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STRENGTH AND CONDITIONING FOR FOOTBALL

In 2012, a multiorganizational taskforce was charged with examining the rash of needless deaths emanating out of National Collegiate Athletic Association (NCAA) Division I football programs that had resulted in the death of 21 players in the previous ten years from either exertional heatstroke or sickle cell trait. The report "The Inter-Association Task Force for Preventing Sudden Death in Collegiate Conditioning Sessions: Best Practices Recommendations" was published later that year in the *Journal of Athletic Training* (Casa et al., 2012). The consensus of the broad array of medical, athletic training, and sport performance organizations such as the National Strength and Conditioning Association (NSCA) and the College Strength Coaches Conditioning Association (CSCCA) was the understanding that developing appropriately designed training programs can maximize sport performance for football players. It was emphasized that an effective strength and conditioning program relies on scientific principles of exercise science intended to stimulate improvements specific to the sport. This should be the basis of the conditioning program. The training culture in the ten years prior to the 2012 report indicated that athlete's development, health, and safety were overshadowed by a desire to enhance athlete toughness, discipline, and focus on success at all costs. Unfortunately, this environment created by a number of coaching staffs around the United States caused numerous but 100% preventable deaths in college football. The issues leading to these deaths were often the result of strength and conditioning coaches using conditioning as a punishment for a bad season, and coaches attempting to build mental toughness through inappropriate training sessions. Furthermore, it was believed that a poor understanding of program progression and setting unrealistic training goals by strength and conditioning coaches contributed to these needless deaths. In general, these coaches lacked the basic understanding of exercise science and the principles of training!

This chapter will provide an overview of the basic principles of training. It provides a review of exercise program development and focuses on the knowledge base that has been developed in the strength and conditioning of football players. Specific discussion will focus on off-season training, inseason training, various modalities of training (e.g., use of Olympic movements, Ballistic training), and training periodization. In addition, discussion will also focus on performance improvements during an athlete's career, with primary emphasis being on both high school and collegiate athletes. What this chapter will not do is provide a "recommended" training program for football. There are so many potential combinations of exercises and training paradigms that make it very difficult to state that one program is more appropriate than another. There are so many variables that can impact training program success; thus, it becomes imperative that the coach provides a scientific justification for the specific exercise prescription. If that occurs, the likelihood of success will be vastly improved and the risk for catastrophic injury will be significantly reduced.

Basic Principles of Training

It is expected that strength and conditioning coaches follow the basic principles of training. That is, program development adheres to the principles of specificity, overload, progression, individuality, diminishing returns, and reversibility (Hoffman, 2014). Figure 3.1 provides an overview of the basic principles of training. The *specificity principle* refers to the development of a training program that focuses on the specific physiological, biomechanical, and medical needs of the sport. It is the goal for all coaches that physical performance improvements directly relate to better football performance. However, the "carryover" effect from the weight room to the field is not 100%. Thus, a 10% improvement in strength or power does not equate to a 10% improvement in football playing ability. To maximize the carryover effect, it is critical that the exercises used and the energy system stressed are consistent with the movement patterns and energy system of the game. Thus, running 5 miles is going to focus on the aerobic energy system, it will have little impact on football playing performance.

The *overload principle* is focused on making the athlete train at a level that they are normally not accustomed to working at. The overload is what will stimulate physiological adaptation. However, this is where many mistakes in the exercise prescription occur. The object of this principle is to make appropriate adjustments to the training program that will provide a stress that is above what the athlete is used to. It is not to force the athlete to exercise at an intensity or a volume that risks their health and well-being. As the athlete adapts, adjustments are made accordingly and this is the basis of the *progression principle*: that the overload will progress as the athlete adapts. However, it is imperative that the coach understands that athletes progress at different rates leading to the important understanding of the *individuality principle*. Two athletes

Principles of Training

Principle of Training	Definition
Specificity	Adaptations are specific to the muscles trained, the intensity of the exercise performed, the metabolic demands of the exercise and the joint angle trained. Except for actual practice of sport – no conditioning program has 100% carryover. To maximize carryover exercises should be selected that simulate sport movement.
Overload	For training adaptations to occur, the muscle or physiological component being trained must be exercised at a level that it is not normally accustomed to.
Progression	Physiological adaptations results in performance improvements. As such, the relative intensity will change requiring that the exercise prescription be modified. This is more appropriately termed progressive overload.
Individuality	Refers to concept that athletes respond differently to the same training stimulus. Variability of the training response is likely related to genetic predisposition and pre-training status.
Principle of Diminishing Returns	Performance gains are related to the level of training experience of the athlete. Freshmen football players will likely experience greater gains in strength than senior football players.
Principle of Reversibility	When training stimulus is removed or reduced (e.g., that may occur due to injury), the ability of the athlete to maintain performance may become reduced, and eventually the effect of this detraining period will cause the prior performance gains to revert back to their original level.

FIGURE 3.1 Principles of Training.

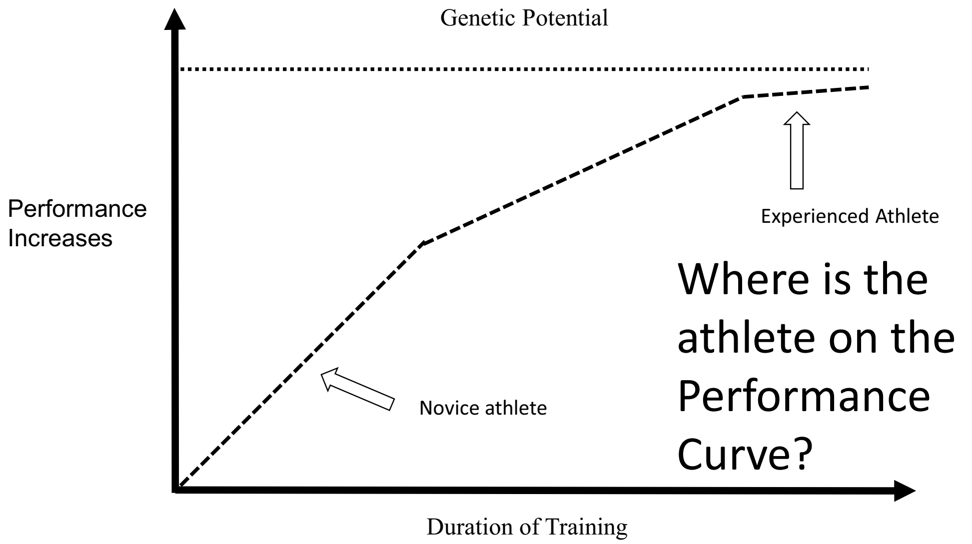

FIGURE 3.2 Performance Training Curve.

Source: Adapted from Hoffman, 2014.

performing the same training program will likely respond differently. That is the primary reason why coaches need to monitor their players on an individual basis and make changes according to the individual results observed. Figure 3.2 highlights the differences in rate of improvement of athletes with varying years of experience. Differences in performance improvements may not be related to a poor effort, laziness, or lack of toughness, but simply a different physiological capability related to genetics or training experience. Coaches need to recognize this and understand that pushing an athlete past their physiological limits may not only increase the risk for overtraining but may increase the risk of a catastrophic outcome related to exertional rhabdomyolysis, heatstroke, or a cardiovascular event. This may be exacerbated with an athlete that has sickle-cell trait (Anderson, 2017).

In the training facility, both young (e.g., first year players) and more experienced athletes will train together. The young players generally have less resistance training experience than the older players, who may be in their fourth or fifth year of competition. These younger players generally have a "greater window of adaptation" that will likely result in a greater response to the training program. This does not necessarily mean that the younger players worked harder than the older players, it is simply the reflection of training experience. That is the basis of the *principle of diminishing returns*. Simply, as you gain strength, power, or speed, your ability to generate further improvement is reduced. However, if you do not provide the appropriate training stimulus, the results can return to baseline level and this is what is referred to as the *principle of reversibility*. This can often be seen following injury, in which the athlete is unable to exercise for an extended period of time, which prevents/limits the athlete from maintaining the required training stimulus.

