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Original Article

Strength in power sports: the latest scientific results.

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Abstract
Problem Statement: During the last decades, 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 elite athletes. Several studies showed 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. To our best knowledge, however, there is no apparent consensus on the appropriate method of strength and muscular power training to enhance performance, especially in typically power sports. On this, some questions remain unresolved and there have focused objective of our study: *How much strength does an athlete need? Is the maximum strength the key for success? Is the muscular power the main issue?*
Approach: Therefore, the aim of this study focuses on a literature scientific search extended about strength in power sports specifically.
Results: Studies in this area continue to contradict because they differ markedly in terms of design factors, including mode, frequency, intensity, frequency of training, and training history of subjects. **Conclusions/Recommendations:** We can conclude that once a given level of strength training intensity has been reached in trained athletes, the appropriate physiological adaptations may well be optimized and that training beyond this limit provides no further benefits.
Keywords: Moderate-volume, training intensity, coaches, training programs, dynamic performance.

Introduction

Strength and power training has been a major issue for researchers and coaches for decades [1]. Unfortunately, despite the increasing volume of studies, there is little research data concerning strength performance in trained athletes [8]. Two major reasons for this may be suggested. Several strength coaches adopt traditional methodologies in resistance training (RT) programs. Further, experimental well design studies in trained participants are very difficult to be attainable [3]. Yet such considerations ought not to detract from the necessity and importance of this type of research in strength and power modalities. Many studies demonstrated that RT can improve athletes' maximal strength and muscular power, as well as reduce the incidence of injury, and contribute to faster injury recovery periods, thereby minimizing the number of missed practice sessions and/or competitions [4,5,6]. Nevertheless, there is no apparent consensus on the appropriate method of RT to enhance strength performance.
Thus, this paper aims to discuss three practical questions: ***How much strength does an athlete need? Is the maximum strength the key for success? Is the muscular power the main issue?***

How much strength does an athlete need?

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 sports scientists [7, 8, 9]. Several experiments claimed that one set per exercise or 3 sets can be equally efficient in strength enhancement whereas other studies have reported that only RT with multiple sets contributed to better results [10, 12]. For example, less experienced subjects can respond favourably to one or more sets per exercise, especially during the initial training weeks. In contrast, experienced RT subjects can only increase strength values by performing more repetitions. More recently, Marques et al. [11] demonstrated 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. In addition, 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

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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. This strategy requires that each repetition must be performed at relatively high velocity, on the assumption that greater gains in power output will be achieved with each repetition. In fact, increasing training volume does not guarantee a better stimulus for improving adaptations during a long-term in-season period [9]. Marques and González-Badillo [2] founded that a short-term RT (12 consecutive weeks) using moderate relative intensity tended to produce significant enhancements in elite team handball players in squat and concentric bench press strength. High intensity RT is seen to result principally in neural adaptations, whereas high volumes of strength training tend to enhance hypertrophic responses [6]. Here, however, there is much debate around 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 maximize neural and morphological adaptations [4]. Recently, Marques and colleagues published two articles [2, 13] concerning changes in strength and power performance in elite senior professional female and male players observed during the in-season. Concerning female top athletes, the in-season RT program progressed from moderate/low-intensity exercise to moderate-volume/medium-high-intensity exercise with constant micro cycle variations. In brief, this experiment showed that elite female volleyball players could increase maximal strength performance using medium/high intensity exercises. Training intensity per week was given as a % of RM. In addition, the RT program express 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. This procedure simultaneously prevents the early onset of muscular and nervous overstrain, and any damaging increase of muscular mass in volleyball players [13]. A short-term RT using moderate relative intensity tended to produce significant enhancements in elite player performance in maximal strength [2, 4, 13].
In resume, 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. Yet, further research is required to investigate the precise mechanisms that underlie the observed impairments in training adaptation during the in-season in elite athletes.

Is the maximum strength the key for success?

Stronger athletes can perform better than those which are not so strong or powerful [16]. Although this statement does not assure a evidence of a cause-effect relationship [14], we suggest that cause-effect is certainly possible. When examining the relationship between maximal strength and specific performance, the majority of studies have not provided conclusive results with some researches reporting a relationship [15, 16] and others failing to observe a association [17, 18]. On this, for example, van den Tillaar and Ettema [17] observed a poor correlation between isometric hand grip strength and ball throwing velocity in a group of female team handball players (r=0.49; p=0.027) as well as for male team handball players (r=0.43; p=0.056). On the other hand, Fleck et al. [19] showed better 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 team handball players. Recently, Marques and González-Badillo [2] observed no relationship between throwing velocity and 1RM in male professional handball players. Moreover, Marques et al. [13] observed significant increases in squat performance following a 12-week RT intervention. However, changes in squat strength failed to produce an association with the vertical jump ability, indicating that, although biomechanically similar, these tests assess are independent of motor qualities. Alén et al. [20] 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. Baker and Nance [21] found poor correlations between maximum strength values (squat and hang clean) and sprint times over 10 and 40m; however, when strength values were normalised by dividing the absolute measures by body mass, better correlations were reported. The hang clean was better correlated to sprint performance than the squat. Baker and Nance [21] also demonstrated 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.

In brief, these experiments have shown that making changes in well trained athletes is more difficult and requires more advanced RT programmes.

Is the muscular power the main issue?

Many sports involve movements that require generation of force over a very short period of time [23, 24]. Such movements include tasks as throwing, jumping, or change of direction [5]. 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 [5].

Therefore, the maximum power is achieved at a compromised level of maximal force and velocity [15]. Improving power output during sports performance is one of the most important goals for strength and conditioning programs [22, 25]. Kawamori and Haff [24] stated that to maximize power output during specific movements in sport, RT program should be incorporated in a long-term strategy. Intuitive training for power out should be performed using the load(s) at which peak power output is attained [26, 28]. Although, there are controversies in the scientific community 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 [1], and it is highly and positively correlated with 1RM [1,27]. Significant correlations between 1RM and peak power (r = 0.77–0.94) have been previously reported in rugby players [21]. Nevertheless, associations between 1RM and peak power can be changed with respect to athlete's maximum strength [28]. Izquierdo et al. [29] have described significant differences in 1RM and power outputs obtained in the bench press movement at loads of 1RM among different sport events (e.g., 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 [29].
We think that some important issues remain unresolved. While it was not our intention to conduct an exhaustive analysis of this issue, we indicate some of them below:

- What is the best method for measuring power output?
- What is the optimal load for a given athlete or type of athlete?

Conclusions/Recommendations

We can assume that high level team sports players can increase RM using moderate volume and medium to high intensity. Once a given level of strength training intensity has been reached in trained athletes, the appropriate physiological adaptations may well be optimized and that training beyond this limit provides no further benefits. The present data suggest that for health and safety reasons, increasing training volume does not always provide a better stimulus for improving adaptations during a short-term training period. Because the majority of power events sports demand a balance between strength, power, and endurance, it would seems important to maintain these resources during the entire season.

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