
Evidence-Based Strength Training: Best Practices for Enhancing Athletic Performance

Cao Yulin¹, Li Jingwen²

Abstract

Physical training forms the foundation of sports training, with strength training being its most critical and essential component. Strength training enhances athletic performance by improving power, endurance, and physical capability. Despite its importance, the methods and parameters for optimizing strength training remain a subject of continuous study and debate among researchers and practitioners. This study addresses this gap by reviewing and analyzing current international research on the best practices for strength training. Specifically, it focuses on identifying the most effective forms of training, optimal intensities, volumes, and frequencies for achieving peak athletic performance. The methodology includes a comprehensive literature review of peer-reviewed journals, meta-analyses, and experimental studies on strength training. The research synthesizes findings to identify patterns and recommendations that can be tailored to the specific needs of Chinese athletes. The analysis reveals that strength training effectiveness depends on individual athlete characteristics, such as age, sport specialization, and training experience. Key findings suggest that high-intensity, low-volume training benefits explosive power sports, while moderate-intensity, high-volume regimens are better suited for endurance-focused disciplines. Training frequency, periodization, and recovery protocols also emerge as crucial factors influencing outcomes. Based on these findings, the study recommends that coaches and sports scientists in China adopt a personalized approach to designing strength training programs. This includes integrating evidence-based practices with Chinese athletes' unique physiological and cultural contexts to maximize training efficacy. Future research should explore long-term adaptations and sport-specific applications to refine these strategies further.

Keywords: *Strength Training Optimization, Athletic Performance Enhancement, Training Intensity and Volume, Evidence-Based Sports Training, Chinese Athlete Development.*

A. Introduction

Strength quality, defined as the capability of the human neuromuscular system to overcome or resist force during physical exertion, is a fundamental component of athletic performance (Bompa & Buzzichelli, 2019). It enables athletes to execute technical movements effectively, improving their speed, endurance, and physical capabilities. High levels of strength are crucial for achieving peak performance, as they form the basis for other physical attributes such as power, agility, and stamina (Suchomel et al., 2016). In countries with advanced sports sciences like the United States, strength training is the core of physical conditioning, emphasizing fast and explosive strength to optimize athletic outcomes (Rønnestad & Mujika, 2014). These methods have become integral to training systems, driven by extensive research that supports their effectiveness in improving athletic performance across various disciplines. In contrast,

¹Southwest University, China. 13399805551@163.com

²Southwest University, China

developing strength training methodologies in China face notable challenges. Despite the growing recognition of its importance in enhancing athletic performance, research on strength training within the country remains sparse, and the existing body of literature is insufficient to inform evidence-based practices (Zhou & Li, 2020). This gap in research limits the ability of Chinese athletes and coaches to benefit from advances in strength training science fully. Additionally, systematic frameworks are lacking for integrating strength training into broader athletic development programs tailored to Chinese athletes' unique cultural and physiological characteristics. Addressing these limitations through comprehensive research and adopting international best practices is essential for improving the effectiveness of strength training in China and fostering the next generation of high-performance athletes.

Globally, strength training has been widely recognized as a cornerstone of athletic performance and overall physical fitness, with extensive research conducted in regions possessing advanced sports science infrastructures. Studies consistently highlight its critical role in enhancing key performance attributes such as explosive power, agility, and endurance, essential for success in competitive sports (Suchomel et al., 2016; Rønnestad & Mujika, 2014). Beyond athletic performance, strength-based physical fitness has also been strongly correlated with improved health outcomes, including enhanced quality of life and increased longevity, particularly in aging populations (Garber et al., 2011). These findings have informed evidence-based training methodologies, emphasizing the importance of individualized programs, periodization strategies, and recovery protocols to optimize results. However, such practices are often region-specific, reflecting the distinct cultural, physiological, and infrastructural factors of the populations they serve. In the Chinese context, the application of strength training principles has seen a rise in popularity, yet the field remains underdeveloped compared to Western countries. Zhou and Li (2020) observed that while the demand for strength training programs has grown among Chinese athletes and fitness enthusiasts, these programs frequently lack scientific rigor and personalization in international practices. This gap may stem from limited research efforts, insufficient collaboration with global experts, and a lack of localized guidelines tailored to the unique needs of Chinese athletes. Addressing this disparity requires a comprehensive review and adaptation of global best practices, integrating cultural and physiological considerations to ensure effective and sustainable strength training strategies for China's diverse athletic population.

