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Optimization Strategy and Empirical Analysis of Super Equal Length Training Method in Improving Lower Limb Strength

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Abstract: *This paper focuses on the application of ultra long length training method in improving lower limb strength. In response to the problems of single parameters and insufficient individual adaptability in traditional training schemes, an optimization system is constructed from three dimensions: training parameter optimization, individual difference adaptation, and joint training strategy. Through a group controlled experiment on 30 male sprinters from a certain university, the experimental group adopted an optimization strategy while the control group received traditional training. After 8 weeks of training, empirical analysis showed that the experimental group's 1RM squat strength increased by 18.7%, vertical jump height increased by 15.3%, pedaling and stretching power increased by 22.4%, and reaction strength index increased by 19.8%. The improvement in various indicators was significantly better than that of the control group (p<0.05), and the risk of injury was reduced by 27.4%. Research has confirmed that parameter dynamic adjustment based on individual differences, a three-level action advancement system, and a joint training mode can effectively improve the development effect of super length training on lower limb strength, providing theoretical basis and practical guidance for scientific sports training and mass fitness.*

Keywords: *Super Equal Length Training Method, Lower Limb Strength, Individual Differences Adaptation*

1. Introduction

Lower limb strength is not only the foundation of running and jumping sports, but also a key link in the energy transmission of the human body's movement chain. Research has shown that for every 10% increase in lower limb explosive power, the starting speed of sprints can be increased by 3-5%, and the vertical jumping height can be increased by 5-8% (Jones et al., 2020). The Plyometric Training method utilizes the rapid transition from centrifugal contraction to centripetal contraction, utilizing the elastic energy storage and neural reflex enhancement effects of muscle tendon units to achieve efficient development of explosive power. The core mechanism lies in the increased excitability of alpha motor neurons activated by stretch reflex and the reutilization of muscle elastic potential energy [1].

However, there is a common problem of empirical parameter setting in current training practices. For example, most studies use fixed jumping depth and height (such as 40-60cm), ignoring the matching relationship between individual muscle strength level and load; The lack of advanced logic in action pattern design leads to novice and high-level athletes adopting similar training programs [2]. This' one size fits all 'training model not only limits training effectiveness, but may also increase the risk of sports injuries such as Achilles tendinitis and patellofemoral pain [5].

The aim of this study is to construct a parameter optimization model for ultra long training based on individual differences, verify the effectiveness of the "parameter optimization mode advancement joint training" strategy in improving lower limb strength, and provide scientific training programs for people with different training levels and specialized needs. At the theoretical level, the research results will improve the load regulation theory of ultra long training; On a practical level, precise training design can not only improve athletes' specialized performance, but also provide a safe and effective training paradigm for public fitness.

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2. Literature review

2.1 Basic theory of super equal length training

2.1.1 Tension Shortening Cycle (SSC) Mechanism

Stretching Shortening Cycle (SSC), as the core mechanism of the super long training method, can be finely decomposed into three closely connected stages, profoundly affecting the effectiveness of muscle power generation and explosive power generation. The first stage is the centrifugal stage, during which the muscles are stretched by external forces, storing elastic potential energy like a stretching spring, while activating the tension reflex within the muscles to enhance nerve excitability; The second stage is the amorization stage, which is the transition period from centrifugal to centripetal contraction. This stage can be called the "golden window" of the SSC mechanism, where muscles need to integrate and transfer energy in a very short period of time to avoid the loss of elastic potential energy in the form of thermal energy; The third stage, centripetal stage, is the process in which muscles combine stored elastic potential energy with nerve drive to rapidly contract and generate strong explosive force.

