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In-Season Resistance Training for Professional Male Volleyball Players

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summary

Strength and power performance are two important factors for elite athletes. This paper provides strategies for strength and power development in professional male volleyball players.

Introduction

Team volleyball is an Olympic sport played professionally in many countries around the world. Despite the increasing professionalization of coaches and athletes, there is little research data concerning performance in professional volleyball players. Two major reasons for this are suggested. Some coaches adopt traditional methodologies in resistance training (RT) programs for team volleyball, incorporating, for example, too much plyometric training or too few weightlifting movements. Also, experimental studies in elite athletes, especially in team sports, are very difficult to put into practice. These difficulties are compounded by a problem discussed by Kraemer (29). The inclusion of a control group in the study of top athletes may be unethical, because the withholding of potentially important training would be detrimental for the development of the players selected (29).

However, such considerations should not detract from the necessity and importance of this type of investigation in team volleyball. Research has shown that RT can improve players' maximal force and power production, reduce the incidence of injury, and contribute to faster injury recovery times, thereby minimizing the number of missed practice sessions and competitions (12, 15, 50). This paper features a brief discussion of the specific RT program used by a professional Portuguese volleyball squad during the 2003–04 in-season. This is followed by a description and rationale of the RT program components. These were grounded in the relevant scientific literature and based upon the authors' experience in the training of professional volleyball players.

Strength Demands in Volleyball

Team volleyball is an explosive sport (7, 13, 22, 35, 45). During a match, players must be physically prepared for continuous jumps (22, 35), changes of direction (7), and spiking the ball explosively (7). Furthermore, because these actions must be expressed over long periods, muscular endurance is also important to maintain high performance levels (13, 45). In short, volleyball athletes need to develop the power to apply their skills, plus muscular endurance to maintain high levels of application throughout the entire game and match.

Specific Strength Development in Professional Volleyball Players

Maximum Strength Training

There are specific forms in which overload may be introduced during RT training (16). From the various training variables, it appears that training intensity is the most important parameter to consider when designing an RT program to target maximum strength in high-level athletes (48, 50). On this issue, research has shown that RT with external loads corresponding to 80–100% of 1 repetition maximum (1RM) is most effective for increasing maximal dynamic strength (15), because this loading range appears to maximally recruit muscle fibers and produce further neural adaptations (44). Between this intensity range of 80–100% of 1RM, experienced weight-trained athletes routinely invest their RT time in the use of excessively heavy loads (>90% of 1RM) (16), because it is commonly believed that effective increases in maximal strength can be achieved by training at these relative intensities. However, it is not known whether optimal intensity stimulus at these extremely heavy loads is effective for the development of maximal dynamic strength in elite volleyball players.

Briefly, our in-season RT program showed that professional volleyball players can increase maximal dynamic strength performance (1RM: 1 repetition maximum lifting weight) using low volume and medium/high intensity. After 12 consecutive weeks of RT, an increase of 1RM bench press and 1RM squat was observed, corresponding to 15% and 19%, respectively. These results were attained after a periodized RT cycle (preparatory period: 8 weeks). Consequently, all the athletes were at good overall condition.

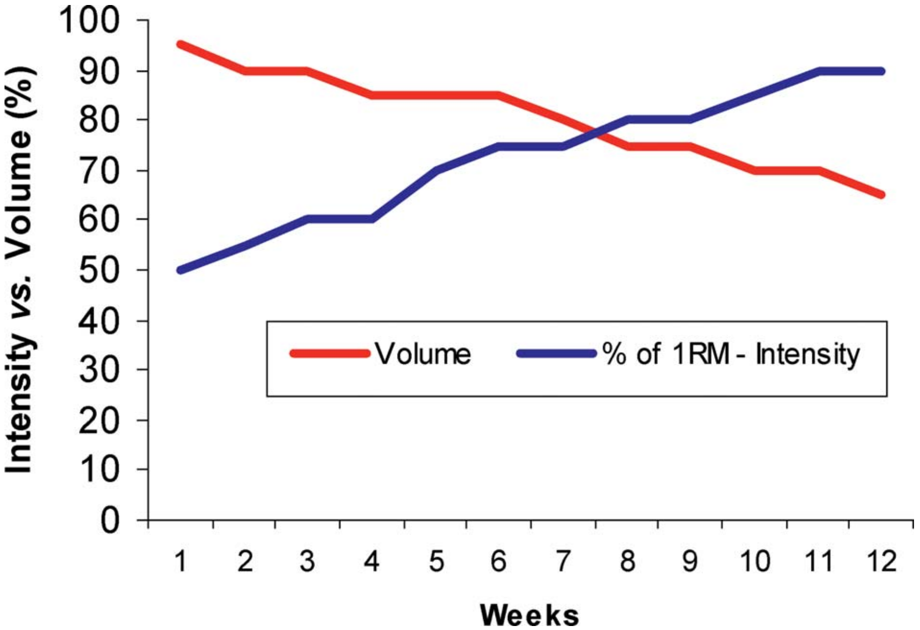

Figure 1. An example of the model used during the 2003–04 in-season for maximal strength development, bench press exercise.

