SPECIAL TRAINING ON LOWER LIMBS SMALL MUSCLE GROUPS STRENGTH

TREINO ESPECIAL SOBRE A FORÇA DOS PEQUENOS GRUPOS MUSCULARES DOS MEMBROS INFERIORES

ENTRENAMIENTO ESPECIAL SOBRE LA FUERZA DE LOS PEQUEÑOS GRUPOS MUSCULARES DE LOS MIEMBROS INFERIORES

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ABSTRACT

Introduction: Specific training with vibration can show short- and long-term effects on neuromuscular capacity. This training method gives muscles a frequent stimulus amplitude variation and can promote muscle strength, explosive power, neuromuscular coordination, and balance training. Objective: This paper compares the effects of strength training with vibration on the strength of small muscle groups in the lower limbs of athletes. Methods: 24 young people were randomly assigned to a low- and high-frequency group. Both groups used traditional strength training with the addition of 30 and 40Hz vibrational training. Training with load intensity between 30 and 70% of maximal strength lasting 60 minutes was repeated in 3 weekly sessions for eight weeks. Functional tests were recorded before and after the experiment, and their results were statistically analyzed. Results: The peak torque of the hip muscles of the two groups of athletes increased significantly after training ($P<0.05$). In the high-frequency athletes, the peak in the hip extensor increased by 15.3% and the flexor by 18.2%; in the low-frequency group, there was an increase of 10.3%, representing a very significant difference ($P<0.01$). Conclusion: Additional vibration stimulation for resistance strength training can effectively improve strength training. With a relatively small load, this training method can effectively improve maximal muscular strength, explosive power, and muscular endurance. ***Evidence level II; Therapeutic Studies - Investigating the results.***

Keywords: Resistance Training; Athletes; Lower Limbs; Neuromuscular Diseases.

RESUMO

Introdução: O treino específico com vibração pode mostrar efeitos a curto e longo prazo sobre a capacidade neuromuscular. Esse método de treino dá aos músculos uma variação de amplitude de estímulo frequente, podendo promover força muscular, poder explosivo, coordenação neuromuscular, e treino do equilíbrio. Objetivo: Este artigo analisa a comparação dos efeitos do treino de fortalecimento com adição de vibração sobre a força dos pequenos grupos musculares nos membros inferiores dos esportistas. Métodos: 24 jovens foram aleatoriamente distribuídos em grupo de baixa e alta frequência. Ambos grupos utilizaram treinamento de força tradicional com adição de treino vibracional de 30 e 40Hz. Treinos com intensidade de carga entre 30 e 70% de força máxima com duração de 60 minutos foram repetidos em 3 sessões semanais durante 8 semanas. Testes funcionais foram registrados antes e depois do experimento e seus resultados foram analisados estatisticamente. Resultados: O pico de torque dos músculos do quadril dos dois grupos de atletas aumentou significativamente após o treinamento ($P<0,05$). Nos atletas de alta frequência, o pico no extensor do quadril aumentou 15,3% e o flexor 18,2%; no grupo de baixa frequência houve aumento de 10,3% representando uma diferença muito significativa ($P<0,01$). Conclusão: A estimulação adicional da vibração para o treinamento de força com resistência pode efetivamente melhorar o treinamento de força. Esse método de treinamento pode efetivamente melhorar a força muscular máxima, o poder explosivo e a resistência muscular com uma carga relativamente pequena. **Nível de evidência II; Estudos terapêuticos - Investigação de resultados.**