Komi's [3] cutting-edge research shows that when the duration of the amorization stage is precisely controlled within 250ms, the retention rate of muscle elastic potential energy can exceed the 60% threshold. This discovery reveals the root of the efficiency of ultra long training - compared to traditional strength training, it focuses more on utilizing the elastic properties of muscle tendon units and greatly improves strength output efficiency through a "store release" energy mode. For example, in deep jump training, athletes accumulate elastic potential energy during the centrifugal phase of jumping from a high platform, and then quickly transition to centripetal takeoff at the moment of landing. If the amorization phase is properly controlled, the stored energy can be efficiently converted into vertical upward explosive force. This unique energy utilization mechanism enables ultra long training to demonstrate advantages that traditional strength training cannot match in improving athletes' explosive power indicators such as sprint speed and jumping height. It also provides valuable theoretical basis for the design of sports training programs.

2.1.2 Neuromuscular regulation mechanism

The neural regulatory mechanism of ultra long training mainly stems from its specific stimulation of muscle proprioceptors. During the training process, the muscles in the centrifugal contraction phase rapidly elongate, strongly activating muscle spindles and Golgi tendon organs. As a length sensor, muscle spindles can keenly perceive changes in muscle length and stretching speed. When stimulated, they quickly transmit signals to the spinal cord, triggering the stretch reflex and stimulating alpha motor neurons, thereby enhancing muscle contractility; As a tension sensor, the Golgi tendon organ can trigger inhibitory reflexes when muscle tension is too high, ensuring the safety of the musculoskeletal system.

Sale (2017) monitored ultra long training using electromyography (EMG) technology and found that during deep jumping movements, the peak electromyographic activity of the quadriceps muscle significantly increased by 23-31% compared to simple squats, indicating that more exercise units were recruited to participate in exerting force. At the same time, the recruitment ratio of type II fast muscle fibers has significantly increased. These fibers have the characteristics of fast contraction speed and high power output, and are the core force for explosive power generation. These neural adaptive changes work together, not only strengthening the nerve's ability to control muscles, but also optimizing muscle contraction patterns, making ultra long training an important training method for developing rapid strength by efficiently enhancing explosive power.

2.2 Lower limb strength assessment system

In the lower limb strength assessment system, quantitative assessment indicators and assessment tools and methods complement each other. The quantitative evaluation indicators mainly cover three dimensions: maximum muscle strength, explosive power, and functional indicators: maximum muscle strength reflects absolute strength level through tests such as 1RM squat and 1RM hard pull; The explosive power is quantified by the longitudinal jump power (calculated according to the formula "Power=body weight x jump height x gravitational acceleration/time") and the reactive power index (RSI=jump height/ground contact time) to quickly exert force; Functional indicators reflect the application of force in actual motion scenarios through variable direction speed (such as T-test testing), multi-level jump distance, and other indicators. The evaluation tools and methods provide technical support for indicator measurement, among which Kistler three-dimensional force plate and other force

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plate equipment can accurately measure vertical pedaling force and power output; Vicon and other infrared motion capture systems can deeply analyze joint kinematic parameters and reveal details of motion patterns; Portable electromyography devices such as Noraxon can monitor muscle activation patterns in real-time and visually present muscle force characteristics (Hume, 2020). These tools work together to achieve comprehensive and accurate assessment of lower limb strength.

2.3 Limitations of existing training strategies

Blindness in setting load parameters. In traditional training, the jumping height is often set according to the empirical rule of "starting at 40cm and increasing by 10cm per week". However, research has shown that the optimal jumping height for trainers weighing 70kg and squatting 100kg in 1RM is 60-70cm, while trainers squatting 80kg in 1RM should start from 40-50cm [4]. The mismatch between load and muscle strength can lead to the failure of SSC mechanism, and even cause excessive load injury due to centrifugal contraction.

Homogenization of action pattern design. Both basketball players and sprinters commonly adopt a fixed progression path of "double foot deep jump single foot deep jump box", ignoring the differences in the characteristics of specific movements. For example, sprinters require more horizontal explosive power, while basketball players focus on vertical takeoff and directional stability (Bompa, 2019).

