A Review of Combined Weight Training and Plyometric Training Modes: Complex Training

William P. Ebben, MS, MSSW, CSCS
Head Strength and Conditioning Coach
Marquette University

Phillip B. Watts, PhD
Health, Physical Education, and Recreation
Northern Michigan University

THE IMPORTANCE OF WEIGHT training for an athlete's physical development is well documented. Although plyometric training has been popular in the U.S. for only about 20 years, its positive effect on human performance has also been well documented (2, 6, 8, 9, 25, 28, 42, 44, 45). The combination of weight training and plyometric training has also been investigated (1, 5, 12, 20, 31).

Strength and conditioning professionals must now find a way to incorporate both types of training for athletes who require muscular power. One method is complex training. Complex training alternates biomechanically comparable high-load weight training and plyometric exercises in the same workout. Combining the bench press with the medicine ball power drop is an example of upper body complex training (9). Although only one training study has examined complex training (41), it has gained some degree of popularity among strength and conditioning professionals.

This review examines (a) weight training as a prerequisite to plyometric training, (b) combined weight training and plyometric training, and (c) complex training. Recommendations are made within the context of accepted principles of strength and conditioning, for the purpose of assessing the usefulness of complex training in developing power for athletic performance.

Weight Training as a Prerequisite to Plyometric Training

To explain complex training, we can begin with a review of how weight training and plyometric training historically have been viewed as complementing each other. For example, frequently published recommendations describe weight training as a prerequisite to plyometric training.

Recommendations include implementing plyometric training after a specific period of preparation, such as 4–6 weeks of weight training (21), after several weeks or months of sprint and resistance training (2), after developing a strength base (4, 9), or after gaining experience in basic jump training and weight training (9).

Functional strength is a prerequisite for plyometrics. Functional strength tests for the lower body include squatting 1-1/2 to 2-1/2 times body weight (2, 42) or squatting 5 repetitions at 60% of body weight in 5 sec or less. Functional strength tests for the upper body include bench pressing body weight (for athletes weighing more than 115 kg, or approx. 250 lbs), 5 hand-clap push-ups, or bench pressing 1-1/2 times body weight.

Weight training is used to prepare for plyometric training to reduce the chance of injury (9, 21, 23), develop a strength base (4, 21, 23, 42), and prepare the musculoskeletal system for high-impact forces. The literature is training program." Newton and Kraemer (28) describe complex training strategies as the complex nature of powerful muscle actions and the need to integrate slow and fast force-production training strategies.

Chu (9) summarizes complex training as follows:

"This method of training should be used with the major weight lifts—squats, inverted leg press, split squats, bench press, power cleans, snatches, and push presses. As a rule of thumb, integrating two major lifts with plyometrics during a workout should yield maximum results." (p. 24)

Other sources discuss complex training in greater detail. Ebben and Blackard (13–15) describe the implementation of complex training along with high-load weight training, Olympic-style lifts, and plyometrics. Fleck and Kontor (19) briefly review the history of complex training and the adaptations in "tension dependent neural mechanisms" associated with complex training.

Chu (11) defines the components and physiology of complex training, making recommendations for exercises and program design. Fees (17) recommends the use of complex training for injury rehabilitation and athlete reconditioning.

Verkhoshansky (40) recommends the complex or variational method of developing explosive strength through use of "consecutive combinations of large and small resistances." He describes a number of complexes, including strength, speed-strength, and jump training, combining structural weight training exercises and jumping exercises. In another article he recommends combinations of squats and jumps in the complex (39).

Complex training has been cited in research studies as well. Adams et al. (1) suggest that training which enhances the transition between strength and speed requires a complex plyometric and weight training program.

Ebben and Blackard (16) surveyed NFL strength and conditioning practices. Of 26 coaches who responded, 7 said they combined weight and plyometric training as complex training. Verkhoshansky and Tatyan (41) conducted two complex-training studies and recommended alternating strength and speed/strength training methods in mixed training sessions.

