In-Season Strength and Power Training for Professional Male Team Handball Players

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SUMMARY

STRENGTH AND POWER PERFORMANCE ARE 2 MAJOR FACTORS RELATED TO PERFORMANCE FOR PROFESSIONAL ATHLETES. THIS ARTICLE PROVIDES STRATEGIES FOR STRENGTH AND POWER DEVELOPMENT IN PROFESSIONAL MALE ELITE TEAM HANDBALL PLAYERS.

INTRODUCTION

Since the 60s, team handball (TH) has established itself as one of the most popular team sports at both national and international levels (6). World championships, continental championships, and international tournaments in TH take place regularly. TH has been played in Olympic competition since the 1972 Olympic games in Munich. Competitive TH requires muscular strength, speed, and endurance. To date, it has been unclear how these parameters change during the season in elite TH players. In fact, few studies (15,16,28,29) have so far attempted to evaluate the effects of heavy resistance training (RT) programs on different physical parameters in competitive TH athletes.

Unfortunately, despite the increasing professionalization of coaches and athletes, there is little research data concerning performance in professional TH players. Two major reasons may be suggested. Some coaches adopt traditional methodologies in RT programs, incorporating, for example, too much plyometric training or few weightlifting movements (28).

It is well known that traditional RT programs can produce desirable results such as improved muscular strength and local muscular endurance. However, it is unlikely that one traditional form of RT appeals to the entire population of trained athletes, and therefore, there is a need to determine alternate methods of RT. Also, experimental studies in elite athletes, especially in team sports, are difficult to put into practice (25). Sometimes, athletes and coaches do not want to participate in research studies, which can often lead to small sample sizes. Additionally, our experience says that it is difficult to communicate with coaches. However, such considerations ought not to detract from the urgency of this type of investigation in TH (26).

Two studies have shown that RT can improve players' maximal strength and power and reduce the incidence of injuries (9,41). This article features a brief discussion of the specific RT program used in-season by a professional Portuguese TH squad. This is followed by a description and rationale of a periodized RT program. These were grounded in the relevant scientific literature and based on the author's long experience in the training of professional TH players. In brief, the present article aims to discuss the following: (a) What are the principal physical demands of the game? (b) How much strength is needed and how to improve performance? and (c) How can we design an efficient in-season RT program for elite TH?

PHYSICAL DEMANDS IN TH

TH is typically an explosive sport (14,26,27). During a match, players must be physically prepared for continuous sprints (6,7), jumps, changes of direction (6,7,28), and explosive ball throwing (3,17,29). The game includes body contact as the defenders try to prevent opponents from approaching the goal. Contact is only allowed when the defensive player frontally opposes the offensive player, that is, between the offensive player and the goal. Furthermore, because these actions must be performed over long periods, muscular endurance is also important to maintain high performance levels (7,38). Thus, TH athletes need to develop power to apply their skills plus muscular endurance to maintain high levels of application throughout the entire game. During

KEY WORDS:
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the in-season, the strategy is to maintain strength and power development and all conditioning with specific TH drills.

SPECIFIC STRENGTH DEVELOPMENT IN PROFESSIONAL TH PLAYERS

MAXIMUM STRENGTH TRAINING

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 (12,13). Maximal strength is defined as the maximal amount of force a muscle can exert. Here, the muscle contractions involved are isotonic. Between this intensity range of 1RM, experienced resistance-trained athletes routinely invest their RT time in the use of excessively heavy loads (>90% of 1RM) (12) because it is widely 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 in developing maximal dynamic strength in elite players. Furthermore, increasing overall training volume does not always provide a better stimulus for improving adaptations during a long-term in-season period (5,12,37).

Marques and González-Badillo (28) observed that a short-term RT program (12 consecutive weeks) using moderate relative intensity tended to produce significant enhancements in top TH players' performance in squat and bench press exercises. The in-season RT program progressed from low-volume/low-intensity exercise to moderate-volume/high-intensity exercise with constant microcycle variations. Volume here represented the total amount of repetitions (reps) (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 TH players can increase 1RM accomplishing only 80% (rounded up) of the maximal number of reps for bench press (interval: 70–85%, Figure 1), 4RM accomplishing only 75% (rounded up) of the maximal number of reps for the squat (interval: 70–95%, Figure 2), and also power clean accomplishing only 80% (rounded up) during 12 consecutive weeks (Figure 3).