***Descritores*:** *Treinamento de Força; Atletas; Membros Inferiores; Doenças Neuromusculares.*

RESUMEN

Introducción: El entrenamiento específico con vibración puede mostrar efectos a corto y largo plazo sobre la capacidad neuromuscular. Este método de entrenamiento proporciona a los músculos una variación frecuente de la amplitud del estímulo, y puede promover la fuerza muscular, la potencia explosiva, la coordinación neuromuscular y el entrenamiento del equilibrio. Objetivo: Este trabajo analiza la comparación de los efectos del entrenamiento de fuerza con la adición de vibración en la fuerza de los pequeños grupos musculares de los miembros inferiores de los deportistas. Métodos: 24 jóvenes fueron asignados aleatoriamente al grupo de baja y alta frecuencia. Ambos grupos utilizaron el entrenamiento de fuerza tradicional con la adición del entrenamiento vibratorio de 30 y 40 Hz. Los entrenamientos con una intensidad de carga entre el 30 y el 70% de la fuerza máxima y con una duración de 60 minutos se repitieron en 3 sesiones semanales durante 8 semanas. Se registraron las pruebas funcionales antes y después del experimento y se analizaron estadísticamente sus resultados. Resultados: El par máximo de los músculos de la cadera de ambos grupos de atletas aumentó significativamente después del entrenamiento ($P<0,05$). En los atletas de alta frecuencia, el pico del extensor de la cadera aumentó un 15,3% y el flexor un 18,2%; en el grupo de *baja frecuencia hubo un aumento del 10,3%, lo que representa una diferencia muy significativa (P<0,01). Conclusión: La estimulación vibratoria adicional para el entrenamiento de fuerza con resistencia puede mejorar eficazmente el entrenamiento de fuerza. Este método de entrenamiento puede mejorar eficazmente la fuerza muscular máxima, la potencia explosiva y la resistencia muscular con una carga relativamente pequeña.* ***Nivel de evidencia II; Estudios terapéuticos - Investigación de resultados.***

Descriptores: *Entrenamiento de Fuerza; Atletas; Miembros Inferiores; Enfermedades Neuromusculares.*

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INTRODUCTION

The method of using vibration stimulation during resistance training in sports training has been generally accepted. Some current research results show that special training can have acute and long-term effects on neuromuscular ability. The biggest feature of this training method is providing and using an unstable sports environment.[1] This training gives the muscles a certain frequency and amplitude of disturbance stimulation to promote muscle strength, explosive power, neuromuscular coordination, and balance training. However, the effect of special training is interfered with by many factors. Speed skating is a physical fitness-led speed event. The athlete's maximum strength performance is not obvious. Therefore, which vibration frequency is the most suitable training effect requires in-depth discussion by the coach. This study mainly used different frequencies of special training combined with resistance training to study the improvement effect of speed skaters' lower limb strength.

METHOD

Research object

The subjects of the study are 24 young female speed skaters. We randomly divide it into a high-frequency group and a low-frequency group. There are 12 people in each group. Both groups used traditional strength training plus vibration strength training.[2] We determine that the vibration frequency of the high-frequency group is 45 Hz, and the vibration frequency of the low-frequency group is 30 Hz. The basic situation of the research subjects is shown in Table 1.

Research methods

We train all athletes for 8 weeks. Schedule 3 training sessions per week. Each training time is 60min. The training items mainly include weight-bearing squat, weight-bearing heel lift, barbell lunge squat, etc. The load intensity is between 30% and 70% of the maximum strength.[3]

We tested athletes' hip and knee joints at 300°/s (rapid) before and after strength training. Repeat 3 times at each speed and take the highest value. The interval of each test in the 20s. Because the squat jump (CMJ) can reflect the ability of the extensor muscles of the lower limbs to turn from eccentric contraction to centripetal contraction quickly. (CMJ) data can indirectly evaluate the level of the explosive power of athletes' lower limbs.[4] Therefore, the vertical jump tester was used to test the subjects' squat and jump (CMJ) movements before and after the strength training. Each person will take 3 tests and record the best results after 20s intervals.

Table 1. The basic situation of the research objects.

	Age	Height (cm)	Weight (kg)	Training years
High frequency group (45Hz)	19.4±2.6	163.8±3.7	57.6±4.8	6.4±2.4
Low frequency group (30Hz)	18.7±2.2	164.7±4.6	59.7±4.1	6.2±3.1

Freely deformable leg motion modeling method

The grid space used in this paper is a cube grid containing the deformed body. It contains the cube of the leg model. It is divided into grid cubes by parallel planes in 3 orthogonal directions (U, V, W). We assume that the cube is divided into m segments in the U direction, divided into n segments in the V direction, and divided into k segments in the W direction. The larger the m, n, k, the smoother the deformation.[5] If the value range of U, V, W is normalized to [0, 1], the same grid space can be applied to multiple objects. There are $(m+1) \times (n+1) \times (k+1)$ control points in this parallel grid cube. The ternary tensor product B spline function composed of these control points can determine any point in the grid space. If we use the $NURBS$ form, we have:

$$D(u,\upsilon,\omega)=\frac{\sum_{a=0}^{m}\sum_{b=0}^{n}\sum_{c=0}^{k}P_{abc}W_{abc}B_{a,p}(u)B_{b,q}(\upsilon)B_{c,r}(\omega)}{\sum_{a=0}^{m}\sum_{b=0}^{n}\sum_{c=0}^{k}W_{abc}B_{a,p}(u)B_{b,q}(\upsilon)B_{c,r}(\omega)} \quad (1)$$