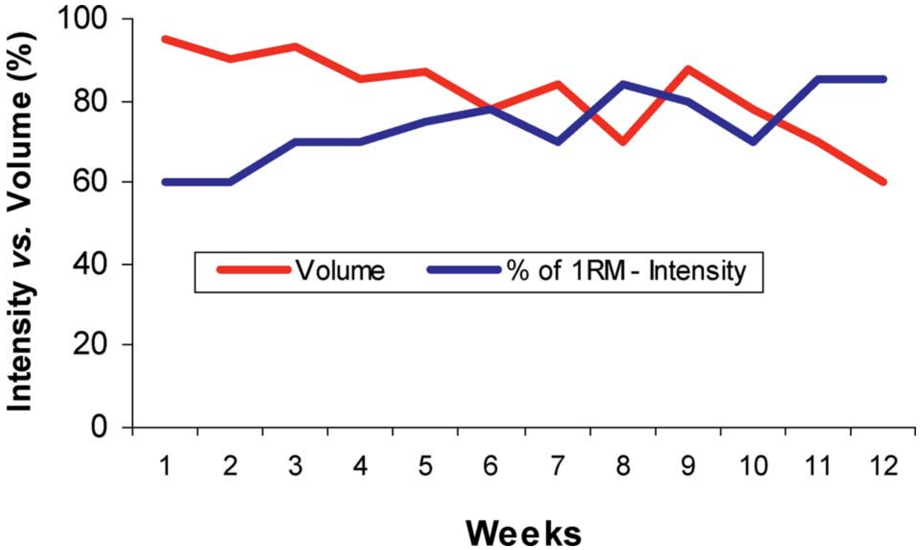

Figure 2. An example of the model used during the 2003–04 in-season for maximal strength development, squat exercise.

The in-season RT program progressed from low-volume/low-intensity exercise to moderate-volume/high-intensity exercise with constant microcycle variations. An RT program can be described by many variables, with training intensity and volume being the principal variables (48). Volume here represented the total amount of repetitions (sets × reps) accomplished per week for the bench press and squat exercises. Training intensity per week was given as a percentage of 1RM. In addition, the RT program indicated that male professional experienced volleyball players can improve 1RM accomplishing only 47% (rounded up) of the maximal number of repetitions for bench press (Interval: 35–60%, Figure 1) and squat (Interval: 35–70%, Figure 2) at loads higher than 50% of 1RM and lower than 85% of 1RM during 12 consecutive weeks (Figure 1 and 2). For example, for a trained athlete with average strength requirements (as in volleyball), the relationship of percentage loads to number of repetitions (rounded up) to failure are as follows (15): 50%, 25 reps; 55%, 20 reps; 60%, 16 reps; 65%, 14 reps; 70%, 12 reps; 75%, 10 reps; 80%, 8 reps; 85%, 6 reps. Our experience revealed that this methodology best optimizes and maintains the maximum strength levels in volleyball players during the period of competition, providing the number of repetitions per series is completed with maximum effort. This

Table 1
Program Guidelines for an In-Season Maximal Strength Development for Professional Male Volleyball Players

Principal exercises	Rationale	Intensity	Sets vs. reps	Rest periods	Days per week
Squat	This exercise develops overall maximum strength in lower-extremities and in maintaining overall conditioning	50–80% of 1RM Maximum speed during concentric phase Control speed during the eccentric phase	3–4 vs. 4–8	3–4 min	2–3
Bench press Lat pull-down Seated pulley row	These exercises develop maximum strength in upper-extremities and stabilize the balance between agonistics and antagonistics muscles	60–85% of 1RM Maximum speed during concentric phase Control speed during the eccentric phase	3 vs. 3–8	2–3 min	2

1RM = 1 repetition maximum. The squat was performed to the parallel position, when the greater trochanter of the femur was lowered to the same level as the knee.

procedure simultaneously prevents the early onset of muscular and nervous overstrain, and any damaging increase of muscular mass (50). Finally, this strategy requires that each repetition be performed at relatively high speed, on the premise that greater gains in muscular power will be achieved with each repetition. Therefore, increasing training volume does not always provide a better stimulus for improving adaptations during a long-term competitive period (16). Marques and González-Badillo (34) found that a short-term RT (12 consecutive weeks) using moderate relative intensity tended to produce significant enhancements in top team handball players' performance in squat and concentric bench press. These conclusions should, however, be interpreted within the context of this population of experienced athletes. Table 1 shows an example set, repetition, and intensity routine for the squat, bench press, lat pull down, and seated pulley row for maximal strength development.