The primary objective of this study is to systematically review and summarize existing international research on strength training, focusing on its key factors, including optimal forms, intensities, volumes, and frequencies. The study aims to offer a scientific foundation for strength training practices in China by analyzing and synthesizing these findings. Furthermore, the research seeks to highlight gaps in the current body of knowledge and propose future directions for domestic strength training research. The ultimate goal is to provide evidence-based recommendations to guide the development of effective, personalized, and culturally relevant strength training programs for Chinese athletes.

Strength training is not merely an athletic requirement but a vital component of overall health and well-being. While advancements in science and technology have reduced the physical demands of daily life, the importance of strength-based fitness in maintaining health and longevity has not diminished (Garber et al., 2011). Developing strength for elite athletes or the general population necessitates a scientific, systematic, and planned approach (Bompa & Buzzichelli, 2019). Given the limited research in China on this critical subject, there is an urgent need to bridge the gap between international practices and domestic applications. By leveraging global insights and adapting them to the Chinese context, this study argues that it is possible to advance the science of strength training in China, fostering better athletic performance and contributing to public health improvements.

B. Methods

1. Research Design

This study utilized a systematic review and meta-analysis design to examine the relationship between the frequency of resistance training (RT) and strength outcomes. The systematic review ensured a comprehensive synthesis of existing English-language research, while the meta-analysis provided quantitative evaluations using a random-effects model to account for variability across studies. This dual approach allowed for the integration of diverse findings into meaningful conclusions while accommodating differences in study methodologies and populations. The research aimed to explore training frequency as a key variable, alongside other potential moderators such as training volume, exercise selection, and participant demographics, to provide actionable insights into optimal strength training practices.

2. Research Procedure

The study began with an extensive literature search across three significant databases: PubMed/MEDLINE, Scopus, and SPORTDiscus. Using carefully selected keywords such as "strength training," "training frequency," "muscle strength," and "resistance training outcomes," the study aimed to identify a comprehensive pool of relevant research. Titles, abstracts, and keywords were reviewed to gather a wide range of potentially applicable studies. Screening and eligibility criteria were then systematically applied to ensure that only peer-reviewed studies focusing on healthy adults and examining the effects of training frequency on strength improvements were included. Studies involving clinical populations, non-English publications, or incomplete and irrelevant datasets were excluded to maintain the study's focus and relevance.

After identifying eligible studies, data extraction was performed systematically to gather key information critical to the study's objectives. Details were collected on participant demographics, such as age, sex, and training experience, as well as on training protocols, including frequency, intensity, and types of exercises. Primary outcomes such as one-repetition maximum (1RM), training volume, and observed strength changes were also extracted. This structured approach allowed the study to compile a robust dataset for further analysis. Subgroup analyses were planned to explore variables such as upper and lower body strength adaptations, the role of training to muscular failure, and differences in outcomes based on age and sex. These methodological steps ensured the study's ability to comprehensively evaluate the impact of training frequency and its interaction with other factors on strength improvements.

3. Data Collection Techniques

Data were systematically extracted and categorized based on key moderators. These included training volume (total workload per session), exercise selection (multi-joint vs. single-joint exercises), upper and lower body strength gains, and whether the training involved muscular failure. Additionally, participant-specific factors such as age and sex were considered by stratifying analyses for young adults versus middle-aged/older adults and men versus women. This structured approach ensured a comprehensive understanding of how training frequency interacts with other variables to influence strength outcomes.