Exercise Program Development

The most difficult aspect in the development of the strength and conditioning program is the implementation of the entire program. The appropriate implementation of resistance training, sprint, and agility training and conditioning is crucial for maximizing performance gains at the appropriate time of the yearly program, while minimizing the risk for overtraining. This is obviously the major focus of periodization, whose theory and efficacy are covered in depth elsewhere (Issurin, 2016; Mujika et al., 2018; Williams et al., 2017), but it will be discussed in relation to football later in this chapter.

It is important to note that no single method of program prescription has universal acceptance. For a training program to be effective, it needs to be based on sound scientific evidence (Hoffman, 2014). The various training methods that exist simply give the strength and conditioning professional tools that can be used at the appropriate time in the yearly training cycle. Although there is often overlap, training programs are specific for each sport; thus, the examples in this chapter will be focused on American football.

Prior to any workout, the strength and conditioning professional must lead or direct a structured warm-up routine to prepare athletes for the subsequent workout. Proper warm-up routines can also reduce the risk for injury during training sessions. Although the use of static stretching exercises was the predominant method of the warm-up in previous generations, a dynamic warm-up that utilizes exercise-specific movement patterns has become more favorable and likely provides the greatest benefit in preparing the athlete for the training session (Opplert and Babault, 2018). It is important to note that the warm-up should not fatigue the athlete for subsequent performance. As athletes move from one training phase to another, it is imperative that they are physically ready for each proceeding phase. The acute program variables of intensity, volume, and exercise selection should progress to provide the necessary overload that can stimulate further adaptation in each subsequent training phase. Emphasis on proper technique should always be a priority. Load should not be emphasized until the athlete has demonstrated successful technique for the exercise.

In the development of the off-season training program for football, the strength and conditioning professional needs to set the training goals for the team and the individual athlete. Training goals for the team are often generic, regarding emphasis on hypertrophy (e.g., muscle growth), strength, or power. However, to optimize the training stimulus and maximize performance benefits, the coach will also need to focus on the individual athlete's strengths and weaknesses. This will allow the training program to be tailored for the specific athlete. Thus, the goals of the off-season training program can and should be general for the team and specific for each athlete. For example, the use of ballistic exercises (i.e., squat jump or bench press throws) may be more effective to install for an experienced football player than for the freshman player (Hoffman et al., 2005b). Coaches need to determine which training component has the greatest chance to stimulate further adaptation.

In general, the off-season training program for football progresses from developing muscle hypertrophy to focusing on strength, power, and speed. However, athletes also need to maintain a minimal level of conditioning. For many sports, this can be accomplished by playing their sport, this though is not possible for football players. These athletes may need to participate in activities such as playing pick-up basketball and racquet sports. The basis of all off-season training programs is to enhance the performance capability of the athlete primarily through increasing strength, power, and speed. In addition, a primary training goal for some football players may include altering body composition by increasing lean muscle mass and decreasing fat mass. At the beginning of the off-season training program, the football player will primarily be in the weight room. The resistance training program generally begins with a preparatory or hypertrophy phase of training that consists of high-volume (greater number of repetitions performed per set) and low-intensity (loads with a lower percentage of the athlete's 1-repetition maximum [1RM]) training. The purpose for this program is to prepare the players for the higher intensity lifting that will be performed during subsequent stages of the training program. The duration for this training phase is approximately four to five weeks. If the athlete is focused on increasing muscle size (may be common among younger athletes), this phase of training can be of longer duration. If the athlete's primary goal is to increase strength and power, then this phase will be used to prepare for more complicated exercises of higher intensity that will be incorporated into the later phases of the training program (Hoffman, 2014).

The next training phase during the off-season training program for football generally focuses on strength development. The intensity during this training phase increases as compared to the preparatory/hypertrophy phase, resulting in fewer repetitions performed per set. As a result, the total volume of training is decreased. During this training phase, additional exercises (primarily multiple-joint, structural movement exercises) can be incorporated into the training program to increase the training stimulus. The coach often incorporates Olympic-style lifting movements (e.g., high pulls) during this phase. These exercises could also appear during the initial phase of training, but inexperienced or novice athletes may benefit from developing a strength base and focusing on proper technique with the traditional power lifting exercises. In addition, the incorporation of these exercises in the latter phases of training provides a degree of variation to the training program that prevents monotony. This training phase is often four to six weeks in duration. During this training phase, plyometric exercises and/or speed and agility drills can also be integrated into the training program.

The next phase of training emphasizes more power production. During this training phase, intensity of exercise is elevated further and training volume is reduced further (keep in mind that there is an inverse relationship between training intensity and training volume – as intensity elevates, volume is reduced). For the collegiate football player, this phase may be interrupted by spring football. If this is the case, the athlete may enter a strength/maintenance program for the duration of spring football. If so, training intensity and training volume are generally reduced. Reductions in training volume can be accomplished by reducing the number of assistance exercises and/or number of sets. However, if an adjustment to the strength and conditioning program is not done, the added load of the spring practice schedule may increase the risk for overtraining. Following spring football, the strength and conditioning professional can begin the resistance training program again from the hypertrophy or preparatory phase before proceeding to the other training phases. This may assist the athlete in recovering from spring football.

During the strength/power phase, a greater emphasis is placed on Olympic and ballistic exercises, especially for the experienced, resistance-trained football player. Exercises, such as the snatch, power clean, and push press, are often added to the program, while some of the traditional power lifting exercises or assistance exercises are removed. Previous research has shown that Olympic exercises can enhance speed and power development in resistance-trained athletes during their off-season training program to a greater extent than the traditional power lifting exercises (Hoffman et al., 2004a). This will be discussed in greater detail later in the chapter. In addition, a speed and agility program is often included during this training phase. These exercises generally do not result in a change to the resistance training program and are compatible for this training phase.

During the power phase of training, a speed and agility routine is often incorporated into the weekly routine of the football player. It is important to recognize that speed and agility training is not intended to enhance the athlete's conditioning. Although it does help and if properly designed, it can contribute to improving the fitness level of the football player, the work-to-rest interval is relatively longer than one would expect when goals include conditioning. For example, the work-to-rest ratio for an exercise that enhances anaerobic capacity may be 1:4; however, when focusing on the quality per repetition, the work-to-rest ratio can elongate to 1:8 (Hoffman, 2014). The focus of agility, speed, and plyometric exercises is on the quality of work, and

TABLE 3.1 Off-Season Resistance Training Program (Four-Days per Week, Split Routine)

Preparatory/Hypertrophy Phase (4–6 Weeks) ★ = *core exercises 1.4 × 8–10 repetitions per set* *Assistance exercise 3 × 8–10 repetitions per set* *Rest between sets: 1 min*		***Strength Phase (4–6 Weeks)*** ★ = *core exercises 1.4 × 6–8 repetitions per set* *Assistance exercise 3 × 6–8 repetitions per set* *Rest between sets: 3 min*		***Strength/Power Phase (4–6 Weeks)*** ★ = *core exercises 1.4 × 4–6 repetitions per set* *Assistance exercise 3 × 4–6 repetitions per set* *Rest between sets: 3 min*		***Peaking Phase (4 Weeks)*** ★ = *core exercises 1.5 × 1–3 repetitions per set* *Rest between sets: 3 min*	
Days 1 + 3	*Days 2 + 4*	*Days 1 + 3*	*Days 2 + 4*	*Days 1 + 3*	*Days 2 + 4*	*Days 1 + 3*	*Days 2 + 4*
Squat★	Bench press★	Squat★	High pulls★	Squat★	High pulls/power clean★	Power cleans (floor)/ snatch (floor)★	Hang cleans/ hang snatches (waist)
Leg extension	Inclined bench press	Dead lifts★	Bench press★	Dead lifts/snatch★	Bench press★	Squat★	Bench press★
Leg curl	Dumbbell incline fly	Leg curls	Inclined bench press	Leg curl	Inclined bench press	Box jumps★	Push jerk/push press★
Standing calf raise	Seated shoulder press★	Standing calf raise	Dumbbell incline fly	Lateral pulldown★	Push press/push jerk★	Seated row★	Power shrugs★
Lateral pulldown★	Upright row	Lateral pulldown★	Seated shoulder press★	Seated row★	Front/lateral raise	Dumbbell biceps curl (3 × 4–6)	Triceps pushdown (3 × 4–6)
Seated row★	Front/lateral raise	Seated row★	Front/lateral raise	Dumbbell biceps curl	Triceps pushdown	Abdominal routine (3 × 20)	Abdominal routine (3 × 20)
Dumbbell biceps curl	Triceps pushdown	Dumbbell biceps curl	Triceps pushdown	Barbell biceps curl	Abdominal routine (3 × 20)		
Barbell biceps curl	Triceps extension	Barbell biceps curl	Triceps extension	Hyperextension			
Hyperextension	Sit-ups (3 × 20)	Hyperextension	Sit-ups (3 × 20)	Abdominal routine (3 × 20)			
Crunch (3 × 20)		Crunch (3 × 20)					

Seventy-two hours between days 1 and 3 and between days 2 and 4. Days 1 and 2 and days 3 and 4 can be performed consecutively. For instance, this split-routine training program can be performed on Monday, Tuesday, Thursday, and Friday (four days per week).

not on the quantity. As the athlete moves into the later stages of the off-season training program, the speed and agility work become more *up-tempo* to contribute to aspects of anaerobic conditioning. However, a longer work-to-rest ratio still requires 100% effort for each drill.

