PROJECTION OF FATIGUE AND NEUROMUSCULAR CHANGES CAUSED BY DIFFERENT EXCISES

PROJEÇÃO DA FADIGA E AS ALTERAÇÕES NEUROMUSCULARES PROVOCADAS EM DISTINTAS ATIVIDADES FÍSICAS

PROYECCIÓN DE LA FATIGA Y LOS CAMBIOS NEUROMUSCULARES PROVOCADOS EN DIFERENTES ACTIVIDADES FÍSICAS

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ABSTRACT

Introduction: Athletes' muscles can be weakened by fatigue caused by excessive activity. This limitation compromises their functional capacity and professional performance. The competition's performance correlates positively with muscular quality of function. The changes analysis caused by different athletic activities in muscle contraction by noninvasive tensiomyography reflects the functional state of the muscles. Still, no experiments are adapted to verify the fatigue risk level. Objective: Verify the possible relationship between exercise and neuromuscular fatigue using noninvasive tensiomyography. Methods: 90 athletes were randomly selected in weightlifting, badminton, and athletics sports. Maximum radial displacement, contraction, delay, duration, and relaxation time indices were collected. Muscle fatigue detection was based on the empirical mode decomposition modeling method with the Rogers sensitivity fluctuation rate. All values were collected in the rectus femoris muscle before and after the exercises. They were statistically treated and compared (P<0.05). Results: All athletes showed a decline in maximum radial displacement values after exercise. It reveals that their muscles are in a considerable state of tension, especially in the track and field group (from 8.57±3.42mm to 5.43±2.14mm). However, the slightest change in delay time was observed in the weightlifting group (16.21±4.15ms initial versus 18.34±3.27ms final). Conclusion: Through tensiomyography technology, it is possible to obtain a relationship between exercise and neuromuscular fatigue, analyzing the physical activity effects in a noninvasive way. ***Evidence Level II; Therapeutic Studies - Investigating the result.***

Keywords: Sports; Athletic Injuries; Electrodiagnosis; Muscular Fatigue.

RESUMO

Introdução: A musculatura do atleta pode ser debilitada com a fadiga ocasionada pelo excesso de atividade. Essa limitação compromete sua capacidade funcional e desempenho profissional. O desempenho nas competições correlaciona-se positivamente com a qualidade da função muscular. A análise das alterações provocadas por distintas atividades atléticas na contração muscular pela tensiomiografia não invasiva reflete o estado funcional dos músculos, porém não há experimentos adaptados para verificar o grau de risco de fadiga. Objetivo: Verificar a possível relação entre exercício e fadiga neuromuscular utilizando tensiomiografia não invasiva. Métodos: 90 atletas foram selecionados aleatoriamente nos esportes de halterofilismo, badminton e atletismo. Foram coletados os índices de deslocamento radial máximo, tempo de contração, tempo de atraso, duração e tempo de relaxamento. A detecção de fadiga muscular foi baseada no método de modelagem da decomposição do modo empírico com o conceito de taxa de flutuação de sensibilidade de Rogers. Os valores dos três grupos foram coletados no músculo reto femoral antes e depois dos exercícios. Foram tratados estatisticamente e comparados(P<0,05). Resultados: Todos os grupos de atletas apresentaram um declínio nos valores de deslocamento radial máximo após o exercício. Isso revela que seus músculos estão em grande estado de tensão, especialmente no grupo de atletismo (de 8.57±3.42mm para 5.43±2.14mm). A menor alteração no tempo de atraso, porém, foi observada no grupo de halterofilismo (16.21±4.15ms iniciais contra 18.34±3.27ms finais). Conclusão: Através da tecnologia de tensiomiografia foi possível obter a relação entre exercício e fadiga neuromuscular analisando os efeitos da atividade física de forma não invasiva. ***Nível de evidência II; Estudos Terapêuticos - Investigação de Resultados.***

Descritores: *Esportes; Traumatismos em Atletas; Eletrodiagnóstico; Fadiga Muscular.*