4. Data Analysis Techniques

The meta-analysis employed a random-effects model to compute pooled effect sizes and confidence intervals, accommodating heterogeneity across studies. Training frequency was categorized into 1, 2, 3, or 4+ sessions per week, but when data for subgroup analyses were limited, the categories were adjusted to 1, 2, or 3 times weekly. Sensitivity analyses were conducted to verify the robustness of the findings. The methodological quality of the included studies was assessed using the modified Downs and Black checklist, which evaluates aspects

such as reporting clarity, internal validity, and bias. The results were synthesized to provide evidence-based conclusions and practical recommendations for optimizing resistance training practices, particularly for populations with limited research, such as in China.

C. Findings and Discussion

1. The Best Form of Strength Training

The specific means of strength training are wealthy, and the commonly used means include resistance training, antagonistic training, elastic band training, self-weight training, electric stimulation strength training, vibrator training, and so on. The traditional strength training methods are mainly free weight resistance training, and the selected movements are mostly barbell compound movements, such as squat, bench press, hard pull, push, high somerset, etc. These movements are considered the best for training essential strength because they mobilize many muscles and joints to participate in the movement, producing the most excellent stimulation of the body. These barbell movements can continuously increase or decrease the training weight within a reasonably flexible range to achieve ultra-progressive load. In addition, these movements cover the basic movement mode of the human body, "squat," "push," and "pull," and the strength acquired by their development is transformed. It can be well transferred to unique sports to achieve the purpose of improving athletic ability.

With the progress of The Times and the development of scientific and technological means, many new strength Training methods have been proposed or invented and applied to training practice, such as Plyometric Training, Electric Muscle Stimulation training, etc. So, what training techniques are most effective for developing strength? Are new training methods better than traditional strength training methods? Suchomel et al. (2018) analyzed the potential physiological characteristics and training considerations affecting muscle strength through the literature review method. They concluded that bilateral training, centrifuge training, centrifuge ultra-constant load training, and variable resistance training could produce the most significant comprehensive strength adaptation. Body weight training, isolation exercises, plyometrics, unilateral training, and kettlebell training may have limited potential to increase maximum strength, but developing a person's ability to express strength for short periods and different types of movement needs Still contributes to strength development (Suchomel et al., 2018).

In an analysis of 10 studies on Electric Muscle Stimulation, Mukherjee et al. (2023) found that all 10 studies reported a significant increase in strength after EMS treatment but no improvement in some measures of functional outcomes related to strength. Moreover, due to methodical differences between studies and inconsistent EMS application methods, the optimal thresholds for duration, EMS intensity, pulse, and frequency cannot be determined (Mukherjee et al., 2023). So it can be seen that electrical muscle stimulation training does bring strength gains, but is it more advantageous than traditional training? A systematic review study by Happ et al. (2022) showed that when the two training amounts are matched, the strength gain of electrical muscle stimulation training is nearly the same as that of traditional strength training (Happ & Behringer, 2022). Compared with electrical muscle stimulation training, traditional resistance strength training is no less effective than the new training, and compared with other new training methods, traditional training is even more effective in some aspects. Kaabi et al. (2022) conducted a study to compare the effects of comprehensive weight-lifting resistance Training and Plyometric Training on the physical performance of elite young table tennis players in 8 weeks. Includes a 5-meter sprint time test, a 20-meter "T" track steering test, standing broad jump, squat jump and squat bar, suspension, bench press, and back squat one repeat maximum power test. It was found that combined with all tests, the weight training group had a greater degree of improvement (12.6 vs. 8.2%) and effect size (1.88 vs. 1.22) than the plyometric training group. Therefore, comprehensive weight training appears to be more effective than

plyometrics alone in improving neuromuscular performance in table tennis players, especially for table tennis sport-specific steering tests such as the 20-meter steering test (Kaabi et al., 2022). Loturco et al. (2022) study on pre-season training of football players found that squats and half squats wearing elastic bands performed in a short period, such as two weeks, are more conducive to accelerating the growth of strength than ordinary squats and half squats (Loturco et al., 2022).