The final phase of the off-season training program for football is the peaking phase. During this training phase, the exercise intensity is at its highest, while training volume is reduced further. During this training phase, the football player focuses on getting into peak condition for the start of preseason training camp. The lower training volume provides the player with additional time to focus on anaerobic conditioning exercises. During the final two to three weeks of the strength/power phase and throughout the peaking phase, the football player's focus will be on getting into peak anaerobic condition to play a competitive football season.

Table 3.1 provides an example of an off-season resistance training program for a football team, while Table 3.2 depicts an eight-week anaerobic conditioning program for preparing football players for the competitive season. This program is an example whose efficacy can be supported by scientific evidence. However, there are a multitude of combinations having

TABLE 3.2 Off-Season Anaerobic Conditioning Program

	Monday	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*
Week 1		Agility and form running	2 × 200 m, 5 × 60 m sprints	Agility and form running	1 × line drill, 2 × intervals	
Week 2		Agility and form running	4 × 200 m, 6 × 60 m sprints	Agility and form running	1 × line drill, 3 × intervals	
Week 3	4 × starts 3 × intervals	Agility and form running	4 × 200 m, 6 × 60 m sprints	Agility and form running	1 × line drill, 3 × intervals	4 × 200 m, 4 × 100 m, 4 × 40 m sprints
Week 4	6 × starts 3 × intervals	Agility and form running	5 × 200 m, 8 × 60 m sprints	Agility and form running	2 × line drill, 3 × intervals	4 × 200 m, 4 × 100 m, 4 × 40 m sprints
Week 5	8 × starts 4 × intervals	Agility and form running	6 × 200 m, 8 × 60 m sprints	Agility and form running	2 × line drill, 4 × intervals	5 × 200 m, 5 × 100 m, 5 × 40 m sprints
Week 6	10 × starts 4 × intervals	Agility and form running	7 × 200 m, 10 × 60 m sprints	Agility and form running	3 × line drill, 4 × intervals	5 × 200 m, 5 × 100 m, 5 × 40 m sprints
Week 7	10 × starts 5 × intervals	Agility and form running	8 × 200 m, 10 × 60 m sprints	Agility and form running	3 × line drill, 4 × intervals	6 × 200 m, 6 × 100 m, 6 × 40 m sprints
Week 8	10 × starts 6 × intervals	3 × line drill	8 × 200 m, 10 × 60 m sprints	Agility and form running	Rest	Report to camp

Notes: Starts – 10-m sprint from 3-point football stance; intervals – run on an oval track, sprint the straightaways (100 m), and jog the turns (100 m); line drill – a shuttle run of goal line to 10-yard line and back, goal line to 20-yard line and back, goal line to 30-yard line and back, and finally goal line to 40-yard line and back; agility and form running include specific drills to enhance change of direction and speed. Form running is focused more on sprint running technique.

similar or greater efficacy that can be used. This program should be examined in the context that there is no spring football. It was a program that was developed and used for a NCAA Division III institution, which did not permit physical contact period during spring football. As a result, the team was trained through the limited spring football period. An argument could be made that this is the best way of preparing football players for the upcoming season. It is difficult at times to understand the importance of putting the pads on during the spring and risk losing key players to injury, when they have yet reached peak condition. Previous research has shown that a large proportion of injuries that occur in spring practices are the result of full-contact drills (Steiner et al., 2016). The emphasis on getting ready for spring football may have been a potential reason for some of the inappropriate training programs used during the onset of the off-season conditioning program that resulted in several catastrophic outcomes. During the same period of time in which more than 20 NCAA Division I athletes have died, only one NFL player has died due to heatstroke (Korey Stringer of the Minnesota Vikings in 2001 at the age of 27) during summer training camp. Most interesting is that the NFL has limited contact time in the off-season, and it doesn't appear to diminish their ability to prepare their players for a grueling 16-game schedule. There does not seem to be any compelling or justifiable reason for full-contact spring football. However, meetings, teaching sessions, and limited drills should be employed, but not at the expense of the off-season strength and conditioning program.

Efficacy of Off-Season Strength and Conditioning Programs for Football

There have been a number of studies that have examined the relationship between strength, speed, and power on football playing performance (Hoffman, 2008). Discussion of these investigations appears in Chapter 4. The magnitude of performance improvements during both inseason and off-season training has been studied less frequently. Most studies that have focused on this question generally compare different acute program variables such as training frequency, modes of exercise, and/or types of training programs using different periodization paradigms. These studies will be the focus of this section.

One of the initial studies examining performance changes during off-season conditioning programs in football analyzed the effect of training frequency (Hoffman et al., 1990). The study was conducted at the University of Connecticut and compared the effect of a three-day, four-day, five-day, and six-day resistance training program on body mass, strength, speed, and vertical jump height during a ten-week off-season training program. Sixty-one players self-selected their training frequency. The players in the three-day per week group performed no more than three exercises per body part, and performed all body parts per workout. The players in the four-day per week group performed a two-day split routine, in which at least three exercises for the chest, shoulders, and triceps were performed on Mondays and Thursdays and exercises for the legs, back, and biceps were performed on Tuesdays and Fridays. Players in the five-day per week group performed three exercises for chest, legs, and triceps three days per week (Mondays, Wednesdays, and Fridays), while performing shoulders, back, and biceps on Tuesdays and Thursdays. Players in the six-day per week group performed four exercises for the chest, legs, shoulders, and triceps on Mondays, Tuesdays, Thursdays, and Fridays, and four exercises for the back and biceps on both Wednesdays and Saturdays. Although players had their choice of exercise, they had to perform the following core exercises: bench press, squat, push press, power clean, and deadlift. Performance improvements as a percentage from baseline can be examined in Table 3.3.

All players in the study were experienced in resistance training with an average experience level of three years. Players in the three-day group were significantly weaker than all other groups in squat strength, while no differences were noted between the groups in bench press strength. The six-day per week training group were significantly slower than all other groups in the 40-yard sprint, and had significantly lower vertical jump power than the three-day group only. Results indicated that the five-day per week training group experienced significant increases in both bench press and squat strength, while the four- and six-day training groups realized significant gains in squat strength only. In the four- to six-day per week training groups, increases in 1RM strength ranged from 6.5% in the strongest group to 7.5%. Improvements in 1RM bench press ranged from 3.5% to 4% in four-, five-, and six-day per week groups. The players in the three-day per week group had the lowest percentage gains, despite being significantly weaker in the squat exercise than all other groups. No changes were noted in speed or vertical jump power. The investigators concluded that the five-day per week training group had the greatest impact on strength. It was also noted that the lack of strength gains in the three-day per week group may have been related to an insufficient use of assistance exercises, which may be important for experienced, resistance-trained athletes (Hoffman et al., 1990).