Complex training also has been recommended for a variety of team sports including basketball, football, hockey, rugby, soccer, and volleyball (1, 7, 11, 27, 40, 52). It has been recommended for individual sports such as Alpine skiing, boxing, figure skating, gymnastics, judo, handball, speedskating, sprint bike racing, swimming, track and field, tennis, and wrestling (1, 2, 7, 10, 11, 13, 21, 22, 24, 30, 33, 40, 41). And it has been indicated for sports involving throwing (38).

Given the frequency with which complex training is mentioned in the literature, it merits consideration as a training method and invites questions about implementation. Research on the effectiveness of complex training, however, is almost nonexistent. We may need to examine the research on combined weight training and plyometric training in order to understand the physiological mechanisms of adaptation.

Possible Mechanisms of Adaptation

At present it would be difficult to offer a definitive explanation on the physiological adaptations of complex training. Theoretically, any number of factors could play a role: (a) neuromuscular, (b) hormonal, (c) metabolic, (d) myogenic, and (e) psychomotor. Table 1 lists proposed complex-training mechanisms of adaptation cited in the literature.

Complex training could serve as a strategy that allows continued neural adaptations in trained athletes in addition to morphological adaptations typically associated with advanced training. It might be further understood by considering the ergogenic advantages associated with warm-up activity.

Perhaps the most powerful adaptation mechanisms of complex training are neuromuscular. High-load weight training increases motorneuron excitability and reflex potentiation, which may create optimal training conditions for subsequent plyometric exercise. Also, the fatigue associated with high-load weight training may force more motor units to be recruited during the plyometric phase, possibly enhancing the training state (11, 39, 40).

Training Studies

A number of training studies, listed in Table 2, have examined combined weight and plyometric training programs (1, 5, 12, 20, 23, 26, 31, 41). But only Verkhoshansky and Tatyan (41) specifically examined complex training. These studies provide evidence of the benefits of combined weight and plyometric training.

Several studies have examined combined weight and plyometric training during the same workout (1, 5, 12, 20, 26, 31, 41). Yet most failed to describe how weight training and plyometric training were combined. While these studies are the best evidence available to demonstrate the effects of combined

Table 1
Proposed Complex Training Mechanisms of Adaptation

Source/Mechanism of Adaptation

Bompa (7)

"a strength training program should utilize free weights in concert with other means of training (medicine balls, apparatus, bounding, etc.). Since the training effect is more complex, they complement each other and therefore are more beneficial to the athlete." (p. 275)

Chu (9)

"Combining strength movement exercises like squats with speed movements like the standing triple jump can be a very effective way to stimulate the neuromuscular system and provide variety for the athlete." (p. 24)

Chu (11)

"Strength training raises the body's ability to excite the motor neurons by 50%. This gives the nervous system more involvement and prepares muscle for even greater challenges." (p. 5)

"In the context of complex training, the primary goal of a strength and power athlete is to first emphasize Type IIb fibers and get Type IIc fibers to act like Type IIb fibers." (p. 10)

"athletes must raise the level of excitement of the muscle fibers and challenge them when they reach their highest level." (p. 13)

"In the complex training system, an athlete can make the greatest gains within the window of super compensation. For that short period, the athlete can take advantage of a system that is maximally aroused and able to face greater challenges." (p. 142)

Fees (17)

"In physiological terms, the precontraction of antagonistic muscles counters the inhibitory neural mechanisms in the agonists." (p. 18)

"The body has been working with heavy objects and thinks it has more heavy work. The neural system remembers the heavy work and responds accordingly." (p. 18)

Fleck & Kontor (19)

"The contractions performed with the heavy resistances are an attempt to bring about adaptations in tension-dependent neural mechanisms that inhibit the excitation of motor neurons in voluntary maximal contractions." (p. 66)

"by doing a light weight after a heavy weight you fool the body into remembering the heavy weight. You therefore obtain a high velocity of movement which will develop power." (p. 66)

Verkhoshansky (39)