In a trained athlete with average strength requirements, the relationship of percentage loads to number of reps (rounded up) to failure are as follows (15): 70%, 12 reps; 75%, 10 reps; 80%, 8 reps; 85%, 6 reps. However, Tables 1 and 2 indicate that the number of performed reps by series was clearly smaller (between 3 and 8 reps) for a given percentage of 1RM or 4RM, for the bench press and the squat exercise, respectively. For the power clean exercise, we consider maximal power output as being attained at between 87 and 93% of 1RM. This strategy requires that each repetition must be performed at relatively high speed, on the premise that greater gains in power output will be achieved with each repetition. Therefore, increasing overall training volume does not always provide a better stimulus for improving adaptations during a long-term in-season period (12,13).

González-Badillo et al. (13) examined the effects of 3 RT volumes on maximal strength in the snatch (Sn), clean and jerk (C&J), and squat (Sq) exercises during a 10-week training period. Fifty-one experienced trained junior lifters were randomly assigned to 1 of 3 groups: a low-volume group (LVG, n = 16), a moderate-volume group (MVG, n = 17), and a high-volume group (HVG, n = 18). The training was periodized from moderate intensity (60–80% of 1RM) and high number of reps per set to high intensity (90–100% of 1RM) and low number of reps per set. During the training period, the MVG demonstrated a significant increase for the Sn, C&J, and Sq movements), whereas in the LVG and HVG, the increase took place only with the C&J exercise and the Sq exercise. The increase in the Sn exercise for the MVG was significantly higher than that in the LVG). There were no significant differences between the LVG and HVG training -induced strength gains.

The authors concluded that junior experienced lifters can optimize performance by exercising with only 85% or less of the maximal volume that they can tolerate. These observations may have important practical relevance for the optimal design of RT programs for trained athletes. In fact, performing at a moderate volume can be more effective and efficient than performing at a higher volume. In summary, some studies (12,13,28) have demonstrated that high-level athletes from different sports can enhance strength values using moderate overall volume. In contrast, other studies (23) found opposite results.

This conflict in the literature with regard to the optimal load for the power clean can in part be explained by numerous methodological differences in the various studies, such as the reporting of average versus peak power

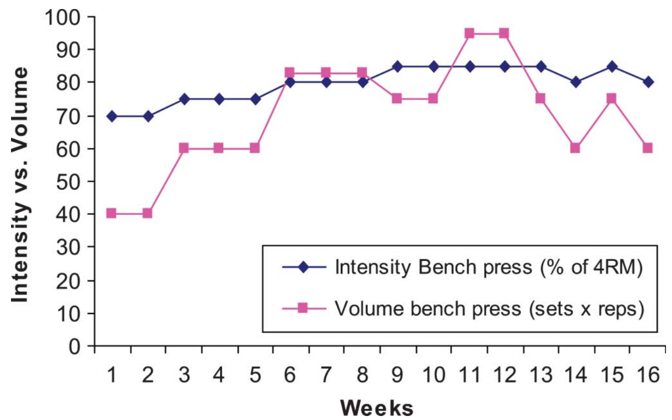

Figure 1. An example of the volume and intensity of the bench press exercise used during the in-season.

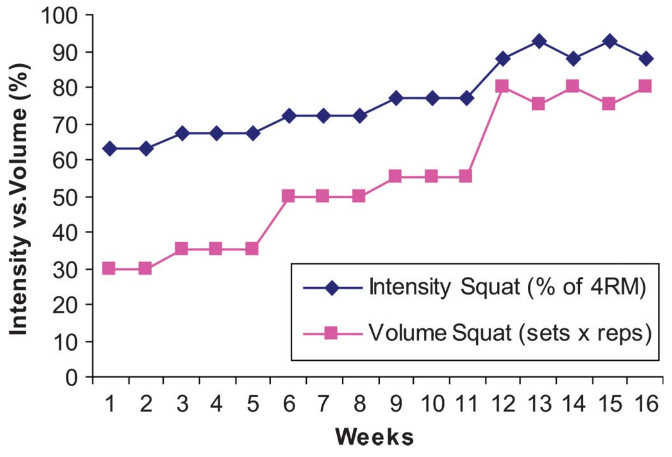

Figure 2. An example of the volume and intensity of the squat exercise used during the in-season.

