ISOMETRIC RESISTANCE TRAINING EFFECTS ON LOWER LIMB MUSCLE ACTIVITY

EFEITOS DO TREINO ISOMÉTRICO RESISTIDO SOBRE A ATIVIDADE MUSCULAR DOS MEMBROS INFERIORES

EFECTOS DEL ENTRENAMIENTO DE RESISTENCIA ISOMÉTRICA EN LA ACTIVIDAD MUSCULAR DE LOS MIEMBROS INFERIORES

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ABSTRACT

Introduction: The high muscular strength in the hip joint is the foundation of jumping ability. Isometric resistance training includes the process of takeoff and landing, recruiting a more extensive set of muscle groups. Objective: Analyze the isometric resistance training effects on lower limb muscle activity, including the coactivation of the antagonist's muscles. Methods: By mathematical statistics, weight-bearing isometric resistance training effects on lower extremity maximal muscle strength and explosive power were observed. Changes in coactivation and preactivation levels of lower extremity antagonist muscles data are evaluated and compared before and after isometric resistance training. Results: The peak angular velocity of the joints at the hip and ankle in the isometric resistance training group is significantly higher than the control group. There was no significant difference in the peak angular velocity of the knee between the groups (P<0.05). Conclusion: Isometric resistance training can shorten the return period, shorten the amortization period, and increase the energy conversion capacity in the muscle-tendon complex. ***Evidence level II; Therapeutic Studies - Investigating the results.***

Keywords: Resistance training; Lower Limbs; Sports; Athletes.

RESUMO

Introdução: A elevada força muscular na articulação do quadril é o que fundamenta a habilidade do salto. O treino resistido isométrico inclui o processo de decolagem e aterrissagem, recrutando um conjunto maior de grupos musculares. Objetivo: Analisar os efeitos do treino isométrico resistido sobre a atividade muscular dos membros inferiores, incluindo a coativação dos músculos antagonistas. Métodos: Por meio de estatísticas matemáticas, observa-se o efeito do treino isométrico resistido com sustentação de peso na força muscular máxima das extremidades inferiores e sua potência explosiva. Os dados das mudanças nos níveis de coativação e pré-ativação dos músculos antagonistas dos membros inferiores são avaliados e comparados antes e após o treino isométrico resistido. Resultados: O pico de velocidade angular das articulações no quadril e tornozelo do grupo de treino isométrico resistido é significativamente maior do que no grupo controle. Não houve diferença significativa no pico de velocidade angular do joelho entre os dois grupos (P<0,05). Conclusão: O treino isométrico resistido pode encurtar o período de retorno, encurtar o período de amortização e aumentar a capacidade de conversão de energia no complexo músculo-tendíneo. ***Nível de evidência II; Estudos terapêuticos - Investigação de resultados.***

Descritores: *Treinamento de Força; Membros Inferiores; Esportes Atletas.*

RESUMEN

Introducción: La elevada fuerza muscular en la articulación de la cadera es lo que fundamenta la capacidad de saltar. El entrenamiento de resistencia isométrica incluye el proceso de despegue y aterrizaje, reclutando un conjunto mayor de grupos musculares. Objetivo: Analizar los efectos del entrenamiento de resistencia isométrica en la actividad muscular de las extremidades inferiores, incluyendo la coactivación de los músculos antagonistas. Métodos: Mediante la estadística matemática, se observó el efecto del entrenamiento de resistencia isométrica con carga de peso sobre la fuerza muscular máxima de las extremidades inferiores y su potencia explosiva. Los datos de los cambios en los niveles de coactivación y preactivación de los músculos antagonistas de las extremidades inferiores se evalúan y comparan antes y después del entrenamiento de resistencia isométrica. Resultados: La velocidad angular máxima de las articulaciones en la cadera y el tobillo en el grupo de entrenamiento de resistencia isométrica es significativamente mayor que en el grupo de control. No hubo diferencias significativas en la velocidad angular máxima de la rodilla entre los dos grupos (P<0,05). Conclusión: El entrenamiento de resistencia isométrica puede acortar el periodo de retorno, reducir el periodo de amortización y aumentar la capacidad de conversión de energía en el complejo músculo-tendón. ***Nivel de evidencia II; Estudios terapéuticos - Investigación de resultados.***

Descriptores: *Entrenamiento de Fuerza; Miembros Inferiores; Deportes Atletas.*

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INTRODUCTION

Strong hip joint muscle strength is the basis of jumping ability, and knee and ankle joint muscle strength guarantees speed.[1] The muscle strength and speed of the lower limbs determine the explosive power of sprinting, basketball, jumping, and other actions that have the characteristics of the lengthening-shortening cycle (SSC).

Muscle contraction produces net joint moment (NJM) and causes the joint rotation to produce angular displacement. The joint angular stiffness is a variable that reflects the elastic coefficient of joint rotation. It is highly correlated with the resilience force and contraction speed of the viscoelastic material of the muscle-tendon complex around the joint.[2] The angular stiffness of the lower limbs is also negatively correlated with the support time. This suggests that SSC actions with shorter support time and higher joint angular stiffness have better results. This study tests the dynamics and kinematics data of in-situ vertical squat and take-off (CMJ) after super resistance training. At the same time, we derive the angular velocity and angular acceleration of the hip, knee, and ankle joints. Calculate the angular stiffness of hip, knee, and ankle joints based on the spring-mass model. This provides a scientific theoretical basis for the practical application of super isometric resistance training.

