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Review Article

STRENGTH IN POWER EVENTS: THEORY AND PRACTICE

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ABSTRACT

Over the last 30 years, strength and power training has been a major issue for, coaches, athletes and researchers. Unfortunately, despite the increasing professionalization of coaches and athletes, there is little research data concerning performance in top athletes. In fact, experimental studies in high level athletes are very difficult to put into practice for many reasons. However, such considerations ought not to detract from the necessity and importance of this type of research in strength and power events. Many experiments demonstrated that a specific strength training program can improve athletes' 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. But, to our best knowledge, there is no apparent consensus on the appropriate method of strength and power training to enhance performance, especially in typically power sports. Therefore, the aim of this paper was to ask practical questions: How much strength should be employed? Is maximum strength the main issue? Is power and rate of force development the key? Is periodization of major importance?

***Key words*:** strength, power, periodization

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INTRODUCTION

Strength and power training has been a major topic for researchers (Marques, 2004). Unfortunately, despite the increasing professionalization of coaches and athletes, there is little research data concerning performance in elite athletes (Marques, 2004). Two major reasons for this may be suggested. Many coaches adopt traditional methodologies in resistance training (RT) programs. Furthermore, experimental studies in top athletes are very difficult to put into practice. These difficulties are compounded by a problem already reported by Kraemer (2005). The inclusion of a control group in the study of top athletes may be unethical, since the withholding of potentially important training would be detrimental for the development of the subjects selected (Kraemer, 2005).

However, such considerations ought not to detract from the necessity and importance of this type of research in strength and power modalities. Several authors demonstrated that RT can improve athletes' 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 (Fleck et al., 1997; Fry et al., 1991; Zatsiorsky, 1995). Nevertheless, there is no apparent consensus on the appropriate method of RT to enhance performance, especially in typically power sports.

Therefore, this paper aims to ask practical questions: ***How much strength should be employed? Is maximum strength the main issue? Is power and rate of force development the key? Is periodization of major importance?***

This paper features a brief discussion of these topics. This is followed by a description and rationale of the RT data components. These were grounded in the relevant scientific literature and based upon the authors' long experience in the training of professional players.

How much strength should be employed?

Several coaches and sports scientists with an interest in RT "world" attempt to identify the proper handling of RT program variables, including the intensity, frequency, and volume of exercises designed to achieve high levels of muscular fitness (ACSM, 2002).

Viru (1993) proposed that the effect of the work performed by an organism partially depends on the total number of repetitions performed. To date, the optimal volume stimuli for the development of strength and the effectiveness of stimuli within the training process have not been satisfactorily ascertained by the scientific community (González-Badillo, et al., 2005). In fact, several studies indicated that one set per exercise or 3 sets can be equally efficient in strength enhancement whereas others have reported that only RT with multiple sets contributed to obtain better results (González-Badillo, et al., 2006). These results could possibly contribute to the variable outcomes of previous studies with respect to the RT experience of participants. This means that less experienced subjects can respond favourably to one or more sets per exercise, especially during the initial training weeks. In contrast, experienced RT participants can only increase strength values by performing higher training repetitions.

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Marques et al. (2006), reported that an in-season RT program 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 in elite male volleyball players, corresponding to 15% and 19%, respectively. An RT program can be described according to many variables, with training intensity and volume being the principal variables (Marques et al., 2006). Volume here represented the total amount of repetitions (sets x reps) accomplished per week for the bench press and squat exercises. Training intensity per week was given as a percentage of 1RM. Additionally, the RT program showed that male experienced volleyball players can improve 1RM accomplishing only 47% (rounded up) of the maximal number of repetitions for bench press (Interval: 35-60%) and squat (Interval: 35-70%) at loads higher than 50% of 1RM and lower than 85% of 1RM during 12 consecutive weeks. For example, for a trained athlete with average strength requirements, the relationship of percentage loads to number of repetitions (rounded up) to failure are as follows: 50%, 25 reps; 55%, 20 reps; 60%, 16 reps; 65%, 14 reps; 70%, 12 reps; 75%, 10 reps; 80%, 8 reps; 85%, 6 reps. 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 variables (Marques et al., 2006).