A later study that was also conducted at the University of Connecticut examined the effect of training experience in performance gains during a ten-week, nonlinear periodized off-season conditioning program (Smith et al., 2014). Players were grouped by years in the program as follows: first-year players were group 1, second- and third-year players were group 2, and fourth- and fifth-year players were group 3. Each training group had different training goals. Group 1 prioritized body mass gains, group 2 prioritized strength gains, and group 3 prioritized power gains. Prior to the training program, no significant differences were noted between the groups in body mass. However, significant differences were noted in 1RM bench press and 1RM squat between the groups, with group 3 being the strongest of the groups. The percent changes from baseline levels during this investigation are depicted in Table 3.3. No significant changes were noted in body mass in any of the groups. Significant increases in 1RM strength for both the bench press and squat exercises were reported in groups 1 and 2 only, but no changes were

TABLE 3.3 Performance Changes (%) During Off-Season Conditioning Programs for Football

Study (Athletes)	*Study Duration*	*Training Frequency*	*1 RM Bench Press*	*1 RM Squat*	*40-yard Sprint*	*VJ Power*	*Body Mass*
Hoffman et al., 1990	10 weeks	Three days	1.8	5.2	0.0	1.2	–0.9
(n = 12,15,23,11,		Four days	3.5	7.3*	0.8	0.2	–1.2*
respectively)		Five days	4.0*	7.5*	0.8	2.3	–0.5
(Collegiate)		Six days	4.0	6.5*	1.0	4.3	–1.2
Bemben et al., 2001 (n = 8) (Collegiate)	9 weeks	Four days	0.2	5.0*	–	–	0.7
Wilder et al., 2001 (n = 9) (Collegiate)	10 weeks	Four days	–	5.3%	–	–	–
Hoffman et al., 2007 (n = 10) (Collegiate)	12 weeks	Four days	6.8*	6.9*	–	–	0.3
Smith et al., 2014	10 weeks	Four days			–		
(n = 20/group)		Group 1	3.4*	6.4*		– 1.5	1.3
(Collegiate)		Group 2	4.0*	7.9*		1.9	0.9
		Group 3	0	– 0.3		– 2.9	1.1
Wroble and Moxley, 2001 (n = 39) (High School)	4 months	Three days	13.2*	13.8*	–	7.0*	5.5*

* = significantly different ($p < 0.05$)

noted in vertical jump power. These results highlight the principle of diminishing returns. The stronger and most experienced athletes experienced only limited gains in strength compared to the other, less experienced and weaker athletes.

The studies specifically examining the efficacy of off-season strength and conditioning programs are limited. To expand the data depicted in Table 3.3, studies that used off-season conditioning to examine various nutrients were added (Bemben et al., 2001; Hoffman et al., 2007; Wilder et al., 2001). These investigations generally used small data sets (subjects per group ranging from 8 to 10); thus, it is important to examine these results within the appropriate context.

An examination of high school football players participating in a four-month, three-day per week training program experienced significant improvements in both bench press and squat strength (see Table 3.3) (Wroble and Moxley, 2001). In addition, significant improvements were also noted in vertical jump height and body mass. However, the gain in body mass appeared to come primarily from increases in fat mass and not from lean mass gains. The authors compared these results to a group of football players who participated in the training program but also played a winter sport. Although strength gains were seen in both groups, the gains achieved by the conditioning only group were significantly greater.

Comparison of Different Modes of Training (Olympic Lifting and Ballistic Training) to Traditional Power Lifting During Off-Season Conditioning for Football

Most resistance training programs for football have traditionally used a power lifting program. In novice resistance-trained athletes, large increases in strength are common during the beginning stages of training. Improvements in various power components of athletic performance, such as vertical jump height and sprint speed, may also be evident (Hoffman, 2014). This is primarily the result of the athlete being able to generate a greater amount of force. As the athlete becomes stronger and more experienced, the rate of strength development decreases and eventually reaches a plateau. At this stage of the athlete's career, not only are strength improvements harder to achieve, but improving maximal strength may also not provide the same stimulus to power performance as it did during the earlier stages of training. In addition, training for maximum force development may have its limitations on improving power performance. An important factor for maximizing power production is exerting as much force as possible in a short period of time. By training for maximal strength through heavy resistance training, the rate of force development does not appear to be enhanced (Kraemer and Newton, 2000). The change in stimulus from a high force and low velocity to one of high force and high velocity may augment performance improvements in experienced, resistance-trained football players. The addition of plyometric and/or ballistic training may provide a greater stimulus for increasing the rate of force development.

The importance of exerting maximal force as rapidly as possible is the basis for success in strength/power sports (Hoffman, 2014). This is referred to as the maximum rate of force development (mRFD). The importance of mRFD is often seen in football. Success is often determined by who controls the line of scrimmage. Who would be victorious between two opposing players of similar size, strength, and technique? It would be the athlete who can reach maximal force faster. As the players slam into one another and attempt to extend their arms and control their opponent, the athlete who can generate maximal force quicker will have an advantage. By incorporating high-velocity movements into the athlete's training program, the rate of force development can be enhanced more so than focusing primarily on increasing maximal strength. Although the rate of force development is improved by heavy-resistance exercise, the magnitude of improvement is superior with higher velocity exercises (Hoffman, 2014).

The goal of enhancing power performance has been the basis for the inclusion of Olympic-style lifts in the training program of football players. For many years, coaches have employed Olympic lifting exercises in the training program of football players, but their efficacy in comparison to the traditional power lifting exercises were largely unknown. Despite the widespread acceptance of Olympic lifting exercises as part of the resistance training program of football players, there has been limited evidence to support the large popularity of this mode of training. The first study to compare Olympic and traditional power lifting training was conducted in NCAA Division III football players during their off-season conditioning program (Hoffman et al., 2004a). Twenty players were assigned to either an Olympic weight lifting or power lifting group. Each group was matched for football position. Subjects were assigned to the Olympic weight lifting group based upon their competency in the techniques demonstrated in previous training programs performed at the college. Both training programs were performed four-days per week for 15 weeks. The preparatory phase of the training program was five weeks in duration and was similar for both groups. During the strength phase of training (weeks 6–10), each group began their specific training program. For the next two phases, each lasting five weeks, players performed their group-specific training program. The only similarity between the training programs was the bench press and squat exercises, which were maintained at similar training volume and intensities, since both of these exercises were part of the athletes testing program. Subjects were provided a range of repetitions to perform at a recommended intensity of their 1RM for each exercise. Table 3.4 provides the training programs for both the Olympic and

TABLE 3.4 Olympic and Power Lifting Training Program Comparisons

Preparatory Phase		*Strength Phase*		*Strength/Power Phase*	
Both Groups		*Olympic Lifting Group*		*Olympic Lifting Group*	
Monday and Thursday	*Tuesday and Friday*	*Monday*	*Thursday*	*Monday*	*Thursday*
Bench Press 4 × 8–10 RM	Squats 4 × 8–10 RM	Snatch (above knee) 5 × 5 RM	Snatch (floor) 5 × 5 RM	Snatch (floor) 5 × 3 RM	Clean (above knee) 5 × 3 RM
Incline bench press 3 × 8–10 RM	Dead Lift 4 × 8–10 RM	Snatch Pull (floor) 5 × 5 RM	Snatch Pull (waist) 5 × 5 RM	Push Jerks 5 × 3 RM	Squats 5 × 4–6 RM
Dumbbell incline Fly's 3 × 8–10 RM	Leg extensions 3 × 8–10 RM	Bench press 4 × 6–8 RM	Push jerk 5 × 5 RM	Squats 5 × 4–6 RM	Jump squats (30% 1RM) 4 × 5 RM
Seated shoulder press 4 × 8–10 RM	Leg curls 3 × 8–10 RM	Dumbbell pulls (floor) 5 × 5 RM	Bench press 4 × 6–8 RM	Box jumps 3 × 8	Dumbbell push press 4 × 3 RM
Upright rows 3 × 8–10 RM	Standing calf raises 3 × 8–10 RM	Push press 5 × 5 RM	Front squat 5 × 6–8 RM	Lunges 3 × 6–8 RM	Snatch pulls (waist) 3 × 3 RM
Lateral raises 3 × 8–10 RM	Lateral pulldowns 4 × 8–10 RM	*Tuesday*	*Friday*	*Tuesday*	*Friday*
Triceps pushdowns 3 × 8–10 RM	Seated row 4 × 8–10 RM	Clean (floor) 5 × 5 RM	Clean (above knee) 5 × 5 RM	Overhead squats 4 × 6–8 RM	Clean pulls (waist) 3 × 3 RM
Triceps extension 3 × 8–10 RM	Biceps curls 4 × 8–10 RM	Clean pull (above knee) 5 × 5 RM	Dumbbell push press 5 × 5 RM	Snatch (floor) 5 × 3 RM	Front squats 3 × 5 RM