METHOD

Research object

Sixteen male basketball players from the athletic school participated in this experiment and were guaranteed to complete the training. The years of exercise are all over 5 years. The exercise grade is 2, and there is no history of lower limb joint muscle injury.[3] We randomly divided the subjects into a super isometric resistance training group (PWT) and a control group (CG). Age, height, and weight were (17.25±1.04) years, (193.29±5.83) cm, (87.85±10.25) kg; (18.25±2.36) years, (188.90±4.39) cm, (87.86±12.60) kg, respectively.

Experimental method

The maximum voluntary contraction (MVC) of the lower extremity muscles of each subject was tested for 1 week before and after training. After the test started, the subject tried his best to lift and lasted for 3s. The sampling frequency of the force plate is 1200 Hz. The peak value of the measured data curve is MVC. The PWT group was trained for 8 weeks, 3 times a week. Ten times before the start of training, 10% MVC weight-bearing CMJ. Athletes are familiar with the training process and warm-up. Super isometric resistance training determines the load to be 30% MVC. The action is to do CMJ for shoulder resistance barbell.[4] The number of training groups is 3 groups, each with 10 groups. The training time is the 20s, and the rest between groups is 2min. The MVC value was re-measured after 4 weeks of training. We tested the lower limb dynamics and kinematics parameters of the two groups of CMJ after the end of the 8-week super isometric resistance training. The subject warmed up with his hands on his hips. Stand on the force plate with feet shoulder-width apart. After keeping the center of gravity stable, quickly squat to the knee joint about 90°, and then quickly try to jump up vertically. Repeat each action 3 times. We analyze the action with the highest jump height.

Data processing

Calculate the angular stiffness of each joint of the lower limbs according to the spring-mass model: $k_j = M_j / \Delta\theta_j$. Where M_j represents the peak value of NJM. $\Delta\theta_j$ represents the angular displacement from the start of CMJ to the moment of maximum flexion of the joint.[5] The slope of the NJM-joint angular displacement curve represents the angular stiffness of the joint. Kinetic data is normalized to body weight.

Human-machine coupling dynamic analysis and simulation of lower limb exoskeleton

The mechanic's formula and moment formula of the Newton-Euler dynamic equation are respectively

$$F = m\text{c} \quad (1)$$

$$M = I_c\varepsilon + \omega \times I_c\omega. \quad (2)$$

The human body's motion state and the exoskeleton are not completely synchronized when starting to walk. There will be a certain amount of elastic vibration between the two, which increases the stretch of the strap and causes a relative displacement between the two, and generates an interactive force. The strap is a flexible structure.[6] Therefore, the interaction force can be simplified as elastic force and substituted into the dynamic model to increase the model's accuracy. The Newton-Euler equation considering the interaction between the human body and the exoskeleton is

$$F_{13,14} = -m_{14}g + m_{14}\text{c}_{14}, \quad (3)$$

$$M_{13,14} = -r_{14,c14} \times F_{13,14} + I_{c14}\varepsilon_{14} + \omega_{14} \times (I_{c14}\omega_{14}), \quad (4)$$

$$F_{12,13} = -m_{13}g + m_{13}c_{13} + F_{13,14} - F'_{13}, \quad (5)$$

$$M_{12,13} = -r_{13,c13} \times F_{12,13} - r_{14,c13} \times F_{13,14} + I_{c13}\varepsilon_{13} + \omega_{13} \times (I_{c13}\omega_{13}) - M_{13,14}, \quad (6)$$

$$F_{11,12} = -m'_{12}g + m'_{12}\text{c}_{12} + F_{12,13} - F'_{12}, \quad (7)$$

$$M_{11,12} = -r_{12,c12} \times F_{11,12} - r_{13,c12} \times F_{12,13} + I_{c12}\varepsilon_{12} + \omega_{12} \times (I_{c12}\omega_{12}) - M_{12,13}, \quad (8)$$

Statistics

We used SPSS11.3 statistical software to perform a one-way analysis of variance on the data. The independent-sample t-test was used to compare the mean of each variable between the two groups.[7] The results are expressed with a significance level of 0.05.

RESULTS

After 8 weeks of the experiment, the CMJ movement of the two groups of subjects from the beginning to the toe-off the ground phase of the hip, knee, ankle joint angular velocity and joint angular acceleration changes with time are shown in Table 1. The peak angular velocity of the hip and ankle joints in the super-isometric resistance training group

Table 1. Angular velocity of the hip, knee, and ankle joints and peak joint angular acceleration ($\bar{x} \pm s$).