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 (González-Badillo, et al., 2005). Marques and González-Badillo (2004) observed 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 (i.e. trained athletes).

González-Badillo et al. (2005), published an interesting article abut this subject. Here, the authors examined the effects of 3 RT volumes on maximal strength in the snatch (Sn), clean & jerk (C&J), and squat (Sq) exercises during a 10-week training period. Fifty-one experienced trained junior lifters were randomly assigned to one 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 1 repetition maximum (1RM) and high number of repetitions per set to high intensity (90–100% of 1RM) and low number of repetitions per set. During the training period, the MVG demonstrated a significant increase for the Sn, C&J, and Sq movements ($p < 0.01$), whereas in the LVG and HVG, the increase took place only with the C&J exercise ($p < 0.05$) and the Sq exercise ($p < 0.01$). The increase in the Sn exercise for the MVG was significantly higher than in the LVG ($p < 0.05$). There were no significant differences between the LVG and HVG training volume-induced strength gains. The authors (González-Badillo, et al., 2005) 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.

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In summary, the latest studies have demonstrated that high level athletes from different sports can enhance strength values using moderate overall volume. However, it is our opinion that further studies are still necessary to clarify this statement.

High intensity RT is seen to result principally in neural adaptations, whereas high volumes of strength training tend to enhance hypertrophic responses (Zatsiorsky, 1995). In the absence of proven research data there is much debate as to the most effective RT program, especially in terms of manipulating volume (number of repetitions) and intensity (repetition maximum load or percentage of maximum load) in order to maximise neural and morphological adaptations in such training (Flech & Kraemer, 1997).

During the last two decades, the North America literature has reported that for maximum strength improvements athletes should perform reps until failure. More recently, in a review article, Rhea et al. (2003) concluded, after analysing more than 100 scientific studies, that non trained subjects can enhance maximal dynamic strength using only ~ 60% of 1RM. By contrast, in trained subjects, the most significant improvements in maximal dynamic strength were mostly observed at higher intensities, at ~ 80% of 1RM. However, neither reps carried out until failure nor high percentages of 1RM produce the better results. In fact, this can be an unnecessarily excessive stimulus that can lead to overtraining or even injures (Marques, 2004). In the last two years, Marques and colleagues published two articles (Marques & González-Badillo, 2004; Marques et al., 2008) concerning changes observed in strength and power performance in elite senior professional female and male players during the in-season. For female top athletes, the in-season RT program progressed from moderate/low-intensity exercise to moderate-volume/medium-high-intensity exercise with constant microcycle variations. Briefly, the present in-season RT program showed that elite female volleyball players could increase maximal dynamic strength performance using medium/high intensity exercises. Training intensity per week was given as a % of RM. In addition, the RT program indicated that female professional volleyball players can improve RM for bench press and squat at loads higher than 50% of RM and lower than 85% of RM during 12 consecutive weeks. For example, 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: 50% - 25 reps; 55% - 20 reps; 60% - 16 reps; 65% - 14 reps; 70% - 12 reps; 75% - 10 reps; 80% - 8 reps; 85% - 6 reps. However, this study reported that the number of performed repetitions by series was clearly smaller (between 3 and 8 reps) for a given percentage of RM. This procedure simultaneously prevents the early onset of muscular and nervous overstrain, and any damaging increase of muscular mass in volleyball players (Marques et al., 2008). Here, Marques and González-Badillo (2004) observed significant increases in 1RM for upper body muscles ($p<0.001$) in 14 professional team handball players after 6 weeks of RT. Furthermore, 4RM parallel squat almost doubled the increased gains.

A short-term RT using moderate relative intensity tended to produce significant enhancements in elite player performance in maximal strength (Marques & González-Badillo, 2004; Marques et al., 2008). Fry et al. (1991), stated that, once a given threshold level of RT intensity has been reached in resistance trained athletes, the appropriate physiological adaptations may well be optimized and that training beyond this limit provides no further benefits.

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In brief, summary, it is difficult to compare results in the scientific literature when studies differ markedly in terms of design factors, including mode, frequency, intensity, frequency of training, and training history of subjects. However, further research is required to investigate the precise mechanisms that underlie the observed impairments in training adaptation during the in-season in elite athletes. Because the majority of power events sports demand a balance between strength, power, and endurance, it would seem important to maintain these resources during the entire season.