"[Complex training is] directed mainly to the development of reactive ability of the nerve-muscle apparatus during significant dynamic effort and speed of switching the muscles from yielding work to overcoming work." (p. 11)

"basic exercise for the development of reactive ability is fulfilled in a background of heightened excitability of the central nervous system, brought about by preliminary fulfillment of exercise requiring great power." (p. 12)

Verkhoshansky (40)

"A weight of 90% of maximum, or 5RM, stimulates maximum effort and at the same time leaves a definite impression on the body. It is expressed in greater excitation of the CNS and maintaining mobilized preparation for execution of maximal effort. Weight of 30% maximum allows for fast development of work effort. If exercise with this weight is executed on a background of the positive consequences from the exercise with large resistance, its training effect is significantly increased. . . . A general adaptive reaction is formed in the body. It is reflected in greater explosive effort." (p. 121)

Verkhoshansky & Tatyan (41)

"[Complex training invokes] a situation in which the positive consequences of previous strength work are used in training for specific speed-strength development." (p. 12)

Table 2 Review of Combined Weight Training and Plyometric Training Research

Researcher	Research focus	Subjects	Duration	Type of WT	Type of plyo.	Exer. order	Prog. des.	Results
Adams et al. (1)	Compared S, P, & SP groups in VJ	48 intermed. weightlifters	6 weeks 2×/week	Parallel squat	DJ, double-leg hop, split squat	P before S on heavy day, S before P on light day	Periodized	S incr. VJ by 3.30 cm; P incr. VJ by 3.81 cm; S & P incr. VJ by 10.67 cm
Blakey & Southard (5)	Assessed effect of combined WT & P on Margaria test & Universal leg press	31 volunteer univ. students	8 weeks 3×/week	Leg press & upper body WT exerc.	In-depth jump, or jumping during normal VB practice	P before WT for 2 of 3 trng. days; P on same day as WT	Progressive incr. in load	3 groups doing DJ at various heights, all improved Margaria power scores ~3.35–5.69 watts
Clutch et al. (12)	Compared WT & DJ group to WT-only group; assessed VJ	16 from univ. WT class & 16 from univ. men's VB team	16 weeks 2×/week	Deadlift, BP, parallel squat	DJ of 0.75m & 1.10m	P before WT during same session	Progressive incr. in load	For WT class, WT & DJ trng. incr. VJ ~3.73 cm vs. WT-only group, for whom VJ decreased ~0.11 cm
Ford et al. (20)	Compared WT & P, WT & wrestling/softball group, & WT only; tested 5 variables incl. 40-yd & VJ	50 high sch. boys from a PE class	10 weeks 3×/week	Squat, deadlift, power clean, & BP	DJ & form running w/ $2\frac{1}{2}$-lb ankle wts	WT & P every other day, presumably in same workout	WT included sets of 8, 5, & 3 reps/session	WT incr. VJ by 1.72 in. & decreased 40-yd by 17 sec; WT & activity incr. VJ by 1.23 in., decr. 40-yd by 0.18 sec; WT & P incr. VJ by 1.77 in., decr. 40-yd by 1.5 sec
Hedrick & Anderson (23)	Compared test scores in squat & clean w/VJ perform.; program included plyomet.	45 college football players	2 years	Squat, power clean, & other football conditioning exerc.	Not specified	Order of WT & P not specified	Periodized (presumed)	Incr. squat & clean performance, avg. VJ incr. of 3.66–10.41 cm
Lyttle et al. (26)	Compared max power trng., combined WT & P, & control group on various tests of dynamic power	33 untrained males	8 weeks 2×/week	WT & P group used squat & BP	WT & P: DJ & med ball throw; max power group: wgtd. squat jump & bench throw	WT & P group did exerc. on same day	Progressive incr. in load	WT & P yielded more signif. results in various power tests than max power trng. or control groups
Polhemus et al. (31)	Compared WT & P to WT-only group; assessed 40-yd, VJ, & SLJ	27 male univ. track & field athletes	6 weeks 3×/week	BP, power clean, squat, military press, mini-gym leaper	Running in place, weighted DJ	P & WT on same trng. days	Pyramid program	WT incr. VJ by 1.3 in., incr. SLJ by 2.0 in., decr. 40-yd by 11 sec; WT & P incr. VJ by 3.0 in., incr. SLJ by 7.25 in., decr. 40- yd by 0.33 sec.
Polhemus et al. (31)	Compared WT & P to WT-only groups; assessed 40-yd, VJ, & SLJ	31 female univ. athletes (no WT exper.)	6 weeks 3×/week	BP, power clean, squat, military press, mini-gym leaper	Running in place, weighted DJ	P & WT on same trng. days	Pyramid program	WT incr. VJ by 1.4 in., incr. SLJ by 1.75 in., decr. 40-yd by 0.33 sec; WT & P incr. VJ by 4.0 in., incr. SLJ by 3.0 in., decr. 40-yd by 0.43 sec.
Verkhoshansky & Tatyan (41)	Compared signif. of exerc. order; assessed WT before P, P before WT, & complex trng.	96 beginning track & field athletes	14 weeks 36 sessions	Squat, supine leg press, one-leg squat, walking w/ partner on shoulders	Squat jump, hop, VJ, SLJ, & triple jump	Compared WT before P, P before WT & complex trng.	Not specified	No numerical data; complex trng. group outperformed WT before P group, & P before WT group
Verkhoshansky & Tatyan (41)	Compared order of WT & P in same trng. session to DJ group	108 beginning track & field athletes	12 weeks 36 sessions	Squat, other unspecified WT exerc.	DJ, other unspecified plyomet.	Compared WT before P, and P before WT in complex group, & DJ control group	Not specified	No numerical data given; DJ group outperformed combined WT & P group