Preparatory Phase		*Strength Phase*		*Strength/Power Phase*	
Both Groups		*Olympic Lifting Group*		*Olympic Lifting Group*	
Monday and Thursday	*Tuesday and Friday*	*Monday*	*Thursday*	*Monday*	*Thursday*
Sit-ups	Sit-ups	Push jerks 5 × 5 RM	Squats 4 × 6–8 RM	Clean pulls (above knee) 3 × 5 RM	Box jumps with dumbbell 3 × 5
		Squats 4 × 6–8 RM	Power shrugs 5 × 5 RM	Bench press 5 × 4–6 RM	Bench press 5 × 4–6 RM
		Lunges 4 × 6–8 RM	Overhead squats 4 × 6–8 RM	Push press 5 × 3 RM	Power shrugs 5 × 5 RM
		Power Lifting Group			
		Monday	*Thursday*	*Monday*	*Thursday*
		Squats 4 × 6–8 RM	Squats 4 × 6–8 RM	Squats 5 × 4–6 RM	Squats 5 × 4–6 RM
		Dead lift 3 × 6–8 RM[1]	Stiff leg dead lift 3 × 6–8 RM	Dead lift 4 × 4–6 RM	Romanian dead lift 4 × 4–6 RM
		Leg curl 3 × 6–8 RM	Leg curl 3 × 6–8 RM	Leg curl 3 × 4–6 RM	Leg curl 3 × 4–6 RM
		Standing calf raise 3 × 6–8 RM	Standing calf raise 3 × 6–8 RM	Standing calf raise 3 × 4–6 RM	Standing calf raise 3 × 4–6 RM
		Lateral pulldown 4 × 6–8 RM	Lateral pulldown 4 × 6–8 RM	Lateral pulldown 5 × 4–6 RM	Lateral pulldown 5 × 4–6 RM
		Seated row 4 × 6–8 RM	Seated row 4 × 6–8 RM	Seated row 5 × 4–6 RM	Seated row 5 × 4–6 RM
		Biceps curl 4 × 6–8 RM	Biceps curl 4 × 6–8 RM	Biceps curl 4 × 4–6 RM	Biceps curl 4 × 4–6 RM
		Sit-ups	Sit-ups	Sit-ups	Sit-ups
		Tuesday	*Friday*	*Tuesday*	*Friday*
		Bench press 4 × 6–8 RM	Bench press 4 × 6–8 RM	Bench press 5 × 4–6 RM	Bench press 5 × 4–6 RM
		Incline dumbbell bench press 4 × 6–8 RM	Incline bench press close grip 4 × 6–8 RM	Incline dumbbell bench press 5 × 4–6 RM[2]	Incline bench press close grip 4 × 6–8 RM
		Incline flys (flat bench) 3 × 6–8 RM	Incline flys (flat bench) 3 × 6–8 RM	Seated dumbbell shoulder press 5 × 4–6 RM	Seated dumbbell shoulder press 5 × 4–6 RM
		Seated dumbbell shoulder press 4 × 6–8 RM	Seated dumbbell shoulder press 4 × 6–8 RM	Upright row 4 × 4–6 RM	Upright row 4 × 4–6 RM
		Upright row 3 × 6–8 RM	Upright row 3 × 6–8 RM	Triceps extension 4 × 4–6 RM	Triceps pushdown 4 × 4–6 RM
		Front raise 3 × 6–8 RM	Lateral raise 3 × 6–8 RM	Sit-ups	Sit-ups
		Triceps extension 4 × 6–8 RM	Triceps pushdown 4 × 6–8 RM		
		Sit-ups	Sit-ups		

Source: Hoffman et al., 2004a.

Note: RM = Repetition maximum.

power lifting groups. In addition to the resistance training program, all players participated in a two-day per week sprint and agility training program. This program was performed during the strength/power phase of the training program, and it was required for all members of the football team, including those participating in the study.

No between-group differences in 1RM bench press and 1RM squat strength were observed between the groups. In addition, no significant change was observed in the 1RM bench press in either the Olympic lifting (4.4%) or power lifting (9.6%) groups, but significant improvements were noted in 1RM squat (12.9% and 12.8%, respectively, for both groups). No significant changes in body mass were noted in either the Olympic lifting (0.8% increase) or the power lifting (0.3% increase) group. Interestingly, the Olympic lifting group had a significantly greater improvement in vertical jump height (5.9%) than the power lifting group (−0.7%). In addition, 40-yard sprint time was reduced in the Olympic lifting group by −1.4%, and by only −0.8% in the power lifting group. Although these differences were not statistically different, the improvements in 40-yard sprint times were 175% greater in the Olympic lifting group compared to the power lifting group (0.07 ± 0.14 s compared to 0.04 ± 0.11 s, respectively). Results of this investigation suggest that an Olympic weight lifting program may provide a greater advantage in improving vertical jump performance than traditional power lifting. In addition, trends seen in 40-yard sprint speed suggested that the sprint and agility training program, performed during the strength/power phase of training in both groups, was a confounding factor that likely affected some of the results observed.

There have been only two other investigations known that have compared Olympic and power lifting training programs in football players. This is a bit surprising considering the importance that is placed on power development in strength/power athletes (Haff, 2001). Channell and Barfield (2008) examined the effect of Olympic and traditional resistance training on vertical jump improvements in high school football players. In this eight-week study, the investigators reported significant improvements in vertical jump performance in both the Olympic (2.46 ± 4.7 cm) and power lifting programs (1.16 ± 3.1 cm). The changes in vertical jump performance represented a 4.5% increase for the Olympic lifting group and a 2.3% increase in the power lifting group. These results were similar to that previously reported by Hoffman et al. (2004a). A subsequent study also examined high school football players performing Olympic lifting or traditional power lifting for eight weeks (Roberts and DeBeliso, 2018). The investigators reported significantly greater improvements in 1RM squat in the Olympic lifting group (17.2% increase) compared to the players participating in the traditional power lifting program (10.6%). Although both groups improved vertical jump performance, no differences were noted between the Olympic lifting (5.3%) and traditional power lifting (5.1%) groups. In addition, no changes were noted in 9.1 m sprint speed. Interestingly, the studies comparing Olympic to traditional power lifting training programs have not been overwhelmingly positive. Although positive trends regarding greater improvements have been noted in lower body strength, speed, and power, these changes have not been statistically convincing. However, it should be acknowledged that small differences may take on a greater magnitude in sports in which success often hinges on a difference of a fraction of a second.

Ballistic training is another training mode that is used to enhance the rate of force development (Kraemer and Newton, 2000). Ballistic exercises such as jump squats, bench press throws, or medicine ball throws allow the athlete to accelerate a force through a complete range of motion. One study examined the effect of adding a jump squat to the training program of competitive football players during the power phase of the off-season conditioning program (Hoffman et al., 2005a). Forty-seven experienced, resistance-trained football players competing at a NCAA Division III institution were assigned to either a group that performed the jump squat exercise with both concentric and eccentric phases of movement, a group that performed the jump squat exercise using only the concentric phase of movement, or a control group (players who did not perform the jump squat exercise) during the team's off-season strength and conditioning program. The squat jump was performed on a device that had the option of unloading the eccentric phase of the jump. Unloading was accomplished via a hydraulic system that was able to catch the bar after it reached its peak height. All squat jumps were performed using 70% of the athlete's 1RM squat. The athletes performed the exercise using shoulder pads to exert effort. No bar was placed across the athletes cervical vertebrae. All groups performed the identical off-season strength and conditioning program. The jump squat exercise was included in the strength/power phase (five weeks) of the athletes' off-season periodized training program. Strength, power, speed, and agility were measured prior to and following the off-season training program. Significant differences were seen in the change (Δ) in 1RM squat and Δ1RM power clean between the jump squat group that used both concentric and eccentric phases of the jump movement compared to the control group. No other between-group differences were seen in these variables, and no significant differences were seen between the groups in Δ speed, Δ agility, and Δ vertical jump height. Although the jump squat was performed on a jump squat machine, the relatively high intensity used for training may have been a disadvantage in stimulating power gains by minimizing velocity of movement compared to lower intensities of training. In addition, a short-duration training program may not have been sufficient to elicit significant changes in an experienced, trained group of athletes. No other studies are known that have specifically examined the effects of ballistic training in competitive football players during any part of the yearly training cycle.