Maximum strength: is this the main issue?

If greater maximum strength makes a difference, then strong athletes will perform better than those that are not as strong or powerful (Marques et al., 2009). Although this method does not provide conclusive evidence of a cause and effect relation, we suggest that cause and effect is certainly possible.

A correlation is a method measuring the strength of the relationship among variables - the correlation coefficient (symbolized as r) ranges from -1.0 to 1.0; the closer the coefficient is to 1.0 the stronger the relationship. A positive correlation between two variables would mean they increase together, a negative correlation would mean an inverse relationship. Hopkins (2000) has ranked correlations as r = 0.0 (Trivial); 0.1 (Small); 0.3 (Moderate); 0.5 (Strong); 0.7 (Very strong); 0.9 (Nearly perfect); and 1.0 (Perfect).

Previous published reports examining the relationship between maximal dynamic strength and specific skills performances have provided equivocal findings with some studies reporting a relationship (González-Badillo & Serna, 2002; Marques et al., 2009) and others failing to observe a positive association (van den Tillaar & Ettema, 2004; Gorostiaga et al., 2005). On this, van den Tillaar and Ettema (2004), observed a weak correlation between isometric hand grip strength and ball throwing velocity for female team handball players (r=0.49; p=0.027) as well as for male team handball players (r=0.43; p=0.056). In contrast, Fleck et al. (1992) claimed stronger correlations with peak torque during shoulder flexion (r= 0.63: 300º sec^{-1}) and elbow extension (r= 0.63: 240º sec^{-1} and r= 0.65: 300º sec^{-1}) in a group of team handball players. More recently, Marques and González-Badillo (2004) observed no relationship between throwing velocity and 1RM in male professional handball players.

Marques et al. (2008), observed substantial increases in squat performance following a 12-week RT intervention. However the change in squat strength did not show an association with any of the vertical jump tasks, indicating that, although biomechanically similar, these tests assess independent motor qualities. This fact further highlights the importance of combining RT with velocity specific power exercises during training and evaluation. The degree of general strength gained through squat training does not seem to affect the degree of change in jumping performance. Alén et al. (1984), observed no change in jumping performance in well-trained athletes following 24 weeks of heavy squat training, while noticing a significant enhancement in 1RM squat strength. In contrast, Marques and González-Badillo (2004) claimed significant correlations (r=0.50; p=0.046) between countermovement jump height and squat exercise. Baker and Nance (1999), found only poor correlations between absolute estimates of maximum strength (squat and hang clean), and sprint times over 10 and 40m. However, when strength

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values were normalised by dividing the absolute measures by body mass stronger correlations were noticed. The hang clean was better correlated to sprint performance than the squat. Although, weightlifting movements (e.g. snatch and clean and jerk) and their variations such as hang cleans may be more accurately described as high power exercises. Here, Baker and Nance (1999), also found that the power output/kg generated during weighted jumps (40-100kg) had correlations with the 10m sprint ranging from r = - 0.52 to - 0.61 and r = -0.52 to - 0.75 for the 40m sprint.

To summarize, 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.

In general, these experiments have shown that an increase in strength is accompanied by an increase in performance among relatively untrained subjects (Sanborn et al., 2000). Making changes in well trained athletes is more difficult and requires more advanced RT programmes.

Power and rate of force development: is this the key?

Power output

Because of the limited time frame for force application in most sports, an often desired result of the RT process is increased power (force x velocity) (Tidow, 1990). Power output development and how this parameter power is affected by training is of keen interest to coaches, athletes, and sport scientists.

Many sports involve movements that require generation of force over a very short period of time (Kawamori & Haff, 2004). Such movements include throwing, jumping, or change of direction (Fry et al., 1991). In such activities, power output is the main determinant of performance. Because power is the product of force and velocity, both components need to be addressed in a training program to develop muscular power. However, force and velocity are not independent of each other in muscle actions. As the velocity of movement increases, the force that muscle can produce decreases during concentric muscle actions (Fry et al., 1991). Therefore, the maximum power is achieved at a compromised level of maximal force and velocity (González-Badillo & Serna, 2000).