3. Optimization strategy for super equal length training method

3.1 Scientific regulation of training parameters

In terms of precise design of load intensity and advanced action mode system for ultra long training, the training effect is optimized through scientific calculation and hierarchical planning. In terms of load intensity design, the formula of "1RM squat x 0.6=optimal jump depth height (cm)" is used to determine the initial jump depth height for the trainer. For example, for a trainer with a 1RM squat of 100kg, the initial height is set to 60cm, and dynamic correction is made every 2 weeks based on muscle strength growth according to "new height=original height x (1+muscle strength growth rate)"; At the same time, optimizing the number of groups and interval time for trainers of different levels, novices use a 3-group x 10 times, 90 second interval arrangement to ensure ATP-CP recovery of 80%, while advanced trainers use 5 groups x 6 times, 120 second interval. Research has shown that this setting can control the power attenuation of each action within 10% (McGill, 2020). In the advanced system of action mode, a three-level training model of "basic advanced specialized" is constructed: in the basic stage (2 weeks), the movement norms are solidified through jumping deep with both feet (40-50cm) and continuous squat jumping; In the advanced stage (4 weeks), athletes need to use single foot deep jumps and lateral box jumps (30-40cm) to enhance unilateral explosive power; During the specialized phase (2 weeks), targeted movements such as sprinters' "starting style deep jump" and basketball players' "landing changing direction jump" are designed based on specific project requirements, thus forming a systematic and step-by-step training plan. As is shown in Table 1.

Table 1 Experimental group training plan (partial)

Special type	Optimization action example	Training targets
Sprint	Diagonal jump depth (15 ° inclination angle)	Improve horizontal stretching force
Basketball	Multi angle jumping depth (front/side/rear direction)	Enhance directional stability
Volleyball	Continuous jumping bar (height 30-50cm)	Increase jump frequency

3.2 Individual differences adaptation strategies

To achieve precision and efficiency in ultra long training, it is necessary to design adaptations from both the training level and specific requirements dimensions. In the hierarchical design based on training level, for the novice group (training duration<1 year), a low-intensity (jump depth height ≤ 40cm) and high repetition rate (12-15 times/group) training mode is adopted, and real-time correction of movements is achieved through video feedback, with a focus on developing neuromuscular coordination ability; The advanced group (with a training period of 1-3 years) implements a training program of medium to high intensity (jumping depth and height of 50-70cm) and moderate repetition times (8-10 times/group), while adding elastic band resistance with a load of 10-15% of body weight to further enhance explosive power output (Figure 1). In terms of specialized demand-oriented training, training parameters are flexibly adjusted based on the energy metabolism characteristics of the project: for fast strength projects such as sprinting and jumping, a "high-intensity+short interval" mode is adopted, such as setting a jump depth of 70cm and an interval of 90 seconds, with a focus on stimulating the phosphate system for energy supply; For endurance projects such as football and basketball, the "moderate intensity+multiple sets" strategy is used, such as jumping 50cm deep, 5 sets of 12 times, and a 60 second interval, to promote the adaptation of the lactate system and achieve a deep fit between training and project requirements (Bangsbo, 2018).

3.3 Joint training optimization strategy

In the joint optimization strategy of ultra long training, by combining ultra long training with traditional strength training and synergistically conducting flexibility and core stability training, the maximization of training effectiveness and comprehensive improvement of athletic performance can be achieved. Specifically, in the combination of ultra long length training and traditional strength training, a "squat jump deep" super group training mode is designed, which involves first performing 3 sets of 5 deep squat exercises with an intensity of 80% RM, and then completing 3 sets of 6 deep squat exercises with a height of 1RM × 0.6 after a 3-minute interval. This mode can effectively improve muscle contraction efficiency by utilizing the "post activation enhancement effect" (PAP). Research data shows that compared to training alone, this strategy can increase explosive power by an additional 12% (Newton, 2019). In terms of collaborative training between flexibility and core stability, dynamic stretching exercises such as high leg lifts and side lunges are arranged before each training session. After the training, static stretching of the hamstring muscles (holding for 30 seconds x 3 groups) is performed. At the same time, core training including flat support and Russian rotation is conducted twice a week to reduce the amplitude of trunk shaking during landing, significantly enhance movement stability, and ensure multi-dimensional training effectiveness and exercise safety.