RESUMEN

Introducción: La musculatura del deportista puede estar debilitada por la fatiga causada por una actividad excesiva. Esta limitación compromete su capacidad funcional y su rendimiento profesional. El rendimiento en las competiciones se correlaciona positivamente con la calidad de la función muscular. El análisis de los cambios provocados por las diferentes actividades deportivas en la contracción muscular mediante la tensiomiografía no invasiva refleja el estado funcional de los músculos, pero no existen experimentos adaptados para verificar el grado de riesgo de fatiga. Objetivo: Verificar la posible relación entre el ejercicio y la fatiga neuromuscular *mediante una tensiomografía no invasiva. Métodos: Se seleccionaron al azar 90 atletas de los deportes de halterofilia, bádminton y atletismo. Se recogieron los índices de desplazamiento radial máximo, tiempo de contracción, tiempo de retardo, duración y tiempo de relajación. La detección de la fatiga muscular se basó en el método de modelado de descomposición modal empírica con el concepto de tasa de fluctuación de la sensibilidad propuesto por Rogers. Se recogieron los valores de los tres grupos en el músculo recto femoral antes y después de los ejercicios. Se trataron y compararon estadísticamente (P<0,05). Resultados: Todos los grupos de atletas mostraron un descenso en los valores del desplazamiento radial máximo después del ejercicio. Esto revela que sus músculos están en un gran estado de tensión, especialmente en el grupo de atletismo (de 8,57±3,42mm a 5,43±2,14mm). Sin embargo, el menor cambio en el tiempo de retraso se observó en el grupo de levantamiento de pesas (16,21±4,15ms iniciales frente a 18,34±3,27ms finales). Conclusión: A través de la tecnología de la tensiomografía fue posible obtener la relación entre el ejercicio y la fatiga neuromuscular analizando los efectos de la actividad física de forma no invasiva.* ***Nivel de evidencia II; Estudios terapéuticos - Investigación de resultados.***

Descriptores: *Deportes; Traumatismos en Atletas; Electrodiagnóstico; Fatiga Muscular.*

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INTRODUCTION

This study analyzes the TMG signal parameters reflected by the athletes' muscles before and after training. In this way, parameters such as delay, contraction, maintenance, relaxation, and maximum amplitude can be determined.[1] This can help us analyze its muscle contraction state. This can truly and objectively reflect the functional state of muscles and the degree of fatigue risk. We divided 90 athletes into badminton groups, lift regrouping groups, and track and field groups according to their respective sports. We used TMG non-invasive measurement technology to measure the TMG signal parameters of the three athletes before and after training.

MATERIALS AND METHODS

General information

The 90 athletes are divided into groups according to the names of their respective sports. The number of athletes in each group participating in the study is equal.[2] The gender ratio of badminton players (male: female) is 16:14. The oldest is 23 years old, and the youngest is 17 years old; the gender ratio of weightlifting team athletes (male: female) is 17:13. The oldest is 23 years old, and the youngest is 18 years old. The gender ratio of athletes in the track and field group (male: female) is 18:12. The oldest is 22 years old, and the youngest is 17 years old.

METHOD

This research adopts an experimental method. The three groups of athletes were involved in related sports. Among them, the badminton group is aerobic exercise, which is reorganized into anaerobic exercise, and the track and field group is a mixed aerobic and anaerobic exercise.[3] Need to pay attention to the following matters during the test: 1) Pay attention to the position of the sensor probe. The position of the probe largely determines the accuracy of the test results. Each muscle test point of the athlete is to find the maximum displacement point during the active contraction of the muscle through structural anatomy. This is to ensure the accuracy of each measurement result. We can use a black marker to mark. 2) Position of electrode sheet. Due to differences in the size and shape of athletes' muscles, the probe should be placed at a 20-50mm distance from the electrode pads. We should select the same muscle and set the same distance for different athletes. 3) The displacement sensor mainly collects data by stimulating the athlete's muscles with electric current, so the setting of the electric current is extremely critical. Usually, the first current output is 20mA, and each time it is increased by 10mA. The interval time is 10s. After the parameter curve is stable, you can stop increasing the current.