values and the use of different data collection equipment. Our experience indicated that this methodology best optimizes and maintains the maximum strength levels in TH players during the in-season, providing the number of reps per series is completed with maximum effort. 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.

According to Carpinelli and Otto (5), progressive overload is necessary for increasing muscular strength. For adaptations to occur, a stimulus in excess of previous stimuli needs to be applied during a RT program. Nevertheless, Fry et al. (11) conceived that once a given threshold level of strength training intensity has been reached in resistance trained elite athletes, the appropriate physiological adaptations may well be optimized and that training beyond this limit provides no further benefits. If greater maximum strength makes a difference, then strong athletes will perform better than those not so strong (41). Although this method does not provide conclusive evidence of a cause and effect relation, we suggest that cause and effect is certainly possible. Previous published reports examining the relationship between maximal dynamic strength and specific skill performances have provided equivocal findings with some studies noticing a relationship (16,17) and others failing to do so (28). On this, Granados et al. (16) reported significant correlations between time devoted to games and changes in velocity at submaximal loads during bench press actions, as well as between changes in muscle velocity output of the upper and lower extremities and changes in throwing velocity. In contrast, Marques and González-Badillo (28) observed no relationship between throwing velocity and 1RM changes in male professional TH players. These authors (28) observed substantial increases in squat performance. Furthermore, the change in squat strength values did not show an association with any of the vertical jump tasks, indicating that although biomechanically similar, these tests assess independent motor qualities.

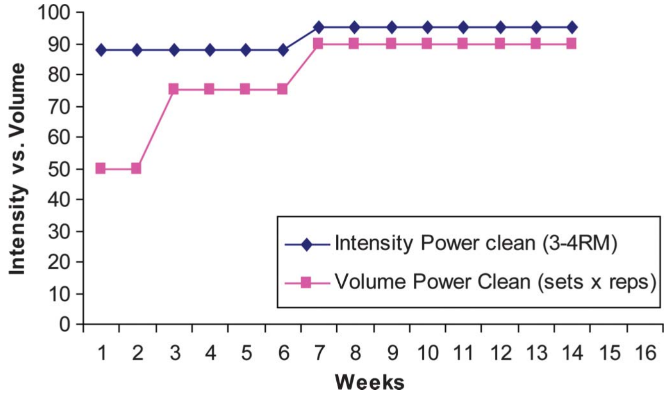

Figure 3. An example of the volume and intensity of the power clean exercise used during the in-season.

Transfer may be conceptually expressed as being a function of the following: gain in performance/gain in trained exercise (41). However, direct transfer to improve sports performance might be limited by such training in experienced athletes. The potential benefit of resisted sports movements such as sprinting requires further research (40).

POWER AND RATE OF FORCE DEVELOPMENT TRAINING

Performance in most competitive activities depends on the athlete's ability to produce force quickly (23,24). Many sports involve movements that require generation of force over very short periods (24). Such movements include throwing, jumping, or changing direction.

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. 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 generates 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