Strength training can also be divided into centripetal, centrifugal, and isometric training, using the three forms of muscle contractions. Although some studies suggest that centrifugal training can lead to more muscle fiber tears to promote muscle enlargement and is more beneficial to strength growth, in practice, there is a group of people who rarely or never do centrifugal training. However, this is a very strong weightlifter. Due to the unique characteristics of snatch and clean and jerk, centrifugal contraction is almost impossible in the special training of weightlifters, and their general physical training is mainly in the form of centripetal contraction of auxiliary movements. However, the weightlifters' squat and hard pull power levels are very high, considering the three major items as a measure of strength level. Even if the bench press is not practiced, it can reach a very high level after learning technical movements. The academic community has not agreed on whether centripetal or centrifugal training is more conducive to strength and muscle growth. Glenn Pendlay, a famous American weightlifting coach, once stressed that only high-weight explosive training in centripetal movement can maximize the muscle and strength growth of the athlete. A systematic review and meta-analysis by Schoenfeld et al. (2017) compared the muscle-building effects of centripetal and centrifugal training on healthy adults after strict resistance training. The results showed that the effect size of centripetal training was more significant than that of centrifugal training. However, statistical significance was not reached (Schoenfeld et al., 2017). Thus, centrifugal training is slightly better than centripetal training in muscle hypertrophy, but the difference is not great. A study by Unlu et al. (2020) compared the effects of centripetal, centrifugal, and centrifugal-centripetal isotonic resistance training at fast and slow speeds to determine whether contraction styles affect muscle and strength gain. It concluded that all training styles will likely increase isotonic strength in the knee extensor muscles. There is insufficient evidence to prove that any particular pattern or speed of muscle contraction is most advantageous (Unlu et al., 2020). In addition to centripetal and centrifugal training, isometric contraction training can promote strength growth. Lum et al. (2023) conducted a study on inline ice hockey players. The experimental group replaced two sets of regular squats in each training session with iso-length contraction squats over 24 weeks, while the control group remained unchanged. The results showed that the experimental group had a more significant improvement in sprint performance than the control group (Lum et al., 2023).

Therefore, it can be believed that all kinds of strength training methods will likely improve strength. Some new training methods have been proven to be effective, but traditional resistance training still has an irreplaceable important role; whether it is centripetal training, centrifugal training, or isometric training, as long as it is appropriately used, it can promote the development of strength under certain conditions.

2. The Intensity of the Training

Load in resistance training is considered a key variable in neuromuscular adaptation. How much load intensity should be used to achieve the best muscle-building effect? This question has been a hot topic. Lacio et al. (2021) systematically reviewed the literature. They compared the effects of low -, moderate -, and high-intensity resistance training on the development of maximum strength and muscle hypertrophy in untrained and trained, healthy adult men in randomized trial designs, with the leading results showing that The amount of strength used in resistance training affects the increase of isotonic and isometric muscle strength. In general, when using medium and high intensity, the gain of maximum muscle strength is higher. In

contrast, when it comes to muscle hypertrophy, most studies show that when resistance training is performed in a state of muscle exhaustion, the intensity used has less of an effect on muscle hypertrophy. The current literature suggests that for healthy adult male populations, the increase in maximum strength is more pronounced at high and moderate intensity. However, for muscle hypertrophy, studies have shown that a broad range of intensities, i.e., 30% to 90% of 1RM, can be used in a healthy adult male population (Lacio et al., 2021). In an experiment conducted by Schoenfeld et al. (2015), subjects were divided into two groups: the low-intensity resistance training group, which repeated each exercise 25-35 times (about 30-50%1RM) until exhaustion; In the high-intensity resistance training group, each exercise was repeated 8-12 times (about 70-80%1RM), and the results showed that compared with the low-intensity group, the subjects in the high-intensity group had significantly more significant improvement in squat strength. The maximum number of reps in bench press 1 (1RM) had a greater tendency to increase (Schoenfeld et al., 2015). In a subsequent systematic review, Schoenfeld et al. (2017) again demonstrated that the most significant power gains are obtained from relatively heavy loads. Muscle hypertrophy can also be achieved in a relatively variable load range (Schoenfeld et al., 2017). These findings are consistent with daily training experience. It is generally believed that the best way to develop maximum strength is first to train the intermuscular coordination factors that increase strength (2 to 6 repetitions at an intensity of 70% to 80% of 1RM) and then train the intramural factors of strength (1 to 3 repetitions at an intensity of 80% to 90% of 1RM).