Power Training

Performance in most competitive activities depends on the athlete's ability to produce force quickly (3, 5). Power may be defined as the product of force and velocity (27, 28, 50). Peak power is the maximum power generated during a given movement and is produced when both force and velocity are at optimum values (40). Power development and how it is affected by training variable manipulation are topics of keen interest to strength coaches and sports scientists. However, the ability to produce force quickly is more highly related to rate of force development (RFD) rather than power (50). The RFD is associated with the concept of explosive strength and is directly related to the ability to accelerate objects or body mass (44). Thus, a greater RFD can increase acceleration capabilities (44, 50). In fact, RFD is an important factor contributing to explosive power production and dynamic performance (e.g., jumping, throwing), especially when performance or the time in which one can apply force lasts less than 250 milliseconds (28).

It has been shown that a major stimulus for the development of muscular power is the conscious effort to produce fast, explosive contractions, regardless of external resistance (38). In addition, intensity for RT is defined in a number of accepted ways (e.g., 4RM or a percentage of 1RM). However, intensity in power training resistances is determined by external loads that allow for power output to be close to the maximum possible. Consequently, an intense power training exercise may require that the athlete generate power output of 80–90% of his maximum even though the external load may only be 50–70% of 1RM. For instance, a resistance of 50% 1RM may equate to very low performance squats but may equate to the highest power output in performing barbell squat jumps (3).

During explosive movements like jumping or spiking, the time over which players can apply force and accelerate external mass (e.g., a ball) is minimal (50). In maximum dynamic contractions, the velocity of muscle shortening decreases with the application of an increased load. According to this phenomenon (i.e., force-velocity relationship), muscle power varies with the external load, attaining maximum values at approximately 30% of peak isometric force

(26), at approximately 30–50% of 1RM (36, 38, 40), and at even higher external loads like 80–100% of 1RM (5). In sport science, many experiments, set up to enhance the performance of the athlete, are based on a force-velocity relationship (15, 50). The relationships between power and velocity and/or force are also a way of examining the force-velocity relationship from another point of view. Because power is a factor in many athletic skills (5), it is clearly useful for researchers to study these relationships, especially when dealing with professional volleyball players. However, the vast majority of strength coaches will not have scientific equipment available (e.g., force plate) to determine the optimal loads for loaded jumps, bench pressing, squatting or weightlifting movements. Additionally, the optimal load that maximizes power output may differ between selected exercises (28). If this is the case, identifying the optimal load for each exercise is important, because training with optimal loads has been suggested as being the most effective method for improving maximal power and a variety of dynamic athletic skills (26), specifically in volleyball (45).

For jumping development, Baker et al. (5) observed that the optimal loads are achieved at 50–60% of 1RM during ballistic exercises such as bench press throw and squat jump. Kawamori and Haff (28) indicated that only 1 study (9) compared the optimal loads between traditional resistance exercises and ballistic resistance exercises that involve relatively similar movement patterns and muscle groups (bench press versus bench throw). Although Cronin et al. (9) found that loads of 50–70% of 1RM were superior for generating greater power output during both bench press and bench throw exercises, Kawamori and Haff (28) argued that more research is needed to clarify this subject. For example, this should investigate whether the optimal loads are different between weightlifting movements (e.g., power clean) and ballistic exercises (e.g., squat jump) (28). It appears that the optimal load for maximum mechanical power output depends on the nature of the exercise or the experience of the athlete (28, 50). Furthermore, the training status of the athlete within a yearly training cycle could also affect the optimal load.

Clearly, not all sports are pure strength sports (48) (e.g., volleyball), and many of them extend over multiple competitions and long seasons. On safety grounds, the authors' own experience indicated that, after the preparatory period (8 consecutive weeks), players should develop maximum strength values (1RM). Once the overall strength (1RM) starts to plateau, then specific power training enables a further increase in power to occur. In general, the load is set as a percentage of the maximum weight the individual can lift while maintaining proper form and technique (the 1 repetition maximum). However, the absolute load used is not the only parameter that must be considered in RT. The power output and force applied to a given resistance are also important parameters. For example, it has been shown that programs using different speeds of movement provide for increases in strength (15, 40, 50). Training with heavy external loads is systematically used to improve maximum strength, whereas training with light loads tends to increase power production (26). In addition, the optimal load that maximizes power output depends on the nature of the exercise or the experience of each athlete (27). On the basis of the specificity of muscular power development, training at the load that maximizes mechanical power output is recommended in order to improve maximum muscular power (26, 28). For example, Kaneko et al. (26) observed that training at the load that produced the highest mechanical power output was most effective in increasing maximum muscular power.