During the last decade many studies have been conducted on this “field”, since power is highly related to distinct sports events like jumping or throwing. Thus, improving power output during sports performance is one of the most important goals for strength and conditioning programs (Baker, 2001). Kawamori and Haff (2004) add that to maximize power output during specific movements in sport, RT program should incorporate in a long-term strategy.

As we said in the opening paragraph, power output has been one of main issues for researches. However, two main questions still have no definitive answer. Is there a power zone for each exercise? How long should be employed a training program based on power?

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Intuitive training for power out should be performed using the load (s) at which peak power output is attained (Thomas et al., 2007). Yet, there are inconsistencies in the literature as to the precise intensity at which this occurs. Peak power generally occurs at approximately 30–80% of 1RM for lower and upper-body movements (Marques, 2004), and it is highly and positively correlated with 1RM (Marques, 2004; Newton et al., 1997). Significant correlations between 1RM and peak power (r = 0.77–0.94) have been previously reported in rugby players (Baker & Nance, 1999). Nevertheless, associations between 1RM and peak power can be changed with respect to athlete's maximum strength (Açi & Açikada, 2007). Izquierdo et al. (2002), have described significant differences in 1RM and power outputs obtained in the bench press movement at loads of 1RM among different sporting events (i.e., weightlifting, team handball, cycling, and middle-distance running). These differences in maximum strength and power outputs were explained by the interaction of long-term, sport-specific training adaptations with maximum strength (Izquierdo et al., 2002). More recently, Açi and Açikada (2007), have added more information on this theme. A total of 56 athletes (13 sprinters, 16 basketball players, 16 team handball players, 5 volleyball players, and 6 bodybuilders) performed bench press at loads of 40, 50, 60, 70, and 80% of 1RM. There were no significant differences in peak power among the participants. This means that long-term sport-specific training adaptations do not play a major role on speed-strength parameters in athletes with similar strength from different sports backgrounds.

In our opinion, some important questions remain unresolved. While it was not our intention to conduct an exhaustive analysis of this issue, we indicate some of them below:

- **Was in fact the TRUE 1RM determinate?** For example, if during the bench press exercise the average velocity during the displacement was equal or superior to $0.3 m/s^{-1}$, it means that the RM value is below the true value (González-Badillo & Serna, 2002). Thus, after the initial testing every training session should be performed with an external load lower than those previously programmed.
- **What is the best method for measuring power output?** For example**,** increasing volumes of research have focused on the load that elicits maximum power output during countermovement jump. Because of a lack of standardization for data collection and analysis protocols, much of this research has thrown up contradictory results.
- **What is the optimal load for a given athlete or type of athlete?** ….still does not have an answer….

These questions and many others can and should be addressed in an effort to provide athletes with the most efficient and effective RT program.

Rate of force development

The rate of force development (RFD) has been one of the most important variables to explain performance in activities where great acceleration is required (Aagaard et al., 2002). In most sports activities, the RFD are strongly related to performance abilities such us as the sprint, the throw, and the jump, in which force production times are reduced (between the 100 and the 300ms) (Açi & Açikada, 2007). This can be related to the fact that the greater the RFD, higher will be the power and the force generated against the same load (Fry et al., 1991; González-

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Badillo & Serna, 2002). However, the literature still tends to produce antagonistic results related to RFD measures and the relation between this parameter and jump performance. For example, several authors have observed important correlations between the isometric RFD and the vertical jump ability (Açi & Açikada, 2007), while others found opposite results on the same subject (Murphy & Wilson, 1996). Perhaps the instruments used in measurement and the fact that the force was some times measured in an isometric way and at other times in a dynamic way can explain the discrepancies. Nevertheless, Marques (2007) indicated that the CMJ height was significantly related with maximum RFD (r=0.807/0.809; time to reach the RFD_{max} (r =-0.791/-774); and the RFD at peak force (r=0.78/79).