D is a point on the deformed object. P is the control point in the parallel grid cube. W is the weight. p, q, r is the order of the B spline basis function of each parameter. They may not be equal to each other. (u, υ, ω) constitutes the parameter coordinate of the object point D, the so-called local coordinate of FFD. Therefore, the problem of determining the local coordinates of FFD is to know the reference coordinates of the control point P and the object point D. We determine the appropriate B spline basis function node vector and each parameter value. p, q, r can be taken as

$$\begin{aligned} &2 \le p \le m+1 \\ &2 \le q \le n+1 \\ &2 \le r \le k+1 \end{aligned} \quad (2)$$

The value of the node vector of the parameter u is

$$u_i=\begin{cases} 0 & i=0 \\ \dfrac{\overrightarrow{P_{000}P_{(i-1)00}}\times\vec{U}}{\overrightarrow{P_{000}P_{m00}}\times\vec{U}} & 1\le i\le(m+1) \\ 1 & i=m+2 \end{cases} \quad (3)$$

The B spline basis function is determined by the Cox - $deBoor$ recursive algorithm:

$$\begin{aligned} &B_{i,1}(u)=\begin{cases}1 & u_i\le u\le u_{i+1}\\ 0 & otherwise\end{cases} \\ &B_{i,2}(u)=\frac{u-u_i}{u_{i+1}-u_i}B_{i,1}(u)+\frac{u_{i+2}-u}{u_{i+2}-u_{i+1}}B_{i+1,1}(u) \end{aligned} \quad (4)$$

The object point D only considers the parameter u. From equation (4), we can get:

$$\overrightarrow{P_{000}D} \times \overrightarrow{U} = \overrightarrow{P_{000}P_{(i-1)00}} \times \overrightarrow{U} + \frac{u-u_i}{u_{i+1}-u_i} \overrightarrow{P_{(i-1)00}\}P_{i00}} \times \overrightarrow{U} \quad (5)$$

We substitute equation (3) into equation (5), we have

$$u = \frac{\overrightarrow{P_{000}D} \times \overrightarrow{U}}{\overrightarrow{P_{000}P_{m00}} \times \overrightarrow{U}} \quad (6)$$

The calculation formula for the v and ω parameter coordinates of the object point D is similar to this.[6] Therefore, if the second-order B spline basis function is used and the weight is initialized to 1, the parameter coordinates of the point D can be easily obtained by equation (6).

Mathematical Statistics

We use paired T-test and independent-sample T-test in SPSS12.0 mean comparison to perform statistical analysis on related parameters.

RESULTS

Changes in peak torque of hip flexors and extensors before and after training

From the changes in the peak flexion and extensor torque of the athletes before and after the training, the peak torque of the hip muscles of the two groups of athletes increased significantly after training (P<0.05). After training, the peak torque of the hip extensor of athletes in the high-frequency group increased to 53.2±21.2. This increases 15.3% compared to before training.[7] The peak flexor torque of the high-frequency group after training increased by 18.2% compared with that before training. Compared with the 10.3% increase in the low-frequency group, this is also a very significant difference (P<0.01). (Table 2)

Changes in peak moments of knee flexors and extensors before and after training

After 8 weeks of vibration strength training, the peak torques of the knee flexors and extensors of the two groups were significantly different from those before training (P<0.01). But after training, the peak torque of the extensor group in the high-frequency group increased by 34.6±13.4. The increase was 19.8%. Similarly, the 17.1% increase of the high-frequency group in the increase of the peak torque of the flexor group was also much greater than the 10.2% increase of the low-frequency group (P<0.01). (Table 3)

The impact of vibration strength training on the explosive power level of athletes' lower limbs

After the vibration strength training, the squat jump (CMJ) in the low-frequency group increased by 5.6%. The height is increased by (2.1±0.6) cm compared with before training. The high-frequency group's squat jump (CMJ) increased by 12.2%. The height is increased by (4.5±1.1) cm compared with before training. The improvement was significant (P<0.05). It can be seen that the two groups also showed a very significant difference in terms of the lifting range (P<0.01). (Table 4)

Table 2. Changes in peak moments of the hip flexors and extensors of the lower limbs of the two groups of athletes before and after training (N.m).