The optimal values for muscular power development obtained on the basis of our personal experience seem to be in accordance with some of the studies discussed by Kawamori and Haff (28) in an important article reviewing this topic. However, other studies reviewed by the same authors (28) show differing results. In fact, very little is known about optimal loadings in muscular power development over relatively long cycles of training, particularly for volleyball players. A suggested schedule of possible power training programs is outlined in Table 2. A vast majority of strength coaches will not have scientific equipment available to determine the optimal load for half squat. In this case, we encourage elimination of this exercise. Special consideration is given in Table 2 to the position of "libero." Each team has the option to register one specialized defensive player, or libero, among the final list of 12 players for whole tournament. Liberos must respond skillfully to a continuous series of emergencies, such as sprinting to the ball, reaching, changing in direction, stopping, and starting. The specific rules for a libero are as follows: (a) he is restricted to performing as a back row player and has no right to complete an attack hit when the ball is above the height of the top of the net; and (b) he may not serve, block, or attempt to block.

Strength Training Versus Endurance Training

Athletes involved in many sports often perform strength and endurance training (32, 33). Volleyball is no exception. Concurrent RT and endurance training appears to inhibit strength development when compared with RT alone (1, 10, 24). However, further research is required to investigate the precise mechanisms that underlie the observed impairments in training adaptation during concurrent training (33).

To our knowledge, only 2 studies have compared the effects of different methods of organizing training workouts (8, 43). Indeed, Sale et al. (43) observed that concurrent strength training and

Table 2
Program Guidelines for an In-Season Power Development for Professional Male Volleyball Players

Principal exercises	Rationale	Intensity	Sets vs. reps	Rest periods	Days per week
Half squat	This exercise is efficient in building powerful legs	Maximal power output with a that subject could reach more than 10–20% of the maximum power obtained in counter-movement jump	2–3 vs. 4–6	3–5 min	1–2
Squat (27)	This exercise is efficient in maintaining powerful legs	50–60% of 1RM Maximum speed during the concentric phase Control speed during the eccentric phase	2–3 vs. 6–8	3–5 min	1–2
Countermovement jump with additional loads (10–60 kg)	Power legs and jumping ability	Maximal power Maximum speed during the concentric phase	2–3 vs. 3–5	3–5 min	1–2
Changes in direction with extra loads (5–10 kg)	Developing acceleration and declaration in lower-extremities	Maximum speed Time of set: 10 sec	3–4 vs. 5–6	3–4 min	1–2
Classic plyometrics (drop jumps; bounding, barriers)	Overall explosive power in lower-extremities Developing acceleration and declaration in lower-extremities	Explosiveness	3–4 vs. 6–8	2–3 min	1
Short sprints (20 m)	Acceleration	Maximal effort	4–5 vs. 3–6	3–4 min	1–2
Power clean (28)	Strength in gluteals and lower back; also general body power	80–90 % of 1RM	3–4 vs. 1–4	4–5 min	2
Bench press (27)	Increase power in upper body	40–50% of 1RM Maximum speed during the concentric phase	3–4 vs. 6–10	2–3 min	2
Medicine ball throw (3–4 kg) Front/overhand/ back and sidearm	Developing and maintaining arm speed	Maximum speed	3 vs. 10	2–3 min	2

1RM = 1 repetition maximum. Half-squat: Descend to a comfortable position where the tops of the thighs are about at a 45-degree angle to the floor. The squat was performed to the parallel position, when the greater trochanter of the femur was lowered to the same level as the knee. Liberos did not perform the half-squat. Countermovement jump with additional loads, changes in direction with extra loads, and short sprints were special for liberos and left-side hitters.

endurance training applied on separate days produced gains superior to those produced by concurrent training on the same day. Although the training programs were held otherwise constant, alternate-day training was more efficient in producing maximal leg press strength gains than same-day training.

Collins and Snow (8) also compared two concurrent training regimens that differed in the sequence of training. One group completed a strength program before endurance training. This sequence was reversed in the other group. Collins and Snow (8) also observed that the sequence of training had no effect on the development of either strength or endurance qualities.