Recently, van den Tillaar and Marques (2009), published an interesting article in order to determine whether two different throwing programs based upon velocity or resistance with the same workload would enhance soccer overhead throwing velocity. The basic principle behind this is thought to lie in the force-velocity relationship of muscles: if athletes become stronger, they should become faster at the same level of force or resistance. However, in many training studies in throwing, RT was introduced in addition to regular training and then compared with controls that did not receive any form of additional training. This shortcoming makes it difficult to identify which aspect of resistance training elicits enhanced performance: is it the training form or added training load? The aim of this study was to compare the effect of specific throwing training based upon resistance (throwing with heavy medicine balls) with training based upon velocity (throwing with a regular sized soccer balls). It was hypothesized that both groups would improve throwing velocity due to the additional training with the same workload. A substantial difference between groups would indicate the influence of the training content. To improve this characteristic, can different training programs be employed, either based on the principles of overload by resistance or by velocity of the exercise? The authors were able to observe that both groups increased throwing velocity significantly with the soccer ball (resistance-training group: 3.2%; p=0.003 and velocity-training group: 5.1%; p<0.001), while no substantial changes were found for throwing with the 5kg medicine ball after the training period. No significant differences between the groups were found, which indicates that both forms of training increased the throwing velocity.

Briefly, the literature presents important knowledge concerning determinant factors to explain performance in activities with acceleration. But perhaps more noticeable were the highly predictive value of the RFD_{max}., as well as the time required to reach RFD_{max}.. in jumping activities.

Nevertheless, is difficult to compare the results of earlier studies that have investigated this subject because of methodological differences, including the method of measurement, training experience, and lack of controlled workload.

Are the Periodization Models of major importance?

Periodization can be defined as a planned distribution of specific variations introduced into training methods programs at regular time intervals (Plisk & Stone, 2003) in order to optimize

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gains in strength, power, muscular hypertrophy, and motor skills, while at the same time minimizing the risks of overtraining (Fleck & Kraemer, 1997).

Two broad models of periodization have been proposed: linear and nonlinear (Rhea et al., 2003). However, in practice, the distinction is not absolute. Periodization by its very nature is non-linear. 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 (Zatsiorsky, 1995; González-Badillo & Serna, 2002; Rhea et al., 2003).

The nonlinear or "undulating" model is also characterized, among other variables, by daily or microcycle (weekly) variations (Plisk & Stone, 2003). These variations attempt to prevent overtraining 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 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 athletes would be required to determine such a benefit.

According to Gamble (2007), this information can lead to much confusion as to which method is superior. Each model has its strong proponents and detractors as well positive and negative research findings. The answer to which periodization model is best might be found in the motor learning and control research literature (Gamble, 2007). Perhaps a development of a non-rigid model of periodization consisting of both linear and non-linear organization, based on the RT experience, training phase, and physical capacity needs is the answer.

Some evidence for the benefit of the combined use of distinct periodization models was observed in the superior strength gains during initial stages of training in strength trained subjects with a daily undulating periodized (DUP) model, in comparison to a linear periodization group (Gamble, 2007). This was results could be explained to the novelty of the DUP scheme for the subjects, whose previous RT had been characterized by classical linear periodization. This is not to say that the DUP approach in the above example can be concluded to be superior. What the findings of Rhea et al. (2003), illustrate is that continuing reliance upon a unique periodization method may produce attenuated strength gains. This is particularly likely to be the case for elite players, who will have a far more RT background history.

Hence, the best approach would appear to be to strategically combine periodization models Periods in the off-season and the pre-season without competitive games will undoubtedly allow different approaches to periodized training from that normally conducive to adequate recovery when matches are scheduled.

To resume, the degree of training variation required appears to be specific to the training experience of the individual. More basic periodization schemes are sufficient for younger

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players, who do not require or benefit from the same multi-layered variation employed with senior athletes (Gamble, 2007).