Note: S = squat group; WT = weight trng group; P = plyometric group; VJ = vertical jump; SLJ = standing long jump; DJ = depth jump; BP = bench press.

weight and plyometric training, they offer little explanatory value for the mechanisms of complex training. Complex training can be further understood through carefully controlled studies that examine exercise order and length of rest between the weight training and plyometric exercises of a complex pair.

Since complex training is likely to be employed by individuals who are already trained, the research should involve trained athletes. Training volume should be quantified and specified; it should follow periodization schedules. Weight training components should include exercises commonly used by athletes in training, such as the parallel squat and power clean.

■ Recommendations for Complex Training

Although there is a lack of research on the effectiveness and mechanisms of complex training, a review of the literature suggests potential benefits of such training. In light of established principles of strength and conditioning, we can offer some recommendations on designing a complex training program.

Periodization

Complex training must be part of a periodized program. First, one must have functional base strength. Complex training can be incorporated after a base strength or "preparation" training cycle of weight training (9, 10, 14, 15, 18, 19, 28, 39, 40, 43, 47).

Complex training should follow established periodization principles associated with plyometric training programs. For example, low-intensity plyometric drills, not in complex pairs, should be introduced in the strength-power cycle. Eventually sport-specific plyometric drills can be paired with functionally similar weight training, as complex training, in the precompetition cycle (10, 14, 15, 28, 40, 47).

Including plyometric drills and reducing the volume of weight training allows for "unloading" and facilitates power development (1, 9, 11, 14, 15, 28, 40, 47). Sport-specific complexes are a form of "functional training" and increase the generalizability of training to the actual athletic activity. Complex training is also time-efficient and offers variation of training methods during the competition cycle.