Table 1 RT programs between week 1 and week 6						
Exercises*	**Session 1**	**Session 2**	**Session 3**	**Session 4**	**Session 5**	**Session 6**
Parallel squat†	70: 3 × 6	70: 3 × 6	75: 3 × 6	75: 3 × 6	75: 3 × 6	80: 3 × 6
CMJ onto a box	3 × 5	3 × 5	3 × 5	3 × 5	3 × 5	3 × 5
Power clean‡	2 × 2 × 4RM	2 × 2 × 4RM	2 × 3 × 4RM	2 × 3 × 4RM	2 × 3 × 4RM	2 × 3 × 4RM
Bench press§	70: 3 × 6	70: 3 × 6	75: 3 × 6	75: 3 × 6	75: 3 × 6	80: 3 × 5
Sprints	3 × 20 m	3 × 20 m	4 × 20 m	4 × 20 m	4 × 30 m	4 × 30 m
	Session 7	**Session 8**	**Session 9**	**Session 10**	**Session 11**	**Session 12**
Parallel squat	80: 3 × 6	80: 3 × 6	85: 3 × 5	85: 3 × 6	85: 3 × 6	90: 3 × 4
CMJ onto a box	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6
Power clean	2 × 3 × 3RM	2 × 3 × 3RM	2 × 3 × 3RM	2 × 3 × 3RM	2 × 3 × 3RM	2 × 3 × 3RM
Bench press	80: 3 × 5	80: 3 × 5	85: 3 × 3	85: 3 × 3	85: 3 × 4	85: 3 × 4
Sprints	5 × 30 m	5 × 20 m	5 × 30 m	5 × 20 m	5 × 30 m	5 × 20 m
	Session 13	**Session 14**	**Session 15**	**Session 16**		
Parallel squat	95: 3 × 3	85: 3 × 4	95: 3 × 3	85: 3 × 4		
Power clean	2 × 2 × 3RM	2 × 2 × 3RM	—	—		
CMJ onto a box	3 × 6	3 × 6	3 × 6	3 × 6		
Bench press	85: 3 × 3	80: 3 × 3	85: 3 × 3	80: 3 × 3		
Sprints	5 × 30 m	5 × 20 m	5 × 30 m	5 × 20 m		
Training summary						
Principal exercises	**Sets × reps¶**	**% of MDE‖**				
Parallel squat	249	81.8%				
Power clean	64	Approximately 90%				
Bench press	203	75.9%				

*Rest intervals of 2 minutes were permitted between sets and between categories.

†Example: 70: 3 × 6: 3 sets of 6 repetitions (reps) with 70 percent of 4RMPS.

‡Example: 2 × 3 × 4RM: 2 sets of 3 reps with weight attained during 4RM test.

§Example: 70: 3 × 6: 3 sets of 6 reps with 70 percent of 1RMBP.

¶The total number of reps lifted during the first training cycle in 1RMBP and 4RMPS exercises.

‖The average percentage in maximal dynamic exercises during the first training cycle (MDE: 1RMBP and 4RMPS).

—, The exercise was not performed.

RM = repetition maximum; RT = resistance training; RMPS = maximum repetition in the parallel squat; RMBP = maximum repetition in the bench press; CMJ = countermovement jump; MDE = maximal dynamic exercises.

equate to the highest power output in performing barbell squat jumps (1,2).

Two studies have described significant differences in 1RM and power outputs obtained in the bench press movement at loads of 1RM in TH players (16,17). On this, Kawamori and Haff (24) argued that more research is needed to clarify this subject. For example, there needs to be investigation whether the optimal loads are different between weightlifting movements (e.g., power clean) and ballistic exercises (e.g., squat jump) (24). It appears that the optimal load for maximum mechanical power