REFERENCES

1. AAGAARD P, SIMOSEN EB, ANDERSON JL, MAGNUSSON P, DYHRE-POULSEN P. Increased rate of force development and neural drive of human skeletal muscle following resistance training. *J. Appl. Physiol*. 2002; 93:1318-1326. [Full text] [Back to text]
2. AÇI A, AÇIKADA C. Power production among different sports with similar maximum strength. *J. Strength Cond. Res*. 2007; 21(1):10-16. [Abstract] [Back to text]
3. ALÉN M, HÄKKINEN K, KOMI PV. Changes in neuromuscular performance and muscle fiber characteristics of elite power athletes self-administering androgenic and anabolic steroids. *Acta Physiol. Scand.* 1984; 122:535-44. [Abstract] [Back to text]
4. AMERICAN COLLEGE OF SPORT MEDICINE. Position Stand. Progression models in resistance training for healthy adults. *Med. Sci. Sport Exerc.* 2002; 34:364–380. [Full text] [Back to text]
5. BAKER D, & NANCE S. The relation between strength and power in professional rugby league players. *J. Strength Cond. Res.* 1999; 13:224-229. [Abstract] [Back to text]
6. BAKER D. Acute and long-term power response to power training: Observations on the training of an elite power athlete. *Strength Cond. J.* 2001; 23:(1)47-56. [Full text] [Back to text]
7. FLECK SJ, & KRAEMER WJ. *Designing resistance-training programs*. Champaign, Illinois. Human Kinetics Books 1997. [Full text] [Back to text]
8. FLECK SJ, SMITH SL, CRAIB MW, DENAHAN T, SNOW RE, MITCHELL MR. Upper Extremity Isokinetic torque and Throwing Velocity in Team Handball. *Journal of Applied Sport Science Research*. 1992; 6:120-124. [Abstract] [Back to text]
9. FRY AC, KRAEMER WJ, WASEMAN CA, CONROY BP, GORDON SE, HOFFMAN JR, MARESH CM. The Effects of an Off-season Strength and Conditioning Program on Starters and Non-starters in Women's Intercollegiate Volleyball. *J. Appl. Sport. Sci Res.* 1991; 5(4):174-181. [Abstract] [Back to text]
10. GAMBLE P. Periodization of Training for Team Sports Athletes. *Strength Cond. J.* 2007; 28(5):56-66. [Abstract] [Back to text]
11. GONZÁLEZ-BADILLO JJ, & SERNA JR. *Programación del entrenamiento de la fuerza*. Barcelona. Inde, 2002. [Abstract] [Back to text]
12. GONZÁLEZ-BADILLO JJ, GOROSTIAGA EM, ARELLANO R, IZQUIERDO M. Moderate resistance training volume produces more favourable strength gains than high or low volumes during a short-term training cycle. *J. Strength Cond. Res*. 2005; 19(3):689-697. [Full text] [Back to text]
13. GONZÁLEZ-BADILLO JJ, IZQUIERDO M, GOROSTIAGA EM. Moderate volume of high relative training intensity produces greater strength gains compared with low and high volumes in competitive weightlifters. *J Strength Cond Res.* 2006; 20(1):73-81. [Full text] [Back to text]
14. GOROSTIAGA EM, GRANADOS C, IBANEZ J, IZQUIERDO M. Differences in physical fitness and throwing velocity among elite and amateur male handball players. *Int J Sports Med*. 2005; 26:225-232. [Full text] [Back to text]