3. Training capacity and training frequency

Strength training should also consider training capacity. Many strength trainers like to perform high-volume training. Schoenfeld et al. (2019) found that muscle hypertrophy follows the dose-response relationship, and with the increase in training amount, the gain becomes larger and larger. While the increase in muscle strength was surprisingly similar across conditions, the study showed that one set of exercises may be as effective at increasing muscle strength as three or five sets at a time. However, in practical experience, it seems that too few training groups or too many training groups can not achieve the best strength growth effect, and there may be an optimal range of the optimal training capacity groups for strength training (SCHOENFELD et al., 2019). A recent study by Aube et al. (2022) confirmed this by examining the effects of three different resistance training volumes (12, 18, and 24) on lower body muscle thickening and strength in trained men, demonstrating that 18 sets were more effective at increasing maximum muscle strength than 12 and 24 sets. This suggests that the amount of training and the physiological adaptation induced by resistance training seem to follow an inverted 'U' pattern (Aube et al., 2022).

In strength training, training frequency is also a factor to consider. Generally, three to five times a week is more appropriate. However, recent studies have shown that different training frequencies produce the same muscle strength adaptation effect if the total training capacity is the same. Hamarsland et al. (2022) compared the effects of training frequency with the same volume on muscle mass and strength gain. Participants were randomly divided into a moderate training frequency group and a high training frequency group to complete 9 weeks of whole-body progressive intensifying resistance training intervention, and it was found that under moderate load, the total amount of resistance training per week was allocated to two or four training sessions. There were no different effects on maximum strength and muscle hypertrophy (Hamarsland et al., 2022). A meta-analysis by Ralston et al. (2018) found that the available data did not provide a strong correlation between increasing weekly training frequency and maximum strength gain among mixed populations. In other words, training frequency does not significantly affect muscle strength gain when the total resistance training capacity is equal in multi-joint composite and isolated movements. More investigations are needed to fully explore the effects of different weekly training frequencies (Ralston et al., 2018). So, can increasing training frequency and increasing training volume provide more muscle strength gains for people of

different ages and genders? The results of a systematic review and meta-analysis by Grgic et al. (2018) suggest that the frequency of resistance training has a significant effect, with higher training frequency translating into an increase in greater muscle strength. However, these effects appear to be primarily driven by training volume, as training frequency has no significant effect on the increase in muscle strength when the volume is the same. Therefore, from a practical point of view, more significant training frequencies can be used to add additional training capacity to promote muscle strength growth. However, it is not clear whether training frequency itself has a significant effect on strength gain. Higher training frequency seems to lead to greater muscle strength in the upper body and women during multi-joint exercise. Younger people respond better to a higher training frequency than older people. Since most current studies have been conducted with untrained participants, more evidence is needed on individuals who have participated in training (Grgic et al., 2018).

In general, resistance training capacity positively correlates with muscle gain and strength gain within a specific range. When the adequate total training amount is the same, the change in training frequency does not have much influence on the training effect.