More recently, Häkkinen et al. (19) examined the effects of concurrent strength and endurance training (SE group) versus RT only (S group) over a period of 21 weeks. The RT program was carried out twice per week for the S group. The RT addressed both maximal strength and explosive strength components. Endurance training was also carried out twice per week. Thus, the SE group trained 2 times per week for RT (using the same RT program as the S group) and 2 more times per week for 30 minutes by bicycle ergometer or by walking. Briefly, the results do not demonstrate the universality of the interference effect in strength development and muscle hypertrophy when RT is performed concurrently with endurance training. However, this experiment revealed that even low-frequency concurrent strength and endurance training leads to interference in explosive strength development (19). This suggests that that the interference effect may also be true when the overall frequency and/or volume of training are higher than was the case in this particular study.

It is difficult to compare results in the scientific literature when studies differ markedly in their design factors, including mode, frequency, intensity, frequency of training, and training history of subjects. Therefore, further research is required to investigate these causes and identify other possible mechanisms responsible for the observed inhibition in strength development after concurrent training (33). On this, further research is necessary to identify the principal mechanisms responsible for strength development in professional class volleyball players during concurrent training. Because volleyball demands a balance between strength, power, and endurance, it would seem important to maintain these resources during the entire season.

Where the competitive schedule is extremely demanding, as it is in volleyball, the muscular endurance training could be done on court with specific sport movements. Coaches may therefore include a simple circuit training that incorporates specific skills and movements normally utilized in play (i.e., those exploiting technique; speed, energy sources, and strength demands).

Strength and Detraining

Athletes often experience interruptions in training sessions and competition programs because of illness, injury, postseason break, or other factors, which may result in a reduction or cessation of their normal physical activity level and performance (20, 21, 25, 31). The magnitude of this reduction may depend upon the length of the detraining period (31, 50) in addition to training levels attained by the subject (25).

The maintenance of athletic performance during a specific detraining period (decreased in RT volume and/or intensity) may also be explained by the continuation of specific sport practices and competitions and, simultaneously, by the short duration of detraining itself (decreased in RT volume and/or intensity). It is unclear whether the inconsistency of results between different studies involving different sports is caused by methodological differences, different training backgrounds, or different population characteristics (15). For example, Kraemer et al. (31) observed that recreationally trained men can maintain jump performance during short periods of detraining (6 weeks). The researchers (31) argued that other factors like jumping technique may be critical for vertical jump performance and may have contributed to the lack of change in jump ability. Marques and González-Badillo (34) found that top team handball players declined in jump ability during a detraining period (7 weeks), though not significantly so. In our opinion, this could suggest that game-specific jumping is a better means of positively influencing jump performance. It might be further inferred that game-specific jumping better promotes jump performance among those sports where jumping is fundamental (34). These findings also corroborate our personal experience. In fact, reducing RT volume (1 session per week or no RT session) for a short time (2–3 weeks) is not synonymous with performance decline.

Periodization in Volleyball

Periodization can be defined as a planned distribution of specific variations introduced into training methods programs at regular time intervals (41) in order to optimize gains in strength, power, muscular hypertrophy, and motor skills, while at the same time minimizing the risks of overtraining (12, 17, 29, 42, 48).

Periodization is the systematic variation of both volume and intensity (3, 4, 41, 48), though it would be problematic to speak of either unrelated to the other. It has been shown that fluctuating workload increments can offer benefits in the reduction of overtraining and stimulate performance gains (46). In fact, periodized variation with specific sequencing of exercise selection, volume, and intensity factors offers a superior method of performance enhancement (46, 47).

Two broad models of periodization have been proposed: linear and nonlinear (6, 42). However, in practice, the distinction is not absolute. Periodization by its very nature is nonlinear. Linear training suggests the indefinite use of a constant training volume and loading scheme. There is only the question of more or less variation in periodization (17, 46, 47).

The nonlinear or undulating model is characterized, among other variables, by daily or microcycle (weekly) variations (17, 42). These variations attempt to prevent overtraining (17) while maximizing the adaptive stimulus (total work). Our personal experience suggests that the undulating model provides the added stress and variation necessary to elicit maximal strength and power gains by altering the volume and intensity of RT workouts on a daily/weekly rather than monthly basis. This model of periodization may prove particularly beneficial for elite volleyball athletes by helping them avoid the plateau effect in strength and power gains. Other alternatives would include the adjustment of volume loads by the judicious manipulation of such density variables as training session frequency and periodicity. However, further research using elite volleyball athletes would be required to determine such a benefit.

Program Design in Volleyball

The Portuguese volleyball First League and European Top Teams Cup run from October to April (Final Four), and formal preseason training starts in mid-August. A typical Portuguese in-season lasts between 20 and 24 weeks. Strength and power development and maintenance over the course of this in-season, as well as injury prevention and recuperation, require careful planning and the implementation of a well-periodized RT program. Therefore, the main goals of our in-season RT program were (a) to improve performance and maintain health; (b) to increase spiking velocity and jumping ability; and (c) to enhance maneuverability and acceleration without loss of balance. The strategies used to meet these goals may vary slightly, depending on the specific situation.