Efficacy of Inseason Strength and Conditioning Programs for Football

The goal of the off-season conditioning programs is to enhance the athletes' potential for success during the season. If the training stimulus is removed, the athlete's ability to maintain strength and power gains would be compromised. This is the basis of the principle of reversibility. During the inseason training program, the primary emphasis is on football practices. However, to maintain the gains made in the off-season, coaches have to maintain a training stimulus. They generally reduce intensity of training to about 80% of the maximum 1RM and also decrease the frequency and volume of training (Hoffman, 2014). The inseason training program generally consists of performing the core exercises twice per week. There have been only a few studies that have examined the effectiveness of inseason training program. Hoffman and Kang (2003) required football players from a NCAA Division III program to perform the power clean (1,3 × 3–5 RM), squat (1,3 × 6–8 RM), push press (1,3 × 4–6 RM), and bench press (1,3 × 6–8 RM) exercises twice per week. All players performed at least one warm-up set and then three sets with a load that allowed them to achieve the required RM. There was 72 h between each training session. The inseason training program began during the preseason and lasted the entire competitive season. Results of the study indicated that football players were able to maintain both their upper and lower body strength during the competitive season, while using a two-day per week maintenance program, with loads equating to 80% of the athletes' 1RM during each training session. An interesting outcome of the study revealed that when training intensity exceeded 80% of the players 1RM, the ability to stimulate strength improvements is significantly greater than when training intensity was below 80%, especially in first-year players. It was suggested that the accumulated fatigue occurring in players who have greater playing time likely limits the extent of muscle adaptation during the season. Interestingly, the intensity of exercise was significantly correlated to the change in both 1RM bench press ($r = 0.68$, $p < 0.05$) and 1RM squat ($r = 0.47$, $p < 0.05$).

Another study from the same research group examined two types of inseason training programs in freshman football players (Hoffman et al., 2003). One program was the traditional linear program in which both workouts of the week were identical and the other program was nonlinear. In the nonlinear program, the exercises were the same, but the intensity and volume of training were different for each workout of the week. The first workout of the week required the subjects to perform three sets at either four to six repetitions (power clean and push press) or eight to ten repetitions (bench press and squat) at 70% of 1RM. The second workout of the week required the players to perform two to four repetitions for three sets for all exercises at 90% of 1RM. Results of the study revealed a significant improvement during the season in the 1RM squat in the linear model but not in the nonlinear model. No significant improvements in the 1RM bench press or in the body mass were noted in either group. The results of these investigations suggested that intensity of training in an inseason maintenance program needs to be at least 80% of 1RM to maintain strength in experienced, resistance-trained football players or stimulate strength improvements in players with limited resistance training experience.

Comparison of Various Periodization Paradigms in Football

The goal of periodized training programs is to manipulate both training intensity and training volume to help the athlete reach peak condition prior to the start of competition (Hoffman, 2014). The concept of periodization primarily came out of the development of year-long or multi-year training programs for weight lifters competing in international competitions (Matveev, 1958). In 1981, Dr. Mike Stone adapted many of these concepts and suggested that it could be applied to the training program of American football players (Stone et al., 1981). Most investigations examining various periodization schemes have not been performed on competitive athletes. Even fewer studies have compared different periodization models to no periodization. Many of the studies that have examined different training modalities or interventions often use a periodized training routine. The duration of the study is often less than 15 weeks in duration. The reason for this study duration is that it fits into the academic semester. Even in the optimal situation, a 15-week periodized training program was not the basis for why periodization programming was developed. Thus, the question of whether a 15-week off-season resistance training program in football players is efficacious compared to no periodization scheme is a legitimate question. Does manipulation of intensity and volume of training effective in a relatively short time period provide any advantage?

Part of the problem in examining this question includes a number of logistical and practical issues. Most athletic teams do not have the roster numbers to provide sufficient statistical power for an extended study examining various training paradigms. This limits the potential to conduct research studies in football players. This requires a tremendous degree of cooperation that unfortunately doesn't always exist. Despite having limited evidence supporting the use of a periodization model for training strength/power athletes, including football players, the concept of periodization has gained widespread acceptance (Issurin, 2016; Mujika et al., 2018; Williams et al., 2017).

The first study to examine the efficacy of periodization in college football players was published in 2009 (Hoffman et al., 2009a). The purpose of the study was to compare two primary periodization schemes (linear and nonlinear) to a no periodization program in NCAA Division III college football players. A common characteristic of conditioning programs in Division III collegiate athletes is a relatively long active rest period between the conclusion of the season and the onset of the off-season training program. Thus, it was important to interpret the results of the study with that important context in mind. Fifty-one experienced, resistance-trained players were randomly assigned to one of three groups that differed only in the manipulation of intensity and volume of training during the four-day per week, split routine, 15-week spring semester off-season resistance training program. A one-week off period occurred after week 7 for spring break. Testing occurred at weeks 0 (pre), 7 (mid), and 15 (post). One group of athletes performed the same training program for the entire study (6–8 RM in traditional power exercises and 3–4 RM in Olympic movement exercises). This was considered the no periodization (NP) group. Another group of athletes were randomized into a linear periodization (LP) group in which they did a four-week hypertrophy (9–12 RM) phase, six-week strength phase (6–8 RM in power lifting exercises and 3–4 RM in Olympic movement exercises), and a four-week power phase (3–5 RM in power lifting exercises and 1–2 RM in the Olympic movement exercises). The final group was a nonlinear periodization group (NLP). They performed a power phase (3–5 RM) twice per week and a hypertrophy phase (9–12 RM) the other two days of the week for the entire training study. The percent changes in strength performance can be observed in Figure 3.3. Significant increases were seen in all three groups in both the 1RM bench press and 1RM squat. However, no differences in the magnitude of improvement were noted between the groups. The greatest increases though were observed in the first seven weeks of training in all three groups. Interestingly, the NLP group experienced no further increase (0.1%) from mid- to post-testing for squat strength. The large increase in strength in the first seven weeks of the training program likely reflects the long detraining period that occurred between the end of the season and the start of the off-season conditioning program. Similar results were also seen in vertical jump performance. Significant improvements were noted in NP (4.1%), LP (2.4%), and NLP (3.2%) between pre to mid. However, no other changes were noted. Thus, during a short-duration training program (~14 weeks), the benefits of a periodized

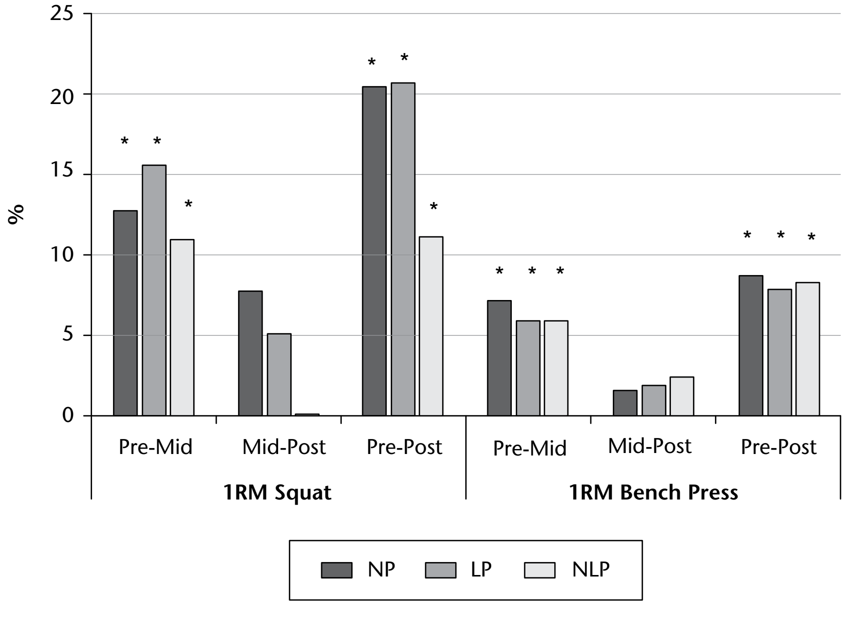

FIGURE 3.3 Comparison of Linear Periodization, Nonlinear Periodization, and No Periodization in Maximal Upper and Lower Body Strength in an Off-Season Conditioning Program for Football. NP = no periodization; LP = linear periodization; NLP = nonlinear periodization; * = significant increase. All data are reported as % increase.