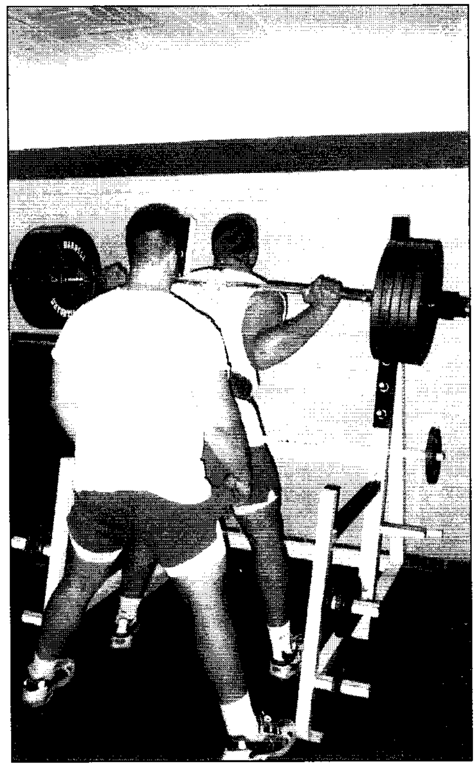
Intensity and Volume

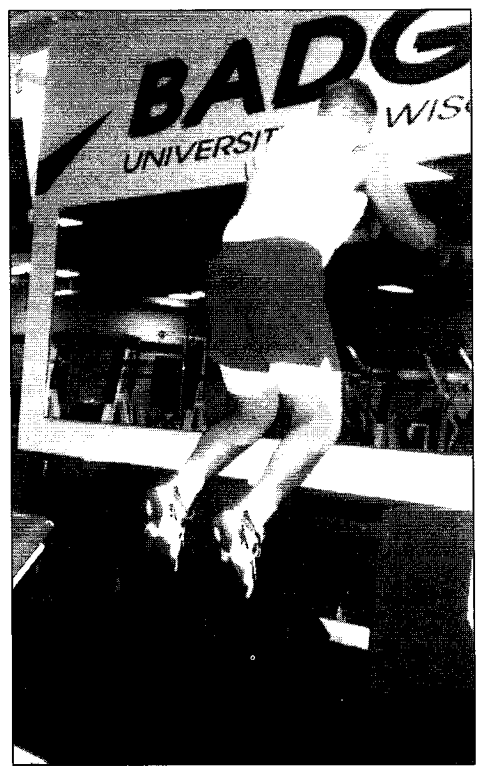
Recommendations for intensity and volume of exercise are consistent. The athlete needs to work at a high intensity level for both weight and plyometric training (1, 2, 9, 11, 14, 15, 21, 28, 40, 47). The volume of complex training should be low enough to guard against undue fatigue so the athlete can focus on quality of work performed.

An example of complex pairs may include biomechanically similar exercises such as bench press and medicine ball power drop, or the squat and squat jump. Two to 5 sets of any complex pair are recommended. The athlete does 2–8 reps during the weight training component and 5–15 reps during the plyometric component (1, 9, 10, 11, 14, 15, 18, 19, 21, 39, 40).

Specificity and Exercise Choice

Recommendations for exercise choice in complex pairs are consistent with the principle of biomechanic and velocity specificity needed for power sports. Complex pairs should include a multijoint weight training exercise followed by a biomechanically similar plyometric exercise





Offensive tackle Chris McIntosh performs the squat (top), followed by the box jump.

(1, 7, 9, 11, 14, 15, 19, 21, 28, 43). Total body or Olympic-style lifts may also be used, followed by plyometric exercises in a complex pair.

Numerous sport-specific combinations of biomechanically similar free-weight and plyometric exercises can be paired in complex training. Furthermore, one should consider unilateral exercises such as single-arm power drops vs. two-arm power drops, since full motor unit activation may occur more readily during unilateral contractions (32).

Training Frequency and Recovery

Recommendations for frequency of, and recovery between, training sessions are consistent. Complex training may be undertaken 1–3 times a week with 48–96 hrs recovery between sessions in which the exercise affects the same muscle group (2, 43). Training with complex pairs in the same session prevents the problem of weight training on one day followed by plyometric training the same muscle group the next day.

For an untrained individual, the initial training cycle would contain no plyometric drills, while for athletes with prerequisite functional strength it would contain limited, low-intensity plyometric drills. Later training cycles such as the precompetitive cycle may contain complex training 2 or 3 days a week (2, 11, 16, 42). One or two complex training sessions a week can be used during the competitive season as a high intensity/low volume, time efficient training method.