In general, our team engaged in 1 to 2 RT workouts per week during the in-season, depending upon travel and competition schedules. Frequently, our team travels to a match play by air and returns within 48 hours. Athletes then generally have 1 session to recover and prepare for play the following day. A significant challenge for coaches is to provide volleyball athletes with adequate recovery time. The central questions involve the optimal weekly balance between recuperation intervals, the intensity of strength and conditioning, and the frequency, intensity, and duration of technical and tactical work.

The RT sessions were scheduled in the mornings (between 9:30 and 10:30), 6 to 8 hours before afternoon practices. During morning practices, however, the head coaches would often require additional technical work with the entire squad, distorting the RT session conditions insofar as players were fatigued by the time they arrived at the weight room to work out. When this happened, we separated the squad into 2 groups, the first going immediately to the weight room to complete the RT program, while the second underwent specific volleyball workout routines. In the next training session, we reversed the order for each group. During less tightly scheduled weeks, RT workouts would be confined to 1 or 2 morning sessions.

During the last 8 weeks, athletes were sorted into 2 groups according to specific needs and levels. Volleyball players were grouped as starters (S; n = 7) and nonstarters (NS; n = 8). Starters and NS participated in 80.6% and 19.4% of total game time, respectively. We used this strategy for the following reasons. Our in-season RT program focused on power maintenance while simultaneously reducing the risk of injuries. The potentially greater competitive stress placed on the S, and the differential physiological and performance effects related to S or NS status have not been clarified in prior sports research, especially in regard to volleyball players (14). Normally we adopt 2 different approaches for S: (a) 1 moderate weight workout (light weights and few exercises) with moderate reps; or (b) a near-total abstention from in-season lifting. The second option is deployed only after a highly concentrated competition microcycle. For example, a rigorous session of squats (80% of a 1RM; 3 sets of 3 reps) may be followed by a less arduous session involving squats at only 80% of a 1RM for a set of 1, or even 2 sets of 1 to 2 reps. In given situations, jump exercises could be completely eliminated during a hard weekly competition, should that appear necessary.

With limited time for training, the in-season is not a time for the indiscriminate use of RT. It must focus on what is most relevant for volleyball players, that is, the rapid exertion of force. For athletes to be able to exert force quickly, coaches must train that quality while maintaining maximal strength during the in-season.

Briefly, our in-season RT program comprehended 2 major phases: Phase A (12 weeks) and Phase B (12 weeks). During Phase A (Table 3), we were particularly interested in improving and/or stabilizing maximal strength gains previously attained during the preparatory period. Since performance in most competitive sports depends on the athlete's ability to produce force quickly (3, 5), specific power exercises were also included.

Harris et al. (23) investigated the effects of 3 different RT methods on a variety of performance variables representing different portions of the force velocity curve, ranging from high-force to high-speed movements. After a 4-week high-volume training period and the pretests, the subjects were randomly assigned to 1 of 3 groups. The groups were high force (HF; n = 13), high power (HP; n = 16), and a combination training group (COM; n = 13); each group trained 4 days per week for 9 weeks. Group HF trained using 80–85% of their 1RM values. Group HP trained at relative intensities approximating 30% of peak isometric force. Group COM used a combination training protocol. Variables measured pretraining and posttraining were the 1RM squat, 1RM 1/4 squat, 1RM midthigh pull, vertical jump height, vertical jump power, Margaria-Kalamen power test, 30-m sprint, 10-yd shuttle run, and standing long jump. Briefly, the results showed that