Source: Data from Hoffman et al., 2009a.

training program may not be realized. Again, it is important to understand that training programs are developed for the entire year. Thus, the benefits of a periodized training program are likely more relevant in having the athlete peak at the appropriate time of the year and minimize the risk of overtraining. However, periodization may not directly be associated with maximal performance development. This is the only investigation that has been conducted on periodization programs in football players. The results do not support the benefits of periodizing the training program, but coaches and sport scientists who work with these athletes do need to monitor their athletes to ensure appropriate loading, which is challenging but provides adequate recovery.

Physical Performance Changes in the Football Player's Career

There are only a limited number of studies that have examined physical and performance changes in high school football players. A recent study indicated that a maturation process is seen in these players with the largest changes in performance occurring between the 10th and 11th grades (Dupler et al., 2010). This appears to be consistent across offensive and defensive players. Consideration for adjusting rosters (e.g., varsity versus junior varsity teams) to account for athlete maturation may provide a method of not pushing or rushing athletes before they are physically ready for the next level of competition.

Anzell and colleagues (2011) examined changes in height, body mass, and body composition in both collegiate and professional football players over several decades. They reported a significant increase in body mass for collegiate (linemen and skill position players) and professional football players (linemen and offensive backs) over time. The investigators also reported a significant increase in percent body fat in college football players (all positions combined) but not in professional players. No changes were observed in body height, in either collegiate or professional players. A similar examination, albeit in Division III college football players who participated in New England schools between 1956 and 2014, reported significant changes in body mass over the 50+years examined (Elliott et al., 2016). Increases in body mass ranged from 5.7% in wide receivers to 37.5% in offensive linemen. Significant increases in height were also seen over time in linemen, tight ends, defensive ends, and quarterbacks. No changes in height were noted in any of the other positions. Changes in height ranged from 1.1% in linebackers to 3.8% in offensive linemen. Others have looked at changes in anthropometry over a much shorter duration. In a study of NCAA Division I football players, Trexler and colleagues (2017) examined 57 football players during a single year and a smaller subset (n = 13) during their four-year collegiate career. Using dual-energy X-ray absorptiometry (DEXA), measurements were taken on four occasions – beginning and end of the off-season (March–May), preseason (mid-July), and the start of the following off-season (March). Significant increases in lean mass were noted from the end of the off-season to the preseason period, and a greater change was noted from the preseason to the start of the following off-season period. Both bone mineral content and bone mineral density increased over time. In addition, significant reductions were also reported for body fat percentage and fat mass. Examination of changes over the player's career indicated that body mass significantly increased between years 1 and 2 and between years 2 and 3. No significant change was noted between the players third and fourth years of eligibility. Weight gain over the four-year career was slightly greater in linemen compared to skill position players (8.5 ± 5.4 kg and 5.4 ± 2.7 kg, respectively). Lean mass was significantly greater in the athletes' fourth year (83.7 ± 8.2 kg) than the previous three seasons (79.4 ± 7.4 kg, 80.6 ± 7.1 kg, and 80.6 ± 7.8 kg, respectively). Lean mass changes over the players' career were also greater in linemen

(6.2 ± 3.2 kg) than skill position players (3.1 ± 2.4 kg). No significant changes were noted in body fat composition or fat mass during the four-year career.

Several studies have examined performance changes in the careers of college football players. A study in NCAA Division I football players reported significant gains in body mass, lean body mass, number of repetitions performed with the 102 kg bench press test, agility, and vertical jump height (Stodden and Galitski, 2010). The investigators reported that during the athletes' four-year career, body mass increased every year but the fourth year. Body mass increased 2.2% for all positions combined from the first to third year, but decreased 1.5% from year 3 to year 4. These results were less than those subsequently reported in both NCAA Division I and Division III players (Hoffman et al., 2011; Jacobson et al., 2013). Table 3.5 compares body mass changes in the four-year career of college football players separated by position. Body mass increased 5.9% during the four-year career of NCAA Division III players (6.1% in linemen and 4.9% in skill position players). Interestingly, NCAA Division I linemen only gained 2.9% body mass during their career, whereas skill position players increased their body mass by 9.0%. The lower body mass gains seen in the Division I linemen compared to the Division III linemen reflect the large difference in body mass seen in the athletes first year of competition. Body size is likely one of the discriminating factors separating Division I and Division III football players. The Division I players were bigger (~23 kg) as freshman, which likely contributed to them being a scholarship athlete compared to the non-scholarship Division III player.

Changes in strength during a four-year career in Division I and Division III football players are depicted in Table 3.6. Improvements in 1RM bench press during a college career in football players have been reported to range between 17.7% and 34.1% (Hoffman et al., 2011; Jacobson et al., 2013; Miller et al., 2002). Improvements in upper body strength among linemen appear to be greater in the Division III players (22.7%) than the Division I players (17.8%). However, Division I skill position players experienced a nearly threefold greater improvement in upper body strength than Division III skill position players (34.1% versus 12.5%, respectively). Similar improvements in squat strength were noted between Division I and Division III linemen (27.4% and 25.6%, respectively), but Division I skill position players had a twofold greater increase (32.4%) in squat strength than Division III skill position players (15.8%). Interestingly, the average

TABLE 3.5 Body Mass Changes in a Four-Year Career in NCAA Division I and III College Football Players

	League and Players	*Year 1*	*Year 2*	*% Change*	*Year 3*	*% Change*	*Year 4*	*% Change*	*Total % Change*
Body mass (kg)	DIII All players	93.7 ± 17.1	95.2 ± 16.7	1.6	97.4 ± 17.1	2.3	99.2 ± 18.6	1.8^	5.9#
	DIII Linemen	105.8 ± 15.3	108.0 ± 14.9	2.1	109.5 ± 14.7	1.4	112.3 ± 15.8	2.6^	6.1#
	DIII Skill positions	81.8 ± 8.3	84.2 ± 8.1	2.9*	85.4 ± 8.9	1.4	85.8 ± 9.3	0.5	4.9#
	D1 Linemen	128.7 ± 12.7	131.2 ± 10.8	1.9*	131.9 ± 8.5	0.5	132.4 ± 8.2	0.4	2.9#
	D1 DB and WR	79.7 ± 7.5	85.8 ± 8.8	7.7*	84.6 ± 8.5	–1.4	86.9 ± 5.7	2.7	9.0#

Source: Data from Hoffman et al., 2011 (NCAA DIII) and Jacobson et al., 2013 (NCAA DI).

Notes: All data are reported as mean ± SD. * = significantly different from previous year; ^ = significantly different from year 1; # = significant improvement in career; DB = defensive backs; WR = wide receivers.

TABLE 3.6 Strength Performance Changes in a Four-Year Career in NCAA Division I and III College Football Players

	League and Players	*Year 1*	*Year 2*	*% Change*	*Year 3*	*% Change*	*Year 4*	*% Change*	*Total % Change*
Bench press (kg)	DIII All players	117.4 ± 20.9	126.7 ± 20.4	7.9*	134.5 ± 21.7	6.2*	138.2 ± 21.9	2.8	17.7#
	DIII Linemen	122.7 ± 20.9	132.2 ± 19.7	7.7*	143.1 ± 20.5	8.2*	150.6 ± 20.0	5.2	22.7#
	DIII Skill positions	112.3 ± 19.1	121.8 ± 19.8	8.4*	125.7 ± 19.3	3.2*	126.3 ± 19.4	0.5	12.5#
	D1 Linemen	159.3 ± 23.6	171.2 ± 17.9	7.7*	181.8 ± 18.7	6.2*	187.7 ± 19.0	3.3	17.8#
	D1 DB and WR	105.5 ± 17.6	125.8 ± 15.2	19.2*	135.5 ± 17.7	7.7	141.5 ± 7.7	4.4	34.1#
Squat (kg)	DIII All players	152.5 ± 27.3	166.4 ± 28.4	9.1*	179.8 ± 30.4	8.1*	184.8 ± 33.7	2.8	21.2#
	DIII Linemen	157.7 ± 28.5	168.6 ± 28.5	6.9*	188.4 ± 29.1	11.7*	198.0 ± 32.3	5.1	25.6#
	DIII Skill positions	147.3 ± 25.0	164.4 ± 28.3	11.6*	170.0 ± 29.2	3.4	170.6 ± 29.4	0.4	15.8#
	D1 Linemen	210.0 ± 33.8	242.8 ± 32.4	15.6*	258.6 ± 26.8	6.5*	267.6 ± 33.6	3.3	27.4#
	D1 DB and WR	155.2 ± 28.0	180.0 ± 26.2	15.8*	196.5 ± 21.6	9.1*	205.5 ± 16.2	4.6	32.4#

Source: Data from Hoffman et al., 2011 (NCAA DIII) and Jacobson et al., 2013 (NCAA DI).

