize their ability to dual task from a cognitive and reactionary component (12). Put simply as "the ability of the nervous system to accommodate changes to joint mechanics," this testing allows us to monitor athletes' abilities to process and integrate visual cues, which has been found to be a "key determinant" of success in team sports (1,7).

THURSDAY

This is the prescribed day for top-end or maximal speed, which is where we build the back half of the 40-yard dash. Running efficiently does not come naturally for most football players, so it is vital we teach these athletes sprint mechanics as though they have never heard of them before, making sure that we do not assume the athletes know anything. However, top-end speed is a skill that I try to avoid over-coaching. In my experience working with such a short time frame, there are only so many changes you should make to a complex motor task. Otherwise, you risk negatively affecting the athlete. To me, it is a matter of identifying the biggest issues, then teaching and training to improve them. In many aspects, fixing the biggest issues will simultaneously fix some of the smaller ones. Our goal as strength and conditioning professionals is to help and not hurt, and in my opinion, this is a fine line when working on top-end speed. The training session then concludes with throws, jumps, or bounds, serving as a bridge into the weight room session later that afternoon.

Like Monday's afternoon session, Thursday afternoon is comprised of sprints, throws, jumps, bounds, cleans, and squats. The exercise selections here depend on factors involving the individual athlete, such as strength to weight ratio (also known as "relative strength"). We also have a great deal of interest in "elasticity," or the athlete's ability to use his stretch-shortening cycle (SSC) and create a shorter coupling time for more explosiveness. Exercise selection is also guided by where we currently are in our training cycle; for example, contrast methods are applied more often as we get into our second block of training. Within each training block, we continue to rely on our VBT and pre-testing numbers to guide our decision-making process. Our constant focus is the quality of each repetition and prioritizing proper execution over load. Once exercise intensity has compromised either the intended technical execution or bar speed, then we adjust loads as needed.

FRIDAY

Morning sessions are very similar to Tuesdays with a slight variation. We rehearse the pro-agility and L-drill for minimal repetitions with the emphasis on drill quality. Sometimes, spending too much time on a drill can create problems; too many repetitions can cause athletes to get bogged down in the drill's minutia, causing paralysis by analysis. Therefore, on Friday mornings we tend to keep the NFL Combine-specific test practice on the shorter side. After those multidirectional drills, we break out into position-specific drills so that linebackers, defensive backs, and offensive and defensive linemen can work with their respective coaches. We also have quarterbacks throwing to wide receivers, tight ends, and running backs. At the end of a hard week of what seems like "non-specific" football preparation, I utilize this session to reinforce the bigger picture and remind our players exactly what it is we are preparing for. I find this is a nice mental reboot for the players, which helps them to take the movement skills we teach in closed drills and apply them to the sport-specific skills of their position.

Like Tuesday afternoon, the Friday afternoon session focuses on upper body strength, but we adjust the muscular endurance strategy used for the bench press test. For some Friday workouts we aim for maximum repetitions at 205 lb, and during other weeks we use 245 lb instead of the standard 225 lb. We never practice with the same load week to week, opting instead to fluctuate between bar speed emphasis at the 205-lb load and muscular endurance overload with the 245-lb load. The session concludes with upper body pulling and scapular stability work.

SATURDAY

Saturday is the second recovery day within the week. Like Wednesday, it becomes a "filler" day for additional practice for drills from a technical standpoint, or video analysis to clarify any issues. Soft tissue work and an auxiliary weight room session including accessory lifts rounds out a typical week of NFL Combine preparation in our facility.

CONCLUSION

The intensity of the NFL Combine and the days leading up to it makes this period one of the most physically and psychologically demanding tests a player will face over the course of his entire career. Several players have told me after the NFL Combine that they felt like they had just played a game. The NFL Combine is comprised of many intricate variables, and as such, a strength and conditioning professional must be able to implement a wide array of strategies to prepare athletes for the vast number of medical, psychological, and athletic tests that the athlete will undergo. It is also important to reinforce to players that they are constantly being evaluated during the NFL Combine. Scouting departments scrutinize everything an athlete does, down to their speech and body language. Although performing well physically is crucial, the number one quality that NFL scouts, coaches, and general managers are looking for in players is a constant drive and a strong will to compete. Those who succeed at the NFL Combine approach their training with this level of focus and determination every day, but to truly shine they must also be surrounded by a performance coaching team who shares their relentless dedication to quality preparation.

TABLE 2. TRAINING MICROCYCLE EXAMPLE

	AM	PM
Monday	Acceleration mechanics—quality emphasis	High effort lower body—speed/power/strength (jumps, throws, cleans, squats)
Tuesday	Multidirectional movement Closed/closed-reactive NFL Combine drill practice	Upper body—225-lb bench press test emphasis
Wednesday	Recovery—foam rolling series, active isolated stretching patterns, barefoot stability, and soft tissue therapy	Technical work—drills, starts, and video analysis Visuomotor training
Thursday	Top-end speed—throws, jumps, or bounds	Lower body speed/power/strength—sprints, throws, jumps, bounds, cleans, and squats (contrast methods in second training block)
Friday	Pro-agility, L-drill, and position-specific drills	Upper body strength—fluctuating emphasis between bar speed and muscular endurance overload Upper body pulling, scapular stability work
Saturday	Recovery—soft tissue work Auxiliary weight room session	Drill technique and video analysis
Sunday	Off	Off

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Loren Landow is the current Head Strength and Conditioning Coach for the Denver Broncos National Football League (NFL) team. Landow is a movement and sports performance expert who is renowned for his ability to analyze and correct biomechanics. Previously, Landow trained thousands of athletes of all ages and abilities, including over 700 professional athletes in the NFL, National Hockey League (NHL), Major League Baseball (MLB), Ultimate Fighting Championship (UFC), Women's National Basketball Association (WNBA), and Olympic athletes in the private sector. Landow has worked with over 70 NFL All-Pros and over 20 first-round draft selections in the NFL. In 18 years of preparing professional football hopefuls for the NFL Combine, the heart of Landow's training philosophy has been to maximize human performance efficiently and effectively, while decreasing the likelihood of injury. His science-based training methods make proper movement mechanics second nature for athletes, allowing them to "do all the right things from the wrong positions" such as those that often manifest in football. Landow has been a keynote speaker for the NSCA National Conference, the ASCA in Australia, the SPRINTZ Conference in New Zealand, and the UKSCA United Kingdom Conference. He serves as a consultant for the University of Colorado Football Team, MLB Texas Rangers, USA Women's National Soccer Team, and the USA Bobsled Team. He is the author of two books, My Off-Season with the Denver Broncos: Building a Championship Team (While Nobody's Watching) and Ultimate Conditioning for Martial Arts. Landow serves on the Board of Directors for the Exercise Science Program at Metro State University, as well as the Board for the Master's program for Setanta College in Ireland. He is the Sports Performance Director for Elite Sports University, an online education website, and also developed the Anterior Cruciate Ligament (ACL) prevention program and the ACL return to sport protocols for the Steadman Hawkins Clinic in Denver, CO. He maintains his ownership as founder of Landow Performance in Centennial, CO.

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