Table 3
Resistance Training Program Design: Phase A

Session	Squat	Power clean	CMJ with additional load	CMJ onto a box (at 60-cm height)	CMJ onto a box (at 70-cm height)	Bench press	Medicine ball throwing
1	Test	…	…	3×6	…	Test	3 × 10:3 kg
2	50:3 × 8	…	…	3 × 6	…	50:3 × 8	3 × 10:3 kg
3	55:3 × 8	…	…	3 × 6	…	50:3 × 8	3 × 10:3 kg
4	55:3 × 6	…	3 × 5:10 kg	3 × 6	…	60:3 × 6	3 × 10:3 kg
5	55:3 × 8	…	3 × 5:10 kg	4 × 6	…	60:3 × 6	3 × 10:3 kg
6	55:3 × 8	…	3 × 5:10 kg	4 × 6	…	60:3 × 6	3 × 10:3 kg
7	60:3 × 6	3 × 4RM	3 × 5:15 kg	…	4 × 6	60: 3x6	3 × 10:3 kg
8	60:3 × 6	3 × 4RM	3 × 5:15 kg	…	4 × 6	70:3 × 6	3 × 10:3 kg
9	60:3 × 6	3 × 4RM	3 × 5:15 kg	…	5 × 6	70:3 × 6	3 × 10:3 kg
10	65:3 × 6	3 × 4RM	3 × 5:20 kg	…	5 × 6	70:3 × 6	3 × 10:3 kg
11	65:3 × 6	3 × 5RM	3 × 5:20 kg	…	5 × 6	75:3 × 6	3 × 10:3 kg
12	65:3 × 6	3 × 5RM	3 × 5:20 kg	…	5 × 6	75:3 × 6	3 × 10:3 kg
13	70:3 × 6	3 × 4RM	3 × 5:25 kg	…	5 × 6	75:3 × 6	3 × 10:3 kg
14	70:3 × 6	3 × 4RM	3 × 5:25 kg	…	5 × 6	75:3 × 6	3 × 10:3 kg
15	75:3 × 5	3 × 4RM	3 × 5:25 kg	…	5 × 6	75:3 × 6	3 × 10:3 kg
16	75:3 × 5	3 × 4RM	3 × 4:30 kg	…	5 × 6	75:3 × 6	3 × 10:3 kg
17	75:3 × 5	3 × 5RM	3 × 4:30 kg	…	5 × 6	80:3 × 3	3 × 10:3 kg
18	75:3 × 5	3 × 5RM	3 × 4:30 kg	…	5 × 6	80:3 × 3	3 × 10:3 kg
19	75:3 × 5	3 × 5RM	3 × 5:25 kg	…	5 × 6	80:3 × 3	3 × 10:3 kg
20	80:3 × 4	3 × 5RM	3 × 5:25 kg	…	5 × 6	80:3 × 4	3 × 10:3 kg
21	80:3 × 4	3 × 6RM	3 × 5:25 kg	…	5 × 6	80:3 × 4	3 × 10:3 kg
22	80:3 × 5	3 × 6RM	3 × 4:30 kg	…	5 × 6	85:3 × 3	3 × 10:3 kg
23	75:3 × 5	3 × 6RM	3 × 4:30 kg	…	…	85:3 × 3	3 × 10:3 kg
24	70:3 × 6	3 × 4RM	3 × 4:30 kg	…	…	70:3 × 6	3 × 10:3 kg

CMJ = countermovement jump. Example of squat measurement: 50:3 × 8 = 3 sets of 8 reps with 50% of 1 repetition maximum (1RM) squat. Example of power clean measurement: 3 × 4 3RM = 3 sets of 4 reps with a load carried out using 3RM power clean. Example of bench press measurement: 50:3 × 8 = 3 sets of 8 reps with 50% of 1RM bench press. Phase A was preceded by a preparatory period.

when considering the improvement of a wide variety of athletic performance variables requiring strength, power, and speed, combination training produces superior results. These results indicate that both heavy ST and explosive-type RT should be embedded in RT protocols to develop muscular power and athletic performance (23).

According to Kawamori and Haff (28), the superiority of a combined training method is supported by a cross-sectional study conduced by McBride et al. (37). The purpose of the experiment (37) was to determine the effect of involvement in power lifting, weightlifting movement, and sprinting on strength and power characteristics in the squat exercise. A standard 1RM squat test, squat jump tests, and vertical jumps with various loads were performed. In short, the weightlifters, who use both heavy RT and explosive-type RT, obtained better results in jump height and mechanical power measures than did power lifters who use only heavy RT.