4. Empirical analysis: Research design and methods

4.1 Experimental subjects

Select 30 male sprinters (aged 20.3 ± 1.8 years) from a certain university's track and field team, all of whom have no history of lower limb injuries and have trained for 2-4 years. The experimental group (n=15) and the control group (n=15) were divided using a random number table method, and there was no significant difference in baseline data between the two groups (p>0.05). As is shown in Table 2.

Table 2 Comparison of lower limb strength indicators between the experimental group and the control group before training ($\bar{x} \pm s$)

Group	Sample size	Age	Training duration	History of lower limb injuries
Experimental group	15	20.1±1.9	2.2-3.8	None
Control group	15	20.5±1.7	2.3-4.0	None
P-value	-	0.563	0.612	-

4.2 Training plan

This study divided the experimental subjects into an experimental group and a control group, and adopted different training intervention plans: the experimental group implemented optimized training strategies, including parameter dynamic adjustment, three-level action advancement system, and joint training mode. The training frequency was set to 3 times a week, and the intervention period was a total of 8 weeks. The specific training schedule is as follows: the first two weeks are the basic training stage, which includes 40-50cm deep jumping exercises (3 groups, 12 times per group) and 70% 1RM intensity squat training (3 groups, 8 times per group); In the advanced training stage of weeks 3-6, the jumping height is increased to 50-60cm (4 groups, 10 times per group), and the squatting intensity is increased to 85% 1RM (3 groups, 5 times per group); During the specialized training phase of weeks 7-8, 15 ° inclined board jumping deep training (5 groups, 8 times per group) will be introduced, and core muscle group strengthening training will be conducted twice a week simultaneously. The control group received traditional training mode, with a fixed 50cm jump depth practice (4 groups, 8 times per group, with a 60 second interval between groups), without involving dynamic parameter adjustment or joint training mode.

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The rest of the training frequency remained the same as the experimental group.

4.3 Measurement indicators and methods

This study aims to collect data on lower limb strength related indicators, as follows: the progressive load method is used to test the 1RM squat, and the maximum weight that the subject can correctly complete the action is defined as 1RM; the Kistler force plate is used to measure the longitudinal jump height, mainly calculating the height of the non pre swing longitudinal jump (CMJ); We calculate the thrust power (Power) and reaction force index (RSI=CMJ height/ground contact time) through force plate data as indicators of explosive force. Data collection was conducted before training, 4 weeks after training, and 8 weeks after training. To ensure testing accuracy, participants were required to refrain from high-intensity training within 24 hours before testing, and the entire process was conducted using a double-blind method, with the same tester strictly following standardized procedures.

5. Empirical results

5.1 Comparison of baseline data between two groups before training

Before training, there was no significant difference between the experimental group and the control group in indicators such as 1RM squat (102.3 ± 12.5kg vs 100.7 ± 11.8kg, $p=0.63$) and vertical jump height (58.7 ± 5.2cm vs 57.9 ± 4.8cm, $p=0.57$), indicating comparability between the groups.

5.2 Changes in indicators after training

5.2.1 1RM squat strength enhancement

After the training intervention, both the experimental group and the control group showed a significant increase in 1RM squat strength, but there was a significant difference in the magnitude of improvement between the two groups ($p<0.05$). Specific data shows that after 8 weeks of training, the experimental group's average 1RM squat strength reached 121.5 ± 13.2kg, a significant improvement of 18.7% compared to the baseline level ($p<0.01$); The control group's 1RM squat strength increased to 108.6 ± 12.1kg, with an increase of 7.8% ($p<0.05$). This result indicates that optimizing training strategies has significant advantages over traditional training modes in promoting maximum strength growth in the lower limbs.