Many published complex-training recommendations follow sound principles of strength and conditioning. Recommendations are consistent for periodization, variation, intensity, volume, exercise choice, specificity, recovery, and training frequency. But they are less certain for exercise order and rest between sets and exercises.

Tentative Recommendations for Complex Training

Exercise Order

Recommendations for exercise order in complex training typically call for high-load weight training followed by functionally similar plyometrics (2, 9, 14, 15, 19, 40). For example, one set of squats followed by one set of depth jumps. Another recommendation is to follow a high-load weight training exercise (e.g., squat) with sport-specific lighter exercises of 30–40% RM such as a jump squat, followed by plyometrics such as depth jumps, creating a 3-exercise complex (15, 19, 40).

Adams et al. (1) suggest doing all plyometric exercises first on a low-intensity weight training day since the fatigue induced by plyometrics will not be as deleterious to the weight training exercise.

It is generally believed that the advantages of complex training accrue from performing plyometrics after weight training, taking advantage of the heightened neural stimulation afforded by the weight training. In a given workout, multijoint complex pairs should be performed before other exercises to ensure that they are done at a high work intensity (43).

Rest Between Sets

As is the case with exercise order, recommendations for rest between sets merely serve as guidelines until empirically determined. Recommendations for rest between exercises in complex pairs range from almost none to 5 minutes (11, 16, 41).

Recommendations for rest between pairs are less clear (i.e., between one pair of biomechanically similar weight and plyometric training exercises and the next pair). However, inadequate rest between sets leaves room for different interpretations. For example, if a weight training exercise is followed by a plyometric exercise (complex pair), then by a second set of weight training and plyometric exercises without adequate rest after the first complex pair, does the plyometric exercise follow the weight training exercise or precede it?

Until more research is conducted, the majority opinion is to perform the plyometric exercise set relatively soon (0–30 sec) after the weight training set so as to take advantage of the possible heightened neural stimulation afforded by the weight training set.

Adequate rest between complex pairs is important. Recommendations are 2 to 10 min of rest after completing one complex pair (weight training + plyometric training exercise) and before beginning the next set of the same pair (11, 16, 41). Generally, strength/power training requires adequate rest between sets to allow the body to replenish the anaerobic energy sources needed for performing high-velocity contractions at high power output (16, 43).

Summary

Stone (36) offers guidelines for coming to a reasonable conclusion regarding strength and conditioning methods. These guidelines are one way to examine the combination of weight training, plyometric training, and sport-specific exercise, as well as complex training.

1. Is the idea logical?

Complex training is consistent with the principles of periodization, variation, specificity, recovery, and individualization. There is no evidence that it has a deleterious effect. Research supports the value of combining weight training and plyometric training in the same sessions.

Weight training, plyometric training, and sport-specific exercise must be combined in some fashion for optimal power development and transfer of training adaptations to athletic activity. Weight training and high-intensity plyometric training on alternating days—for the same muscle groups, as is often recommended—violates the principle of recovery.

Recommendations have been made for training intensity, volume, exercise choice, recovery, and training frequency. There is also the educational value of directly pairing activities such as bench press and medicine ball chest pass. It allows athletes to correlate the functional value and the unique training stimulus of each type of biomechanically similar exercise.

Finally, complex training may be administratively advantageous. It allows the coach to supervise athletes' weight training and plyometric training during a single session, on the same day, in the same facility.

2. Has the idea been tested subjectively?

Complex training has been employed for some time, and numerous recommendations appear in the literature.