 ISSN 1988-5202

15. HOPKINS WG. Measures of reliability in sports medicine and science. *Sports Med*. 2000; 30:1-15. [Abstract] [Back to text]
16. IZQUIERDO M, HÄKKINEN K, GONZALEZ-BADILLO JJ, IBANEZ J, GOROSTIAGA EM. Effects of long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports. *Eur. J. Appl. Physiol.* 2002; 87:264-271. [Abstract] [Back to text]
17. KAWAMORI N, & HAFF GG. The optimal training load for the development of muscular power. *J. Strength Cond. Res*. 2004; 18(3):675-684. [Abstract] [Back to text]
18. KRAEMER WJ. The body of knowledge: use and professionalism. *Strength Cond. J.* 2005; J. 27(1):33-35. [Abstract] [Back to text]
19. MARQUES MC, & GONZÁLEZ-BADILLO JJ. In-season resistance training and detraining in professional team handball players. *J. Strength Cond. Res*. 2004; 20(3):563-571. [Abstract] [Back to text]
20. MARQUES MC, GONZÁLEZ-BADILLO JJ, KLUKA D. In-season strength training male professional volleyball athletes. *Strength Cond. J.* 2006; 28(6):2-12. [Abstract] [Back to text]
21. MARQUES MC, VAN DEN TILLAAR R, GABBETT TJ, MACHADO-REIS V, & GONZÁLEZ-BADILLO JJ. Physical fitness qualities of professional volleyball players: determination of positional differences. *J Strength Cond Res*. 2009; 23(4):1106-11. [Abstract] [Back to text]
22. MARQUES MC, VAN DEN TILLAAR R, VESCOVI JD, GONZÁLEZ-BADILLO JJ. Changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. *J Strength Cond Res*. 2008; 22(4):1147-55. [Abstract] [Back to text]
23. MARQUES MC. O *Treino de Força no Alto Rendimento*. Da Teoria à Prática. Livros Horizonte, 2004. [Back to text]
24. MARQUES MC. *Relación entre los valores de fuerza y su entrenamiento con la velocidad en lanzamientos, desplazamientos y saltos*. Ph.D. diss., Dept. Deportes e Informática. Universidad Pablo de Olavide. Sevilla, Spain, 2007. [Back to text]
25. MATAVUJ D, KUKOLJ M, UGARKOVIC D, TIHANYI J, JARIC S. Effects of plyometric training on jumping performance in junior basketball players. *J. Sports Med. Phys Fitness*. 2001; 41:149-164. [Abstract] [Back to text]
26. MURPHY AJ, WILSON GJ. Poor correlations between isometric tests and dynamic performance: relationship to muscle activation. *Eur. J. Appl. Physiol*. 1996; 73:353-357. [Abstract] [Back to text]
27. NEWTON RU, & MCEVOY P. Baseball throwing velocity: a comparison of medicine ball training and weight training. *J. Strength Cond. Res.* 1994; 8(3):198-203. [Abstract] [Back to text]
28. NEWTON RU, MURPHY AJ, HUMPHRIES BJ, WILSON GJ, KRAEMER WJ, HÄKKINEN K. Influence of load and stretch shortening cycle on the kinematics, kinetics, and muscle activation that occurs during explosive upper-body movements. *Eur. J. Appl. Physiol. Occup. Physiol.* 1997; 75:333-342. [Abstract] [Back to text]
29. PLISK SA, & STONE MH. Periodization Strategies. *Strength Cond. J.* 2003; 25(6):19-36. [Abstract] [Back to text]

 ISSN 1988-5202

30. RHEA MR, ALVAR BA, BURKETT LN, & BALL SD. A meta-analysis to determine the dose response for strength development. *Med Sci. Sports Exerc*. 2003; 35:456-464. [Abstract] [Back to text]
31. RHEA MR, BALL S, PHILLIPS W, & BURKETT L. A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *J. Strength Cond. Res*. 2003; 16(2):250-255. [Abstract] [Back to text]
32. SANBORN K, BOROS R, HRUBY J, SCHILLING B, O'BRYANT HS, JOHNSON RL, STONE MH. Short-term performance effects of weight training with single sets to failure versus multiple sets not to failure in women. *J. Strength Cond. Res*. 2000; 14(3):328-331. [Abstract] [Back to text]
33. THOMAS GA, KRAEMER WJ, SPIERING BA, VOLEK JS, ANDERSON JM, MARESH CM. Maximal power at difference percentages of one repetition maximum: Influence of resistance and gender. *J. Strength Cond. Res*. 2007; 21(2):336-342. [Abstract] [Back to text]
34. TIDOW G. Aspects of strength training in athletics. *New Studies in Athletics*. 1990; 1:93-110. [Back to text]
35. VAN DEN TILLAAR R, & ETTEMA G. Effect of body size and gender in overarm throwing performance. *Eur J Appl Physiol*. 2004; 91:413-418. [Abstract] [Back to text]
36. VAN DEN TILLAAR R, MARQUES MC. Effect of two different training programs with the same workload on soccer overhead throwing velocity. *Int J. Sport Physiol Perfor*. 2009; 4(4):474-84. [Abstract] [Back to text]
37. VIRU A. About training loads. *Modern Athlete Coach*. 1993; 31:32-36. [Back to text]
38. WILSON GJ, LYTTLE AD, OSTROWSKI KJ, & MURPHY AJ. Assessing dynamic performance: a comparison of rate of force development tests. *J. Strength Cond. Res*. 1995; 9(3):176-181. [Abstract] [Back to text]
39. ZATSIORSKY VM. *Science and Practice of Strength Training*. Champaign, Illinois: Human Kinetics Books. 1995. [Back to text]