Table 4
Resistance Training Program Design: Phase B

Session	Principal exercises							
	Squat	Power clean	CMJ with additional load	CMJ onto a box (at 90-cm height)	CMJ onto a box (at 100-cm height)	CMJ onto a box (at 80-cm height)	Bench press	Medicine ball throwing
1	Test	Test	…	…	…	…	Test	…
2	50:3 × 6	80:2 × 3	3 × 4:30 kg	5 × 6	…	…	50:3 × 6	3 × 10:3 kg
3	55:3 × 6	80:3 × 3	2 × 4:30 kg	3 × 6	…	…	50:3 × 6	3 × 10:3 kg
4	55:3 × 6	80:2 × 4	4 × 4:40 kg	5 × 6	…	…	60:3 × 6	3 × 10:3 kg
5	55:3 × 6	80:3 × 3	2 × 4:30 kg	3 × 6	…	…	60:3 × 6	3 × 10:3 kg
6	55:3 × 6	80:3 × 4	4 × 4:40 kg	5 × 6	…	…	60:3 × 6	3 × 10:3 kg
7	60:3 × 6	85:2 × 3	3 × 4:40 kg	3 × 6	…	…	60:3 × 6	3 × 10:3 kg
8	60:3 × 6	80:3 × 4	4 × 4:30 kg	5 × 6	…	…	70:3 × 6	3 × 10:3 kg
9	60:3 × 6	85:3 × 3	3 × 3:50 kg	3 × 6	…	…	70:3 × 6	3 × 10:3 kg
10	65:3 × 6	80:3 × 4	3 × 4:40 kg	5 × 6	…	…	70:3 × 6	3 × 10:3 kg
11	65:3 × 6	90:2 × 1	3 × 3:50 kg	3 × 6	…	…	75:3 × 4	3 × 10:3 kg
12	65:3 × 6	85:3 × 3	3 × 4:40 kg	5 × 6	…	…	75:3 × 4	3 × 10:3 kg
13	70:3 × 6	90:2 × 2	3 × 4:50 kg	…	3 × 6	…	75:3 × 6	3 × 10:3 kg
14	70:3 × 6	85:3 × 3	2 × 3:60 kg	…	5 × 6	…	75:3 × 6	3 × 10:3 kg
15	75:3 × 5	90:3 × 2	3 × 3:50 kg	…	3 × 6	…	75:3 × 6	3 × 10:3 kg
16	75:3 × 5	85:3 × 3	3 × 3:60 kg	…	5 × 6	…	75:3 × 6	3 × 10:3 kg
17	75:3 × 5	90:3 × 2	3 × 3:50 kg	…	3 × 6	…	80:3 × 3	3 × 10:3 kg
18	…	85:3 × 3	3 × 3:60 kg	…	5 × 6	…	80:3 × 3	3 × 10:3 kg
19	75:3 × 5	85:3 × 3	3 × 3:50 kg	…	…	3 × 6	80:3 × 3	3 × 10:3 kg
20	80:3 × 4	80:2 × 4	3 × 4:40 kg	…	…	5 × 6	80:3 × 4	3 × 10:3 kg
21	80:3 × 4	85:3 × 3	…	…	…	3 × 6	80:3 × 4	3 × 10:3 kg
22	80:3 × 5	80:2 × 4	…	…	…	5 × 6	85:3 × 3	3 × 10:3 kg
23	75:3 × 5	…	…	…	…	…	85:3 × 3	3 × 10:3 kg
24	70:3 × 6	…	…	…	…	…	70:3 × 6	3 × 10:3 kg

CMJ = countermovement jump. Example of squat measurement: 50:3 × 6 = 3 sets of 68 reps with 50% of 4 repetition maximum (4RM) squat. Example of power clean measurement: 80: 2 × 3 = 2 sets of 3 reps with a load carried out using 1RM power clean. Example of bench press measurement: 50:3 × 6 = 3 sets of 6 reps with 50% of 4RM bench press. Phase A was preceded by a preparatory period.

Phase B was incorporated immediately prior to the Portuguese League playoffs and the European Cup Final Four. This was a critical time for our squad, who often competed 2 or 3 times per week, alternating National League games and European Cup matches. Physical and psychological recovery time must be allowed for between games and travels. During team practices, athletes focused on refining technical and tactical work and conditioning. In addition, during Phase B, the RT program was designed in order to maximize muscular power without incurring undue risks of overtraining or injury.

The major differences between the periodization models used during Phase A and Phase B were adjustments made to overall volume and greater variation introduced into certain exercises such as weightlifting movements and jump exercises (Table 4). Prolonged competition (e.g., 24 consecutive weeks) periods require some manipulation of the intensity on a weekly or microcycle basis.

Practical Applications

Given this article's focus upon a presumed readership of strength and conditioning coaches, the authors have assumed a familiarity with RT exercises such as bench press, squat, plyometrics, and weightlifting movements. We merely suggest and deploy concepts based on the scientific literature and our professional experience with professional volleyball athletes.

By implementing both speed-oriented and strength-oriented training strategies or a specific power training method, power and other performance variables may be enhanced (2, 44). Wilson et al. (49) have indicated just such a combination of methods involving the implementation of both speed-oriented and strength-oriented training strategies or a specific maximal power (Pmax) training method. The Pmax load method of training may lead to a broader range of adaptations than the specific adaptations that appear to occur through either strength-oriented or speed-oriented training alone (49). However, for Pmax training, debate still continues regarding precisely which range of resistances allows power to be maximized during resistance exercises.

For a sport with multiple major matches spread across several months (i.e., volleyball in-season), the goal is to preserve maximal strength, muscular power, and performance levels by following a maintenance RT program of moderate volumes and intensities (17). ♦

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