Notes: All data are reported as mean ± SD. * = significantly different from previous year; # = significant improvement in career; DB = defensive backs; WR = wide receivers.

squat strength of Division I skill position players was similar to or greater than that seen in Division III linemen. The ability of strength performance to differentiate between different levels of play will be discussed in further detail in Chapter 4. Examination of year-to-year strength improvements indicated that the greatest gains in strength occurred during the athlete's freshman year (year 1). Significant strength gains were also reported during the sophomore off-season (between years 2 and 3) in all Division I athletes, but only linemen at the Division III level. Skill position players for Division III football experienced significant strength gains in both the bench press and squat exercises only following the freshman off-season. These differences in the magnitude of strength gains among skill position athletes in the two divisions of play are not clear, but it may be related to the size of the strength and conditioning staffs and access to training tables common in Division I programs that do not occur at the Division III level. Considering that the skill position players have a much greater window of strength adaptation available to them, external factors such as facility, personnel, and nutrition may have all contributed to these differences.

Table 3.7 depicts changes in 40-yard sprint speed and vertical jump height in the career of Division I and III football players. Significant improvements were noted in Division III players (both linemen and skill position players) in vertical jump height (Hoffman et al., 2011). However, in contrast to strength performance, significant changes in vertical jump height (a measure of lower body power) took longer to achieve. Significant gains were not seen until the athlete's senior year. This may reflect a greater emphasis on power training in these older athletes. These results were consistent with other longitudinal studies examining collegiate football (Miller et al., 2002). No changes in vertical jump height were noted in the four-year career of Division I

TABLE 3.7 Speed and Jump Performance Changes in a Four-Year Career in NCAA Division I and III College Football Players

	League and Players	*Year 1*	*Year 2*	*% Change*	*Year 3*	*% Change*	*Year 4*	*% Change*	*Total % Change*
40-yard Sprint (s)	DIII All players	5.05 ± 0.34	5.01 ± 0.37	−0.8	4.97 ± 0.37	−0.8	4.95 ± 0.35	−0.4	−2.0
	DIII Linemen	5.24 ± 0.35	5.23 ± 0.38	−0.2	5.18 ± 0.37	−1.0	5.13 ± 0.37	−1.0	−2.1
	DIII Skill positions	4.86 ± 0.20	4.81 ± 0.21	−1.0	4.77 ± 0.23	−0.8^	4.77 ± 0.20	0	−1.9#
	D1 Linemen	5.36 ± 0.23	5.29 ± 0.23	−1.3	5.17 ± 0.22	−2.3	5.17 ± 0.19	0	−3.5
	D1 DB and WR	4.58 ± 0.16	4.53 ± 0.11	−1.1	4.53 ± 0.16	0	4.50 ± 0.10	−0.7	−1.7
Vertical jump height (cm)	DIII All players	64.9 ± 9.5	66.5 ± 9.2	2.5	66.4 ± 9.0	0	69.7 ± 9.8	5.0*	7.4#
	DIII Linemen	61.0 ± 10.1	62.6 ± 8.4	2.6	63.6 ± 9.2	1.6	66.3 ± 9.5	4.2^*	8.7#
	DIII Skill positions	68.4 ± 7.5	69.8 ± 8.5	2.0	69.6 ± 7.7	−0.3	73.4 ± 8.9	5.5^	7.3#
	D1 Linemen	65.5 ± 7.1	64.8 ± 7.6	−1.1	67.1 ± 7.9	3.5	67.3 ± 6.6	0.3	2.7
	D1 DB and WR	83.1 ± 5.8	86.9 ± 6.6	4.6*	88.9 ± 6.4	2.3	89.9 ± 6.1	1.1	8.2#

Source: Data from Hoffman et al., 2011 (NCAA DIII) and Jacobson et al., 2013 (NCAA DI).

Notes: All data are reported as mean ± SD. * = significantly different from previous year; ^ = significantly different from year 1; # = significant improvement in career; DB = defensive backs; WR = wide receivers.

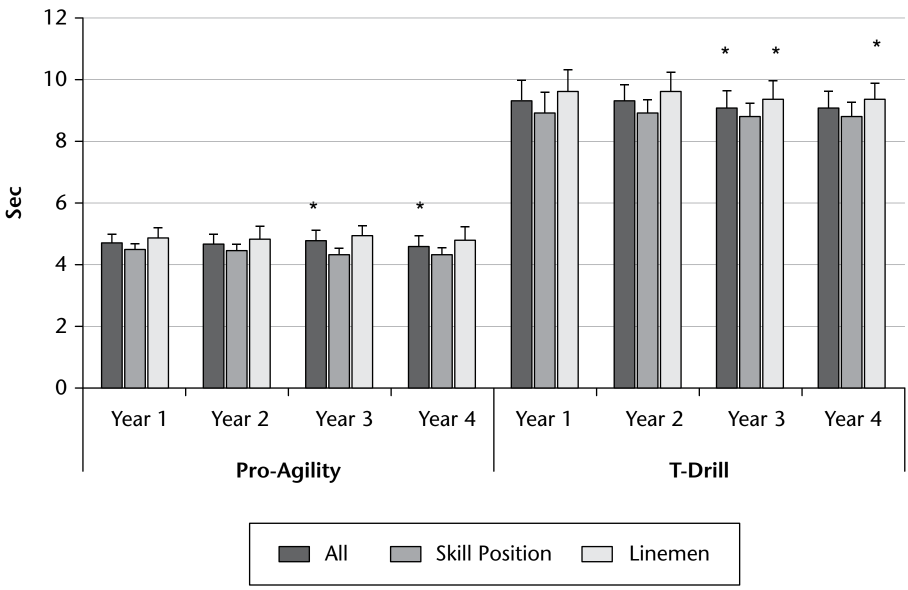

FIGURE 3.4 Changes in Agility Performance in Division III College Football Players.

* = significantly different from year 1. All data are reported as mean ± SD.

Source: Data from Hoffman et al., 2011.

college linemen, but a significant change was seen in Division I skill position players (Jacobson et al., 2013). The largest gains were noted in the athletes' freshman year. This is consistent with the improvements seen in strength. It is likely that the greatest physical trait that separated the Division I skill position players from the Division III players was speed. Their greatest window of opportunity was actually in improving strength. Thus, the significant strength improvement in lower body strength in these athletes during their freshman year had a greater impact on power performance. Keep in mind that power is defined as force × velocity. As velocity was already at a high level, it was the force potential that had the greatest window of growth.

The ability to improve speed and agility appears to be limited. If speed is improved, it generally occurs during the later stages of the athlete's playing career (Hoffman et al., 2011; Jacobson et al., 2013). Division III athletes appeared to decrease 0.1 s from their 40-yard sprint time during their four-year career, while Division I skill position players were slightly less (0.08 s) and linemen almost twice as much (0.19 s). It is likely that these performance variables are a function of genetic factors that impact the athletic potential of all athletes. Similar results were also noted in agility improvements. A nonsignificant 0.11 s decrease in time was noted in agility time (pro-agility test), but a significant improvement in time for the T-drill (0.22 s from freshman to junior seasons) in Division III football players (Hoffman et al., 2011) (see Figure 3.4).

Summary

To maximize the benefit of off-season conditioning programs, the strength and conditioning professional needs to understand the basic principles of training and develop scientifically sound training programs. It becomes imperative that strength and conditioning professionals are able to set appropriate training expectations and provide the correct exercises and loading schemes that maximize physiological adaptation from training. Most strength gains are observed during the early part of the athletes' career, while speed and agility improvements may take longer to develop. One of the more interesting issues related to the development of the yearly training program is the necessity of manipulating training intensity and training volume. Limited evidence suggests that there is no advantage in periodized training programs during a 15-week off-season training program.