EFFECTS OF THE VIBRATIONAL STIMULATION ON THE MUSCLE STRENGTH OF THE KNEE JOINTS OF ATHLETES

EFEITOS DA ESTIMULAÇÃO DA VIBRAÇÃO SOBRE A FORÇA MUSCULAR DAS ARTICULAÇÕES DO JOELHO DOS ATLETAS

EFECTOS DE LA ESTIMULACIÓN POR VIBRACIÓN EN LA FUERZA MUSCULAR DE LAS ARTICULACIONES DE ATLETAS

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ABSTRACT

Introduction: The traditional lower extremity muscle strength training consists mainly of resistance training, where training intensity is gradually increased, targeting strength gain. Objective: Study the effect of different vibration frequencies on muscle strength training of tennis players' knee joints. Methods: Using PHYSIO-PLATE vibration training platform, tennis players of a Beijing team were subjected to different frequencies of strength training with vibrational stimulation; after eight weeks of systematic strength training, the vibration frequencies were 30Hz and 45Hz, with amplitude of 7mm. Results: After the experiment, the relative peak torque and total work of the knee extensor muscles in subjects in groups I and II were significantly improved (P<0.05), generating a significant increase in rapid maximal power start. Conclusion: The vibrational stimulation addition to muscle strength training can effectively enhance its effect, including characteristics such as maximal strength, rapid strength, and muscular endurance with a relatively small load. ***Level of evidence II; Therapeutic studies - investigation of treatment outcomes.***

Keywords: Vibration; Muscle Strength; Knee Joint; Tennis.

RESUMO

Introdução: O método tradicional de treinamento de força muscular das extremidades inferiores consiste principalmente no treinamento de resistência, onde é aumentada gradualmente a intensidade do treinamento visando o ganho de força. Objetivo: Estudar o efeito de diferentes frequências de vibração sobre o treino de força muscular nas articulações do joelho de tenistas. Métodos: Usando a plataforma de treinamento de vibração PHYSIO-PLATE, os tenistas de uma equipe de Pequim foram submetidos a diferentes frequências de treinamento de força com estimulação vibratória, após oito semanas de treinamento de força sistemático, as frequências de vibração foram de 30Hz e 45Hz, com amplitude de 7mm. Resultados: Após o experimento, o torque de pico relativo e o trabalho total dos músculos extensores do joelho nos indivíduos dos grupos I e II foram significativamente aprimorados (P<0,05), gerando um significativo aumento na potência máxima rápida de arranque. Conclusão: A adição do estímulo vibratório ao treinamento de força muscular pode efetivamente melhorar seu efeito, incluindo características como a força máxima, força rápida e resistência muscular com uma carga relativamente pequena. ***Nível de evidência II; Estudos terapêuticos - investigação dos resultados do tratamento.***

***Descritores*:** *Vibração; Força Muscular; Articulação do Joelho; Tênis.*

RESUMEN

Introducción: El método tradicional de entrenamiento de la fuerza muscular de las extremidades inferiores consiste principalmente en el entrenamiento de la resistencia, donde la intensidad del entrenamiento se incrementa gradualmente con el objetivo de ganar fuerza. Objetivo: Estudiar el efecto de diferentes frecuencias de vibración en el entrenamiento de la fuerza muscular de las articulaciones de la rodilla de los tenistas. Métodos: Utilizando la plataforma de entrenamiento de vibración PHYSIO-PLATE, los jugadores de tenis de un equipo de Pekín fueron sometidos a diferentes frecuencias de entrenamiento de fuerza con estimulación de vibración, después de ocho semanas de entrenamiento de fuerza sistemático, las frecuencias de vibración fueron 30Hz y 45Hz, con amplitud de 7mm. Resultados: Después del experimento, el par máximo relativo y el trabajo total de los músculos extensores de la rodilla en los sujetos de los grupos I y II mejoraron significativamente (P<0,05), generando un aumento significativo en el inicio de la potencia máxima rápida. Conclusión: La adición de la estimulación vibratoria al entrenamiento de la fuerza muscular puede mejorar eficazmente su efecto, incluyendo características como la fuerza máxima, la fuerza rápida y la resistencia muscular con una carga relativamente pequeña. ***Nivel de evidencia II; Estudios terapéuticos - investigación de los resultados del tratamiento.***

***Descriptores*:** *Vibración; Fuerza Muscular; Articulación de la Rodilla; Tenis.*

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INTRODUCTION

The traditional method of lower extremity muscle strength training is mainly resistance training, which gradually increases the training intensity through long-term resistance to improve the lower extremity muscle strength. These traditional training methods are relatively monotonous, and it is increasingly difficult to meet the needs of today's fierce competition in competitive sports.[1,2] Vibration training has attracted widespread attention as a new training method in recent years, vibration training mainly uses mechanical vibration to stimulate the central nervous system, mobilize a large number of muscle fibers and increase the activity of high-threshold muscle fiber units, which enhances the high-frequency and intermittent discharge capacity of motor units. Vibration-stimulated strength training is an emerging strength training method, which has attracted more and more attention from domestic and foreign experts because of its ability to effectively improve muscle strength and explosive power with a small load.[3,4] In this study, by using the PHYSIO-PLATE vibration training platform, two different frequencies of vibration stimulation strength training were performed on the second-line tennis players of a Beijing team, in an attempt to explore more effective methods and means to improve the effect of vibration muscle strength training.[5]