There are four main steps for TMG data collection: the first step is to install the tripod and the mechanical frame. We install the displacement sensor on the mechanical frame and check whether the power supply of the electrical stimulation console has been connected.[4] Connect the console and the sensor and use the data cable as the carrier to connect the computer. Finally, connect the current output and insert the electrode sheet. The second step is to download the TMG test software and enter the relevant information of the tester. Finally, determine the muscles to be tested. The third step is to take the prone or supine position according to the specific requirements of the test. We let it relax the muscles and adjust the mechanical frame so that the sensor probe is perpendicular to the muscle belly. In this way, the maximum radial displacement of the athlete's muscles can be obtained. The fourth step is to set the console output current to complete the first data collection. After an interval of 10s, increase the 10mA current to measure the second data until the graph is stable.

Observation indicators

TMG measurement parameters mainly include the maximum radial displacement (Dm), contraction time (Tc), delay time (Td), duration (Ts), and relaxation time (Tr). Where Dm represents the maximum value of the lateral movement of the muscle when the current is stimulated,[5] this indicator is a manifestation of muscle tension. Tc represents the time it takes for the muscle contraction to reach its maximum value under the stimulation of external force. Td represents 10% of the overall movement time of the muscle under the stimulation. It shows the contraction response of muscles to external stimuli. Ts represent the duration of muscle contraction. Tr is a downward curve of 90% to 50%, which reflects the fatigue state of the muscles.

Muscle fatigue detection based on empirical mode decomposition modeling method

The surface EMG signal is a non-stationary time-series signal. The parametric model analysis will be limited.[6] The time series is composed of trend item $d(t)$, period item $p(t)$, and random interference item $r(t)$. The trend item can be regarded as the phenomenon of baseline drift during signal acquisition. The period term reflects the periodic changes of the signal. After separating the trend items, the remaining two items can be used for zero-stationary time series analysis.

$$x(t) = d(t) + p(t) + r(t) \quad (1)$$

$x(t)$ finite number of eigenmode components and a residual signal are decomposed iteratively using a filtering process based on cubic spline interpolation for signal A.

$$x(t)=\sum_{j=1}^{n} IMF_j(t)+c(t) \tag{2}$$

In formula (2), n is the number of decomposition IMF. $c(t)$ is the residual signal (trend term). Rogers proposed the concept of sensitivity fluctuation ratio (SVR). The SVR index is used to evaluate the sensitivity and concentration of the target parameter to the degree of fatigue. The numerator of this parameter is the characteristic parameter volatility, and the denominator is the characteristic parameter concentration.[7] The larger the fluctuation range of the characteristic parameter, the smaller its jitter, and the larger the SVR index value of this parameter. The better the characterization effect of fatigue. The formula for calculating the SVR index after normalizing the characteristic parameters is as follows:

$$SVR=\frac{Max(\hat{x})-Min(x)}{\sqrt{1/N\sum_{n=1}^{N}(\hat{x}_n-x_n)^2}} \tag{3}$$

In formula (3) N is the signal length. $\hat{x}$ represents the curve fitting result to the x true value. Here we take the first-order fit. After removing the trend term, it can be regarded as a stationary process by reconstructing the eigenmode components, and the time series model can be used for modeling and forecasting. The minimum residual variance determines the order of the model. The smaller the residual variance, the more reasonable the corresponding order. The residual variance S^2 is defined as

$$S^2=\frac{\sum_{i=k+1}^{N}[x(t)-\sum_{k=1}^{p}\varphi(k)x(t-k)]}{N-k} \tag{4}$$

$$r(k)=\frac{\sum_{t=1}^{N}[x(t)-\bar{x}][x(t+k)-\bar{x}]}{\sum_{t=1}^{N}[x(t)-\bar{x}]^2} \tag{5}$$

$$\varphi(k)=\begin{cases} r(1), & k=1 \\ \dfrac{r(k)-\sum_{j=1}^{k-1}\varphi(k-1,j)r(k-j)}{1-\sum_{j=1}^{k-1}\varphi(k-1,j)r(j)}, & 1<k\le p \end{cases} \tag{6}$$

In the formula $\bar{x}$ is the mean value. $\varphi(k)$ is the partial correlation coefficient. $r(k)$ is the autocorrelation coefficient.