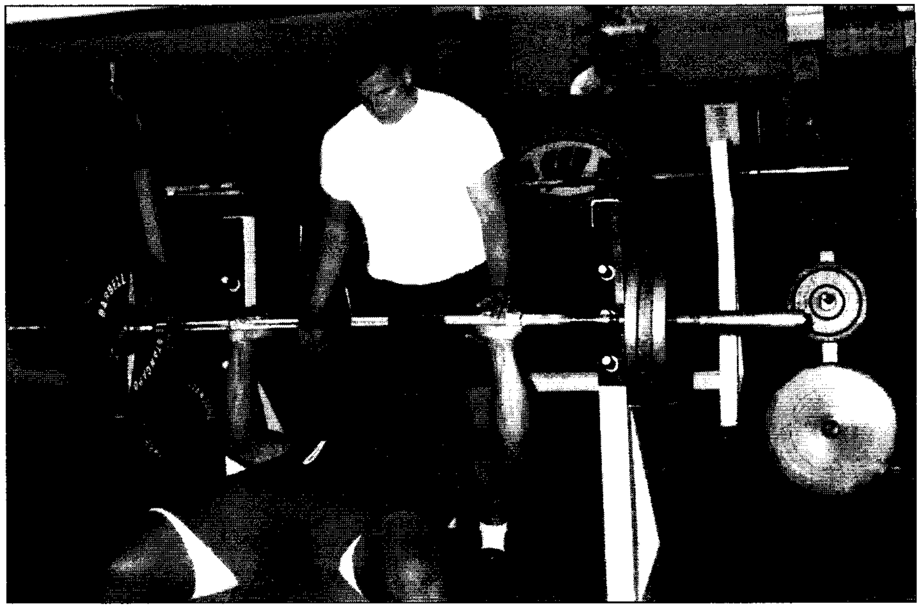
3. Has the idea been tested objectively?

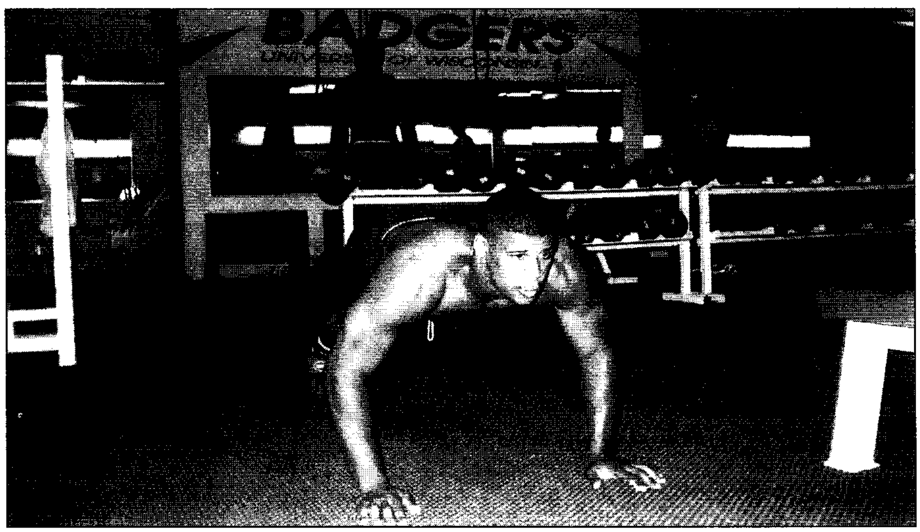
Studies of complex training are limited to the work of Verkhoshansky and Tatyan (41), yielding inconclusive results. Other researchers point to the significant advantages of combining weight training and plyometric training methods in the same session. They found superior improvements in the vertical jump, 40-yd dash, and standing long-jump when compared to weight training alone (1, 12, 20, 23, 26, 31, 41). There are no empirically established guidelines for recommendations on exercise order, length of rest between sets, and number of complexes per workout.

4. Is there enough information for making a judgment?

There is no evidence that complex training is harmful or impairs development in athletes who already possess prerequisite functional strength. Complex training is logical, administratively efficient, and offers advantages associated with combined weight training and plyometric training.

Complex training most likely will offer an enhanced training stimulus for athletes possessing functional strength and athletic development (9, 21, 28, 41). It may or may not offer the optimal training stimulus. However, it is worth implementing and assessing subjectively as well as researching objectively.





Fullback Cecil Martin does a bench press (top), followed by a plyometric push-up.