METHOD

Experimental subjects

The experimental subjects of this research are second-line tennis players of a certain team in Beijing, with a sample size of 10, and they are randomly divided into two groups, group I is the middle and low frequency vibration strength training group, the athletes receive vibration stimulation with a frequency of 30 Hz during strength training; Group II was a sub-high frequency vibration strength training group, the athletes received vibration stimulation at a frequency of 45 Hz during strength training, and the slow relative peak torque, single maximum work power, and total work were selected as the reflections of maximum muscle strength, evaluation index of rapid strength and muscular endurance.[6] The basic information of the subjects is shown in Table 1.

Research methods

Before the formal training, the athletes first used the CES muscle strength test and training system to test the maximum isokinetic force of the lower limbs, and then based on the athletes' maximum muscle strength, select 30 percent of maximal muscle strength as an additional load for strength training.[7,8] The athletes performed vibration training for a total of 8 weeks, 2 times a week, 6 sets each time, each set of 40 seconds, during this period, the athletes completed 10 deep squats at a time, and kept the knee angle at 120°~140 for 10 seconds, as well as 10 semi-squats with knee angle controlled at 120°~140°, resting for 40 seconds between sets, the athlete is required to perform explosive force when squatting, and the ankle is involved in the final force.[9] The vibration frequency stimulation received by group I was 30 Hz, and the vibration frequency stimulation received by group II was 45 Hz, with an amplitude of 7 mm.

One week before and after the experiment, the subjects' knee joints were tested for isokinetic muscle strength at a slow speed of 60°/s and a fast speed of 240°/s.

ETHICAL COMPLIANCE

Research experiments conducted in this article with animals or humans were approved by the Ethical Committee and responsible authorities of Huzhou University, Huzhou College, Xihua University and Chengdu Sport University following all guidelines, regulations, legal, and ethical standards as required for humans or animals.

RESULTS

Effects of two vibration stimuli on the relative peak torque of knee flexor and extensor groups

The relative peak torque (PT/BW) is an index reflecting the relative maximum force of the lower limb flexor B group T and extensor group contraction. After the experiment, the relative peak torques of the left and right knee flexor and extensor muscles of the subjects in groups I and II increased to varying degrees, in group I, the left and right paramuscularis of the knee joint increased by 10.5% and 9.88%, respectively, while the left and right flexor muscles of the knee joint increased by 6.30% and 9.30%, respectively; In group II, the extensors increased by 19.66% and 19.88% ($P<0.01$), respectively, and the flexors increased by 19.30% and 23.30% ($P<0.01$). Compared between groups, the increase in peak torque was significantly different ($P<0.01$). (Table 2)

Influence of two vibration stimuli on the ability of knee flexors and extensors to perform fast function

In this study, the rapid one-time maximum work power (PP) was used to reflect the ability of the athlete's knee joint to perform work quickly. According to Table 3, after the experiment, the fast single maximum work power of the left and right knee flexors and extensors of the subjects in group I and group II has been improved to varying degrees, among them, there was a significant difference in the increase of the maximum working power of the flexor and extensor group before and after the experiment in group I ($P<0.05$), and there was a very significant difference in group II ($P<0.01$). Compared between groups, there was a significant difference in the increase of single maximum working power ($P<0.05$).

The possible mechanism of the effect of two vibration stimuli on the relative peak torque of the knee flexor and extensor groups

The relative peak torque is used as the evaluation index of the isokinetic test, which reflects the maximum contraction force of the muscle (group). In this study, the maximal contraction force of the left and right knee flexors and extensors of the two groups increased, among which the increase of the maximum contraction force of the muscle group in group II was significantly greater than that in group I, and there was a significant difference between the groups. This result shows that under the same amplitude, vibration stimulation with relatively high vibration frequency can have a better effect on the maximum contraction force of the muscle (group). As an external stimulus, vibration stimulation has its particularity compared with traditional strength training methods in strength training. Vibration stimulation can produce acceleration, and the phenomenon of "overweight" and "weightlessness" caused by acceleration makes the load change constantly in actual exercise. According to N=G+ma, in the "overweight" stage, the load that athletes bear is far greater than the actual load. At the same amplitude, the faster the vibration frequency, the greater the acceleration, and the greater the load on the muscles during vibration training, the more motor units a muscle recruits during actual exercise, the more pronounced the increase in muscle contraction force.