5.2.2 Vertical jump height and explosive power enhancement

In terms of vertical jump height and explosive power indicators, the experimental group showed better training adaptability. After training, the vertical jump height of the experimental group increased to 67.7 ± 5.9cm, achieving a 15.3% increase; The extension power and reaction strength index (RSI) increased by 22.4% and 19.8%, respectively. In contrast, the vertical jump height of the control group increased to 61.2 ± 5.5cm, with a growth rate of only 5.7%. Through inter group comparative analysis, the experimental group showed significantly better improvement in the above three indicators than the control group ($p<0.05$, see Table 3 for details), indicating that the optimized training program has higher training benefits in improving lower limb explosive power and jumping ability. As is shown in Table 3.

Table 3 Comparison of vertical jump height and explosive power indicators between two groups after training ($x \pm s$)

Index	Group	Before training	After 8 weeks of training	Growth rate	P-value
Vertical jump height (cm)	Experimental group	58.7±5.1	67.7±5.9	15.3	<0.01
	Control group	57.9±4.8	61.2±5.5	5.7	<0.05
Extension power (W)	Experimental group	-	-	22.4	<0.01
	Control group	-	-	8.3	<0.05
RSI	Experimental group	-	-	19.8	<0.01
	Control group	-	-	4.2	<0.05

5.3 Security analysis

In the training safety assessment, there was a significant difference ($p<0.05$) in the incidence of adverse events between the experimental group and the control group. The experimental group reported a total of 4 cases of muscle soreness during the 8-week training period (incidence rate of 26.7%), and no severe sports injuries occurred; The control group recorded 8 cases of muscle soreness (incidence rate

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53.3%), of which 2 subjects needed to pause training due to symptoms of Achilles tendinitis. Based on risk ratio analysis, the experimental group showed a 27.4% reduction in injury risk compared to the control group. This result indicates that optimizing training strategies not only has advantages in training effectiveness, but also demonstrates higher practical value in preventing sports injuries and ensuring training safety.

6. Conclusion

This study systematically evaluated the effects of different intervention strategies on lower limb strength, explosiveness, and training safety by comparing optimized training strategies with traditional training modes. The main conclusions drawn are as follows:

In terms of training effectiveness, the experimental group adopted significantly better parameter dynamic adjustment, three-level action advancement, and joint training strategies than the traditional training mode. The data shows that the experimental group's 1RM squat strength increased by 18.7%, which is 10.9 percentage points higher than the control group's (7.8%) improvement, confirming that the optimization strategy has significant advantages in breaking through strength bottlenecks and strengthening muscle recruitment ability. At the same time, the experimental group showed an increase of 15.3%, 22.4%, and 19.8% in vertical jump height, pedaling power, and reaction strength index, respectively, all significantly higher than the control group ($p<0.05$), indicating that this strategy can effectively improve neuromuscular coordination and lower limb explosive ability, providing theoretical support for the comprehensive improvement of exercise performance.

The safety analysis results indicate that optimizing the training strategy performs well in preventing sports injuries. The incidence of muscle soreness in the experimental group was only 26.7%, significantly lower than the 53.3% in the control group, and there were no cases of severe sports injuries; In the control group, two subjects suspended training due to tendinitis, confirming that the traditional fixed load training mode has a higher risk of overuse injury. Optimization strategies can effectively reduce local muscle fatigue accumulation by dynamically adjusting training parameters, achieving a dynamic balance between training intensity and recovery ability, which is of great significance for the sustainability of long-term exercise training.

In summary, dynamic parameter adjustment and joint training strategies can not only significantly improve lower limb strength and explosive power, but also have higher training safety, providing empirical evidence for the scientific design of sports training programs. However, this study still has certain limitations: the sample size is small and all are healthy adults. Subsequent studies can expand the sample range to include people of different ages and exercise levels, and extend the intervention period to further verify the universality and long-term effects of this strategy. In addition, future research can combine multidimensional indicators such as electromyographic signals and sports biomechanics to deeply analyze the mechanism of optimizing training strategies, providing richer references for theoretical innovation and practical applications in the field of sports training.

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