Statistical methods

The TMG test index data of athletes involved in this research are analyzed by statistical software.[8] The TMG index is expressed as the mean difference. P<0.05 indicates that the data results are different.

RESULTS

Comparison of Dm values before and after the three groups of exercises

The Dm value of the three groups of athletes had little difference before training, but the DM value decreased to varying degrees after training.[9] The specific values are shown in Table 1 (P<0.05). After exercise, the Dm value of the three groups of athletes decreased in different ranges. This shows that their muscle tension has increased compared with that before exercise.

Comparison of Tc values and Td, Tr, and Ts values before and after the three groups of exercises

Table 2 shows the comparison of the Tc and Td values of the rectus femoris (RF) before and after the three groups of exercises.[10] The comparison of Tr and Ts values before and after the three groups of exercises is shown in Table 3 (P<0.05). Delay time, contraction time, maintenance time, and relaxation time all increased. The order of increase was the track and field group, the badminton group, and the reorganization.

Table 1. Comparison of Dm values before and after the three groups of exercise [$n(\bar{x}\pm s)$].

Group	n	Before training (mm)	After training (mm)
Badminton team	30	8.12±3.33	7.67±2.64
Reorganization	30	7.47±3.21	7.21±2.80
Athletics Team	30	8.57±3.42	5.43±2.14
P value		>0.05	<0.05

Table 2. Comparison of Tc and Td values before and after the three groups of exercise [$n(\bar{x}\pm s)$].

Group	n	Tc before training (ms)	Tc(ms) after training	Td before training (ms)	Td(ms) after training
Badminton team	30	22.41±6.34	31.87±3.67	15.14±5.13	21.18±3.15
Reorganization	30	21.54±5.12	24.61±4.11	16.21±4.15	18.34±3.27
Athletics Team	30	21.47±4.92	45.87±3.42	16.34±4.57	31.14±3.28
		>0.05	<0.05	>0.05	<0.05

Table 3. Comparison of Tr and Ts values before and after exercise [$n(\bar{x}\pm s)$].

Group	n	Tr(ms) before training	Tr(ms) after training	Ts before training (ms)	Ts(ms) after training
Badminton team	30	17.41±4.33	32.56±3.67	17.14±5.13	23.18±3.15
Reorganization	30	19.54±4.87	25.31±4.11	17.32±4.57	20.11±3.27
Athletics Team	30	20.47±4.92	43.18±3.42	18.18±4.38	34.12±3.28
P		>0.05	<0.05	>0.05	<0.05

DISCUSSION

Bone, bone connection, and skeletal muscle constitute the human body's movement system, playing a protective role. In the human motion system, muscles are equivalent to power devices. It is innervated by the nervous system, with the bone knot as the hub. It produces lever movement by contracting and pulling the attached bone.[11] The movement effect will have a direct impact on the human movement system. Athletes may deteriorate their muscles due to physiological aging of the human body and over-exercise, and their functional ability will eventually decrease their athletic performance. Therefore, athletes' competitive level and competition performance positively correlate with their muscle function level. In most studies, muscle fatigue is done by monitoring static or dynamic force. They use biochemical techniques to measure substrates, metabolites, or other chemicals or use electromyography (EMG), muscle torque generation, and shear wave ultrasound elasticity to evaluate them. Although the above method has achieved good results, it also has some technical defects. Therefore, in this study, the international advanced and mature non-invasive measurement technology (TMG) was used to measure the relevant parameters of the muscle belly reflecting the TMG signal before and after muscle training. In this way, the possible relationship between exercise and neuromuscular fatigue and the effect of exercise on muscle mechanics can be obtained.

This study showed that the DM values of the three groups of athletes all declined after exercise. This shows that his muscles are in a state of tension, especially in the track and field group. The DM value decreased most significantly. This shows that the more severe the muscle tension after exercise. At the same time, the various indicators of the athletes have improved to varying degrees after exercise (P<0.05).

CONCLUSION

Through the TMG non-invasive measurement technology, the possible relationship between exercise and neuromuscular fatigue and the effect of exercise on muscle mechanics can be obtained. This provides an important reference for sports training.

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