As can be seen from Table 4 in terms of neuromodulation, vibration stimulation, as an exogenous stimulus, can stimulate the proprioceptors of muscles, especially the excitability of primary muscle spindle afferent fibers.[10]

Table 1. Basic information of experimental subjects.

Group	N	Age	Height	Weight	Years
I	5	15.8±0.5	168.8±4.0	59.5±8	5.2±1.5
II	5	15.2±1.0	167.5±5.0	55.5±5	4.8±1.5

Table 2. List of changes in peak torque of left and right flexor and extensor muscles of knee joint (unit: N.m).

Muscle group	Group		Before experiment	After the test	Value added	Growth rate
Extensor muscles	I	left	300.7±19.4	331.2±25.3	30.5±31.2	10.5%
		right	299.5±24.4	328.2±30.8	28.7±31.5	9.9%
	II	left	265.8±30.8	317.7±36.4*	52.0±15.4△	19.7%
		right	268.5±17.1	321.0±26.1*	52.5±29.7△	19.9%
Flexors	I	left	149.3±20.9	158.2±20.4	9.0±7.4	6.3%
		right	151.7±24.0	165.3±23.5	13.5±10.3	9.3%
	II	left	135.0±17.3	161.2±23.5*	26.3±9.3△	19.3%
		right	139.3±19.9	171.0±19.4*	31.7±8.3△	23.3%

Note: Comparison before and after the experiment in the same group, *P<0.05, **P<0.01; comparison between groups after the experiment, ΔP<0.05, ΔΔP<0.01. (the same below)

Table 3. List of changes in fast single maximum work power of left and right flexor and extensor muscles of knee joint (unit: W).

Muscle group	Group		Before experiment	After the test	Value added	Growth rate
Extensor muscles	I	left	236.2±9.2	290.8±19.0	54.5±21.1	23.2%
		right	230.0±16.9	301.7±33.3	71.7±19.9	28.9%
	II	left	209.0±3.48	289.3±60.7	80.2±31.8△	37.8%
		right	197.8±28.4	276.7±61.3	79.0±35.0△	38.7%
Flexors	I	left	159.0±17.6	192.5±32.2	33.5±18.3	20.7%
		right	157.7±17.4	193.5±29.2	35.7±19.9	22.7%
	II	left	151.3±42.4	191.7±28.2	40.5±22.4△	30.7%
		right	156.0±46.2	203.3±33.1	47.3±19.0△	33.9%

Table 4. List of changes in total work of left and right flexor and extensor muscles of knee joint (unit: W).

Muscle group	Group		Before experiment	After the test	Value added	Growth rate
Extensor muscles	I	left	2000.0±163.3	2375.0±250.0*	375.0±95.7	18.6%
		right	1975.0±125.8	2375.0±359.4*	400.0±270.8	19.9%
	II	left	1750.0±331.6	2075.0±340.3*	325.0±50.0	19.0%
		right	1700.0±141.4	2125.0±263.0*	425.0±150.0	23.2%
Flexors	I	left	1300.0±270.8	1525.0±386.2*	225.0±125.8	16.7%
		right	1425.0±270.8	1675.0±359.4*	250.0±238.0	17.0%
	II	left	1158.7±249.3	1450.0±331.6*	291.3±176.9	26.0%
		right	1222.0±210.6	1500.0±244.9*	278.0±97.0	23.2%

DISCUSSION

In this study, after eight weeks of systematic training, the subjects in Group I and Group I both improved the fast single maximum work power of the left and right lateral flexor and extensor muscles of the knee joint to varying degrees, and the increase amplitude showed the same phenomenon as the relative peak torque, and there was a significant difference between groups. Vibration stimulation can increase the frequency of nerve impulses, synchronization is enhanced, which allows for faster mobilization of large C motor neurons, as a result, the activation of type I muscle fibers is accelerated, that is, under the same load stimulation, more motor units are recruited to participate in the work, resulting in an increase in the gradient of muscle contraction force, which enhances the ability of muscles to perform work quickly. Total work (TW) can reflect the overall functional ability in the process of muscle-like contraction, the improvement of total work reflects the improvement of the ability of the muscle to maintain a certain intensity load or movement quality to a certain extent, that is, the improvement of the muscle endurance level. In this study, according to the experimental results, the extensor strength was developed at the same time, and the flexor strength was also developed accordingly.

CONCLUSION

The whole body vibration stimulation is added to the anti-load strength training, which can effectively improve the training effect of the strength of the knee joint muscles. Vibration-stimulated strength training can effectively improve maximal and rapid strength and endurance levels of the knee muscles with relatively small loads. Under the same amplitude, sub-high frequency vibration stimulation can more effectively improve the maximum strength and rapid force of knee joint muscles than medium and low frequency vibration stimulation. Vibration-stimulated strength training can maximize active muscle strength at the same time, the strength of the antagonistic muscles has also been developed to a certain extent.

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