Muscle group	Group	Before the experiment	After the experiment	Value-added	Percentage %
Extensor	High frequency group	346.6±51.2	399.8±47.3	53.2±21.2	15.3
	Low frequency group	342.7±46.6	372.4±49.6	29.7±18.7	8.7
Flexor	High frequency group	137.8±22.8	162.9±23.7	25.1±16.4	18.2
	Low frequency group	141.7±18.6	156.3±20.2	14.6±7.8	10.3

Table 3. Changes in peak moments of knee flexors and extensors of the lower limbs of the two groups of athletes before and after training (N.m).

Muscle group	Group	Before the experiment	After the experiment	Value-added	percentage %
Extensor	High frequency group	174.6±22.4	209.2±19.4	34.6±13.4	19.8
	Low frequency group	168.7±25.2	186.3±27.3	17.6±9.7	10.4
Flexor	High frequency group	115.4±18.9	135.1±19.0	19.7±11.2	17.1
	Low frequency group	118.3±20.3	130.4±23.5	12.1±8.4	10.2

Table 4. The squat jump height (CMJ) before and after training in the two experimental groups (cm).

Group	Before the experiment	After the experiment	Value-added	percentage %
High frequency group	36.8±2.9	41.3±2.6	4.5±1.1	12.2
Low frequency group	37.2±2.4	39.3±1.8	2.1±0.6	5.6

DISCUSSION

By improving the ability of the athlete's nerve-muscle system to dominate the muscles, it can improve the coordination and cooperation between the speed skaters' body muscles and muscle groups.[8] This way, the effectiveness and economy of completing technical actions can be improved. This is an important development trend of special strength training in current speed skating sports. At the same time, this is also an effective way to improve the competitive ability of high-level speed skaters.

Vibration strength training has been applied to a certain extent in athlete training. Many studies have proven that vibration strength training has acute and long-term effects on athletes' neuromuscular capabilities.[9] The current research on vibration strength training mainly focuses on the most suitable amplitude and vibration frequency, intensity, type, and duration of exercise required for training.

Vibration strength training can effectively improve the rapid strength of lower limb muscles. From the CMJ test results showing the explosive power of the lower limb muscles, it can be seen that the speed skaters' CMJ scores have also improved in different ranges after vibration strength training. This shows that the athlete's squat and jump performance improved during the 8-week vibration strength training; the athlete's leg strength. Especially the explosive power has been effectively improved. This indirectly proves the vibratory strength training for speed skaters. This training has a very good effect on improving the explosive power of speed skaters' legs.

Different vibration frequencies have different training effects on athletes. After strength training, the peak flexion and extension moments of the hip and knee joints or the CMJ test scores of the athletes in the high-frequency group increased significantly higher than those in the low-frequency group.[10] This shows that the training stimulus of high-frequency vibration strength for athletes is significantly better than low-frequency vibration strength training. This affects the intensity of vibration that the muscles bear during vibration exercises. Only the parameters related to the special training must be large enough to cause the improvement of muscle performance. In addition, the higher the vibration frequency, the faster the length of the fibers in the muscle spindle changes. The frequency and intensity of the impulse of nerve impulses will also increase and increase accordingly. In this way, more motor units can be recruited to participate in exercise and better improve neuromuscular coordination.

CONCLUSION

Speed skaters have undergone 8 weeks of vibratory strength training with an amplitude of 4mm, and the peak moments of the hip and knee joint flexors and extensors can be significantly improved. The athlete's squat jumping performance has also been effectively improved. The peak torque of the lower limb joints of the athletes in the high-frequency group and the squat jump (CMJ) performance were significantly higher than those in the low-frequency group. This shows that vibration stimulation (45Hz) has significantly higher training effects on athletes' lower explosive limb power than low-frequency vibration stimulation (30Hz). Therefore, higher frequency vibration strength training should be adopted for the special training of athletes.

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