MEASUREMENT OF LOCAL CONSISTENCY OF THE WHOLE BRAIN AFTER AEROBIC EXERCISE BASED ON MAGNETIC RESONANCE IMAGING

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MEDIÇÃO DA CONSISTÊNCIA LOCAL DE TODO O CÉREBRO APÓS EXERCÍCIOS AERÓBICOS COM BASE EM IMAGENS DE RESSONÂNCIA MAGNÉTICA

MEDICIÓN DE LA CONSISTENCIA LOCAL DE TODO EL CEREBRO DESPUÉS DEL EJERCICIO AERÓBICO BASADA EN IMÁGENES DE RESONANCIA MAGNÉTICA

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ABSTRACT

Introduction: The rapid development of rs-fMRI in recent years can provide new scientific evidence of the plasticity of the child's brain. Objective: To reveal the effect of short-term moderate-intensity aerobic exercise on local consistency of brain function in children at rest, and to provide new evidence for elucidating the relationship between physical exercise and plasticity of children's brain. Methods: Using resting state functional magnetic resonance imaging (rs-fMRI) technology and local consistency (ReHo) analysis method to detect a 30-min short-term moderate-intensity aerobic exercise before and after children's brain function local consistency changes; using the Flanker task measurement Changes in children's executive function before and after exercise. Results: 1) A 30-min short-term moderate-intensity aerobic exercise made the children's bilateral posterior buckle back, left dorsolateral prefrontal lobe, left frontal medial gyrus, bilateral central posterior gyrus, left suboccipital gyrus, and tongue gyrus. 2) A 30-minute short-term moderate-intensity aerobic exercise improves children's executive function. 3) ReHo increases in bilateral posterior buckle gyrus, bilateral central parietal posterior gyrus, and left dorsal lateral prefrontal lobe are significantly associated with improved executive function. Conclusions: Short-term moderate-intensity aerobic exercise can improve brain plasticity and executive function by increasing local consistency of brain function in children at rest. ***Level of evidence II; Therapeutic studies - investigation of treatment results.***

Keywords: Exercise; Magnetic resonance imaging; Whole brain.

RESUMO

Introdução: O rápido desenvolvimento dos rs-fMRI nos últimos anos pode fornecer novas evidências científicas da plasticidade do cérebro da criança. Objetivo: revelar o efeito do exercício aeróbio de intensidade moderada de curta duração na consistência local da função cerebral em crianças em repouso e fornecer novas evidências para elucidar a relação entre exercício físico e plasticidade cerebral em crianças. Métodos: Usando a tecnologia de imagem de ressonância magnética funcional em estado de repouso (rs-fMRI) e o método de análise de consistência local (ReHo) para detectar exercícios aeróbicos de intensidade moderada e de curta duração 30 minutos antes e depois de alterações de consistência local na função cerebral das crianças; usando a medição de Flanker das mudanças na função executiva das crianças antes e depois do exercício. Resultados: 1) Um curto exercício aeróbico de 30 min de intensidade moderada fez com que as crianças se curvassem para trás, lobo pré-frontal dorsolateral esquerdo, giro frontal medial esquerdo, giro central posterior bilateral, giro suboccipital esquerdo e giro da língua. 2) Um exercício aeróbico de curta duração, 30 minutos e intensidade moderada melhora a função executiva das crianças. 3) Aumentos em ReHo no giro da fivela posterior bilateral, no giro parietal posterior central bilateral e no lobo pré-frontal lateral dorsal esquerdo estão significativamente associados à função executiva melhorada. Conclusões: O exercício aeróbico de intensidade moderada de curto prazo pode melhorar a plasticidade cerebral e a função executiva, aumentando a consistência local da função cerebral em crianças em repouso. ***Nível de evidência II; Estudos terapêuticos - investigação dos resultados do tratamento.***

Descritores: *Exercício físico; Imageamento por ressonância magnética; Cérebro inteiro.*