Joint	Group	Angular velocity/((°)·s^{-1})	Angular acceleration/((°)·s^{-2})
Hip	CG	317.35±191.23	2213.64±334.87
	PWT	422.59±132.21	10785.90±911.70
Knee	CG	710.23±354.56	4378.94±575.54
	PWT	707.06±333.11	17860.60±809.11
Ankle	CG	608.48±54.67	802.92±53.44
	PWT	659.23±188.65	10690.81±110.55

was significantly higher than that in the control group. There was no significant difference in the peak knee angular velocity between the two groups.[8] The super-isometric resistance training group's peak angular accelerations of hip, knee, and ankle joints were significantly higher than those in the control group.

There was no significant difference in the slopes of the a-b and a-b' line segments of the knee joint NJM-angular displacement curve between the two groups. This indicates that there is no significant difference between the two groups in the angular stiffness of the knee joint.[9] The slope of the ankle joint NJM-angular displacement curve a-b' line segment is greater than a-b. This indicates that the angular stiffness of the ankle joint in the PWT group was significantly higher than that in the CG group. (Table 2)

Table 2. Angular stiffness of hip, knee, and ankle joints ($\bar{x} \pm s$).

Group	Hip	Knee	Ankle
CG	0.03±0.01	0.03±0.00	0.05±0.01
PWT	0.04±0.01	0.03±0.00	0.09±0.02

DISCUSSION

During the experiment, the angles of the hip, knee, and ankle joints of each subject's CMJ movements were monitored, and the movements that did not meet the standard were removed. This reduces the error of the results and ensures the reliability of the experimental results.[10] We use the ternary phase diagram to analyze the angle distribution of the hip, knee, and ankle joints. The study found that 16 subjects had less variability in CMJ movements. The angles of the joints of the lower limbs are concentrated and overlapped.

Some scholars pointed out that the SSC centrifugal process allows individuals to stimulate the relevant muscle tissues around the joints for an appropriate length of time. This can improve cross-bridge formation. The direct result of muscle contraction is the angular displacement of joint rotation. In this study, the CMJ action strategies of the subjects were more consistent.[11] Under the condition that the angular displacement of each joint of the lower limbs is relatively constant, the higher the contraction speed of the muscles, the greater the angular acceleration of the joints. At this time, the joint angular velocity is also faster. This shows stronger lower limb muscle power. The joint angular velocity and angular acceleration are derived from the differentiation of angular displacement and angular velocity concerning time variables. The shortening of support time increases the angular velocity of the joints and is also the key to the angular acceleration of the joints. In this study, the support time of the super isometric resistance training group ((0.25±0.0s) was significantly shorter than that of the control group ((0.32±0.1s) (P<0.05)). This shows that the super isometric resistance training can significantly reduce the support time of SSC and shorten the spread Long return period. This strengthens the energy conversion ability of the lower limb muscle-tendon complex and improves the utilization rate of elastic energy.

The potential energy of the tendon as the series elastic element of the muscle is stretched before the centripetal contraction determines the muscle power output. The faster shortening speed of the sarcomere requires faster cross-bridge circulation. This will cause the cross-bridge contact points to decrease to achieve the best overlap position of the thick and thin filaments. This training is conducive to the production of muscle strength. The viscoelastic characteristics of the muscle-tendon complex and the stretch reflex are the main factors that play a role in super-isometric resistance training. This encourages it to bear and absorb the burden of high impact at the beginning of the support. The activation of the stretch reflex is a reflection of the motion control feedback function.

Super isometric resistance training is based on CMJ. Carry the barbell on the shoulder to complete the lower limb SSC. After applying a certain resistance, the subjects used more hip and ankle strategies to balance the trunk and effectively complete the CMJ movement. The subjects in this study developed effective lower limb neuromuscular adaptation after 8 weeks of training. The hip and ankle joints' angular velocity and angular stiffness have significant differences between the two groups.

In comparison, the knee joints' angular velocity and angular stiffness are not significantly different between the two groups. This indicates that super-isometric resistance training stimulates the stretch reflex of the muscle-tendon complex around the hip and ankle joints. At this time, it is more conducive to developing hip and ankle muscle explosive power.

The goal of the experimental design is to improve the muscle strength and explosive power of the lower limbs. A training program is a small number of groups, a suitable number of repetitions, and a medium-intensity load. In super isometric resistance training, the coach should encourage rapid and explosive exercise. This can be achieved by minimizing the length of the amortization period and by reducing the support time. According to the eccentric-concentric contraction time, some scholars divide SSC into two categories, fast and slow. Slow SSC movements are characterized by large angular displacements of the hip, knee, and ankle joints and long contraction time. They are classified into those with a support time> 0.25s. The characteristics of fast SSC action are small angular displacement and short amortization period, classified into those with a support time of <0.25s. Strength and physical fitness workers must be familiar with and follow these principles.

CONCLUSION

Super isometric resistance training can significantly reduce the SSC support time and shorten the amortization period. At this time, it can improve the energy conversion ability of the muscle-tendon complex from eccentric contraction to concentric contraction and increase the explosive power of lower limb muscles. Super isometric resistance training is suitable for sprinting, basketball, jumping, and other sports that require rapid joint angular velocity, angular acceleration, and explosive force of the lower limbs.

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