Table 2
RT programs between week 7 and week 12

Exercises*	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
Parallel squat†	70: 3 × 6	70: 3 × 6	75: 3 × 6	75: 3 × 6	80: 3 × 6	80: 3 × 6
CMJw‡	20 kg: 3 × 5	20 kg: 3 × 5	20 kg: 3 × 5	25 kg: 3 × 5	30kg: 3 × 5	30kg: 3 × 5
Power clean§	2 × 3 × 3RM	2 × 3 × 3RM	2 × 2 × 3RM	2 × 2 × 3RM	2 × 2 × 3RM	2 × 2 × 3RM
CMJ into a box	3 × 5	3 × 5	3 × 5	3 × 5	3 × 6	3 × 6
Bench press¶	70: 3 × 6	70: 3 × 6	75: 2 × 6	75: 3 × 6	80: 3 × 5	80: 3 × 5
Sprints	3 × 20 m	3 × 20 m	4 × 20 m	4 × 20 m	5 × 30 m	5 × 20 m
	Session 7	**Session 8**	**Session 9**	**Session 10**	**Session 11**	**Session 12**
Parallel squat	85: 3 × 6	85: 3 × 6	95: 3 × 3	85: 3 × 4	95: 3 × 3	85: 3 × 4
CMJw‡	35 kg: 3 × 5	35 kg: 3 × 5	35 kg: 3 × 5	35 kg: 3 × 5	30 kg: 3 × 5	30 kg: 3 × 5
Power clean	1 × 2 × 3RM	1 × 2 × 3RM	—	—	—	—
CMJ into a box	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6
Bench press	85: 3 × 3	85: 3 × 4	85: 3 × 3	80: 3 × 3	85: 3 × 3	80: 3 × 3
Sprints	5 × 20 m	5 × 30 m	5 × 30 m	5 × 20 m	5 × 30 m	5 × 20 m
	Training summary					
Principal exercises	**Sets × reps**‖	**% of MDE****				
Parallel squat	186	81.6%				
Power clean	32	Approximately 95%				
Bench press	159	79.1%				

*Rest intervals of 2 minutes were permitted between sets and between categories.

†Example: 70: 3 × 6: 3 sets of 6 repetitions (reps) with 70 percent of 4RMPS.

‡CMJ with additional weight.

§Example: 2 × 3 × 4RM: 2 sets of 3 reps with weight attained during 3RM test.

¶Example: 70: 3 × 6: 3 sets of 6 reps with 70 percent of 1RMBP.

‖The total number of reps lifted during the second training cycle in 1RMBP and 4RMPS exercises.

**The average percentage in maximal dynamic exercises during the second training cycle (MDE: 1RMBP and 4RMPS).

—, The exercise was not performed.

RM = repetition maximum; RT = resistance training; RMPS = maximum repetition in the parallel squat; RMBP = maximum repetition in the bench press; CMJ = countermovement jump; CMJw = with countermovement jump; MDE = maximal dynamic exercises.

output depends on the nature of the exercise or the experience of the athlete (41). Furthermore, the training status of the athlete within a yearly training cycle could also affect the optimal load.

The power output and force applied to a given resistance are also key parameters. For example, it has been shown that programs using different speeds of movement provide for increases in strength (30,31). Training with heavy external loads is systematically used to improve maximum strength, whereas training with light loads tends to increase power production. In addition, the optimal load that maximizes power output depends on the nature of the exercise or the experience of each athlete. On the basis of the specificity of muscular power development, training at the load that maximizes mechanical power output is recommended to improve maximum muscular power (12).

The rate of force development (RFD) has been one of the most important

variables to explain performance in activities where great acceleration is required (29,33). In most sports activities, the RFD is strongly related to performance abilities such as the sprint, throw, and jump, in which force production times are reduced. This can be related to the fact that the greater the RFD, the greater will be the power and force generated against the same load. However, the literature still tends to produce antagonistic results related to RFD measures and the relation between this parameter and basic skill performances. For example, several authors have observed important correlations between the RFD and the explosive abilities, whereas others found opposite results on the same subject (23). It may be surmised that the instruments used in measurement and the fact that the force was at times measured in an isometric way and at other times in a dynamic way might explain the discrepancies (41).

The optimal values for muscular power development obtained on the basis of our personal experience seem to accord with some of the studies discussed by Kawamori and Haff (24) in an important article reviewing this topic. However, very little is known about optimal loadings in muscular power development over relatively long cycles of training for TH players. Moreover, the ability to produce force quickly is more highly related to RFD rather than to power (41). The RFD is associated with the concept of explosive strength and is directly related to the ability to accelerate objects or body mass (33). Thus, a greater RFD can increase acceleration capabilities (33).

PERIODIZATION IN TH

Periodization can be defined as a planned distribution of specific variations introduced into training methods at regular time intervals to optimize gains in strength, power, muscular hypertrophy, and motor skills, while at the same time minimizing the risks of overtraining (8,9,41).