4. The effects of training on exhaustion

Exhaustion refers to the exhaustion of muscle energy and material during training, and can no longer continue to work to complete the training activities. Although studies have shown that exhaustion training benefits muscle building, there is still some debate about whether to achieve exhaustion during strength training. Grgic et al. (2022) analyzed 15 relevant studies and concluded that increasing strength and muscle size does not require training to exhaustion. However, although non-exhaustion training is more beneficial to strength growth, exhaustion training mode does not seem to harm muscle strength adaptability. More studies should be conducted in older adults and highly trained individuals to enhance the generalizability of these findings (Grgic et al., 2022). Lasevicius et al. (2022) found that muscle exhaustion promoted more significant muscle hypertrophy in low-load resistance training but not in high-load resistance training. When doing low-load training, the intensity of the training seems more important than the total amount of training in increasing muscle mass. In contrast, muscle exhaustion does not provide any additional benefit for high-load training. Consistent with previous studies, the increase in muscle strength was more pronounced than the effect of muscle hypertrophy when heavier loads were used (Lasevicius et al., 2022). Davies et al. (2016) conducted a systematic review and meta-analysis of the effects of exhaustive and non-exhaustive training on muscle strength. The results showed that although non-exhaustive training had a statistically significant effect on muscle strength compared with exhaustive training, a slight percentage improvement shown is unlikely to be meaningful (Davies et al., 2016). Therefore, we believe similar muscle strength enhancement can be achieved through exhaustive and non-exhaustive training. To achieve the effect of muscle and strength enhancement through exhaustive training, attention should be paid to maintaining a high training intensity. In addition, there seems to be no need for exhaustive training to maximize muscle strength. However, if exhaustive training is to be included in the program, it should be left as much room as possible to avoid the risk of injury and overtraining.

5. Impact of variation training

Due to the body's adaptive resistance and diminishing marginal effect, any type of training will train the phenomenon of reduced effectiveness after some time. At this time, by changing the movement of training, group times, interval time, etc., will play a new stimulus. However, this change should not be made too frequently and randomly, but at least after 4 weeks of a training program to allow the body to adjust. Training methods that produce high levels of soreness as an inherent feature of the program can lead to long-term systemic severity because arbitrary selection of training content prevents the trainer from adapting to stimuli, which can

undermine the trainer's fitness rather than bring about health and strength. In a 9-week experiment, Costa et al. (2022) made the experimental group perform different resistance training on the same muscle group during weekly practice, while the control group remained unchanged. After the training, the value of 1RM was increased in all exercises in both groups, and there was no significant difference between the two groups (Costa et al., 2022). This proves that changing training too often does not yield additional benefits. However, progressive load and periodic changes are still two important principles in strength training. In a recent comprehensive study, Spiering et al. (2023) summarized some conclusions on strength gain, namely: First, maximum subjective effort is given during training to generate maximum neural activation in muscles to produce powerful contractions, including centrifugal and centripetal movements, and the training is conducted through complete stroke movements to induce muscle metabolic stress; Second, optimize the amount of training for each training session, start each training set with minimal fatigue, optimize recovery time between training sessions, and cyclize training stimuli over time. Finally, when traditional resistance training cannot be performed, increasing, decreasing, or maintaining training intensity is appropriate (Spiering et al., 2023).

D. Conclusion

This study highlights several critical principles for practical strength training. First, traditional resistance training should be the core methodology, supplemented with diverse training approaches to optimize performance and adaptability. An intensity of at least 70% of one-repetition maximum (1RM) is essential to stimulate strength and hypertrophy effectively. Training volume and frequency must be carefully balanced, maintaining a level slightly above maintenance capacity to encourage muscle development while avoiding overtraining. Although moderate exhaustion can benefit muscle-building exercises, excessive fatigue should be avoided, mainly when the primary goal is to improve strength. Lastly, training adaptations should be monitored, and adjustments should be made when progress stagnates, though changes should be measured and not overly frequent to ensure consistent improvement.

Future studies should explore the long-term effects of varied training methods and intensities across different populations, including athletes and general fitness enthusiasts, to advance the understanding and application of strength training. Research should also investigate the interplay between training frequency, volume, and recovery strategies to provide more precise guidelines for designing individualized programs. Additionally, it is crucial to develop localized studies in regions like China to address cultural, physiological, and logistical factors unique to the population. By incorporating these recommendations, strength training programs can become more evidence-based, culturally relevant, and effective in meeting the diverse needs of athletes and the broader public.

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