Two following broad models of periodization have been proposed: linear and nonlinear (4,8,32,34,35). 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 (4). The nonlinear or "undulating" model is also characterized, among other variables, by daily or microcycle (weekly) variations (4,8,18). These variations attempt to prevent overtraining while maximizing the adaptive stimulus (total work). Rhea et al. (32) found that continuing reliance on a unique periodization method may produce attenuated strength gains. This is particularly likely to be the case for elite players, who will have a greater RT background history. Hence, the best approach would appear to be to strategically combine periodization models. During the off-season and the preseason without competitive games will undoubtedly allow different approaches to periodized training from that normally conducive to adequate recovery when matches are scheduled.

The work of Marques and González-Badillo (28) 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 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 (36). However, further research using elite athletes would be required to determine such a benefit. This information can lead to much confusion over which method is superior. Each model has its proponents and detractors as well as positive and negative research findings. The answer to which periodization model is best might be found in the motor learning and control research literature. Perhaps, development of a nonrigid model of periodization consisting of both linear and nonlinear organization, based on the RT experience, training phase, and physical capacity, needs is the answer.

PROGRAM DESIGN FOR TH

Several studies showed (19,20,21,30) that considering the improvement of a wide variety of athletic performance variables requiring strength, power, and speed produces superior results. By implementing both speed-oriented and strength-oriented training strategies or a specific power training method, power and other performance variables may be enhanced (22,40). Wilson et al. (39) have indicated this combination of methods involving the implementation of both speed-oriented and strength-oriented training strategies or a specific maximal power training method. This 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 (39).

The Portuguese TH 1st League and Cup runs from October to May, and formal preseason training starts in mid August. A typical Portuguese in-season lasts 26 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 to (a) improve specific game performance and maintain health, (b) increase throwing velocity and jumping ability, (c) enhance maneuverability and acceleration without loss of balance, and (d) tackle capacity.

The strategies used to meet these goals may vary slightly, depending on the specific situation. In general, our team engaged in 2 RT workouts per week during the in-season, depending on travel and competition schedules. Frequently, our team travels to a match play by air and returns within 24–48 hours. Athletes then generally have one session to recover and prepare for playing the following day. A significant challenge for coaches, then, is to provide TH 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 for Monday and Wednesday mornings (between 10:30 and 11:30), 8 hours before afternoon practices.

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 TH players, that is, the rapid exertion of force. In order for athletes to be able to exert force quickly, coaches must train that quality while maintaining maximal strength during the in-season. In brief, our in-season RT program has used 2 major phases: phase 1 (6 weeks) and phase 2 (6 weeks). During phase 1 (Table 1), we were particularly interested in improving maximal strength gains previously attained during the preparatory period. Because performance in most competitive sports depends on the athlete's ability to produce force quickly, specific power exercises were included.

Phase 2 was incorporated immediately before the Portuguese League play-offs and the European Cup Final Four. This is a critical time for TH players 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 2, the RT program was designed to maximize muscular power without incurring undue risks of overtraining or injury.

The major differences between the periodization models used during phase 1 and phase 2 were adjustments made to overall volume and greater variation introduced into certain exercises such as weightlifting movements and jump exercises (Tables 1, 2). Prolonged competition (e.g., 26 consecutive weeks) periods require some manipulation of the intensity on a weekly or microcycle basis.

The latter stages of the in-season may well be regarded as critical in determining the fortunes of an elite squad, as it is during this period that play-off highlights are contested. Thus, during the last 8 weeks, athletes are sorted into 2 groups according to specific levels. TH players were matched as starters (S; n = 7) and nonstarters (NS; n = 10). S and NS participated in approximately 75% and approximately 25% of total game time, respectively. Our in-season RT program focuses 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 elite athletes (10).

Normally, we adopt 2 different approaches for S: (a) one moderate weight workout (lightweights 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 1–2 reps. In given situations, jump exercises could be completely eliminated during a "hard" weekly competition.

PRACTICAL APPLICATIONS

By implementing both speed-oriented and strength-oriented training strategies, or a specific power training method, power and other performance variables may be enhanced. Wilson et al. (39) 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 training method. However, for power training, debate still continues regarding precisely which range of resistances allows power to be maximized during resistance exercises.

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