RESUMEN

Introducción: El rápido desarrollo de rs-fMRI en los últimos años puede proporcionar nueva evidencia científica de la plasticidad del cerebro del niño. Objetivo: Revelar el efecto del ejercicio aeróbico de intensidad moderada a corto plazo sobre la consistencia local de la función cerebral en niños en reposo y proporcionar nueva evidencia para dilucidar la relación entre el ejercicio físico y la plasticidad del cerebro de los niños. Métodos: uso de la tecnología de imágenes de resonancia magnética funcional (rs-fMRI) en estado de reposo y el método de análisis de consistencia local (ReHo) para detectar un ejercicio aeróbico de intensidad moderada a corto plazo de 30 minutos antes y después de los cambios de consistencia local de la función cerebral de los niños; utilizando la medición de Flanker de *los cambios en la función ejecutiva de los niños antes y después del ejercicio. Resultados: 1) Un ejercicio aeróbico de intensidad moderada y corta duración de 30 min hizo que los niños se doblaran hacia atrás, lóbulo prefrontal dorsolateral izquierdo, circunvolución medial frontal izquierda, circunvolución posterior central bilateral, circunvolución suboccipital izquierda y circunvolución de la lengua. 2) Un ejercicio aeróbico de intensidad moderada a corto plazo de 30 minutos mejora la función ejecutiva de los niños. 3) Los aumentos de ReHo en la circunvolución de la hebilla posterior bilateral, la circunvolución posterior parietal central bilateral y el lóbulo prefrontal lateral dorsal izquierdo se asocian significativamente con una función ejecutiva mejorada. Conclusiones: El ejercicio aeróbico de intensidad moderada a corto plazo puede mejorar la plasticidad cerebral y la función ejecutiva al aumentar la consistencia local de la función cerebral en niños en reposo.* ***Nivel de evidencia II; Estudios terapéuticos: investigación de los resultados del tratamiento.***

Descriptores: *Ejercicio físico; Imagen por resonancia magnética; Cerebro completo.*

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INTRODUCTION

At present, the plasticity of the brain has become the frontier and hotspots of multidisciplinary research, and functional magnetic resonance imaging (FMRI) is suitable for the positioning and quantitative study of the brain due to its advantages of non-invasive, high temporal and spatial resolution. So far, the selection of the plasticity index of the brain has only one side, which only involves the structural change of the brain area and the activation level of the relevant brain area in the task state. There is still a need for more comprehensive scientific evidence to support this view.[1]

In recent years, the rapid development of RS-FMRIs in recent years can provide new scientific evidence for revealing the new scientific evidence of the plasticity of the child's brain. Studies have confirmed that synchronization of spontaneous neuropathy is common. The increase in the recovery value of spontaneous neuropathy in healthy individual brain can be considered to be enhanced and optimized in the brain area, which means that the plastic change of the brain is active. Based on this, this study assumes:

A 30-min moderate-intensity aerobic exercise increases the local consistency of children's brain function.

This study intends to use a classic side-wing task to measure children's execution function (the brain's advanced cognitive function), and discuss the changes and execution functions of further administrative functions before and after a medium-intensity aerobic exercise in 30 minutes. Relationship interference. (2) The increase in the recovery of the brain sector related to children's administrative functions is related to improving implementation functions.

Many studies have confirmed the positive impact of exercise on children's cognitive functions, especially performing functions, initially through brain plasticity. (3) Comprehensive brain areas where short-term medium intensity aerobic exercise increases rest, which leads to brain plasticity and performance.

In summary, this study intends to explore the influence of short-term medium intensity aerobic exercise on children's restoration rest, and explore the relationship with the implementation function.

METHODS

Research object

After screening, 10 10-year-old children (5 males and 5 females) were recruited. Selection criteria: 1) No history of brain trauma and neurological diseases, no history of mental disorders and genetic diseases; 2) Good physical and mental condition; 3) Han nationality; 4) Right-handed; 5) Normal weight (BMI is within 16-20) ; 6) Normal intelligence (exclude children with IQ<90 by the Wechsler Intelligence Scale); 7) No attention deficit hyperactivity disorder symptoms (excluded by the attention and behavior assessment scale); 8) Visual acuity or corrected visual acuity> 0 8.8; 9) Meet the requirements of magnetic resonance scanning (checked by examination sheet of brain imaging center); 10) Sign informed consent. This experiment was approved by the Ethics and Human Protection Committee of the Brain Imaging Center of the State Key Laboratory of Cognitive Neuroscience and Learning in our university.

Research methods

Short-term moderate-intensity aerobic exercise program

Adopting domestic and foreign relevant research established children's moderate-intensity aerobic exercise standard: the individual's maximum heart rate (HR-max) of 60% to 69%, where HRmax is determined by the formula (HRmax=220-age). Carry out aerobic exercise on the power bike, the cycling rhythm is 30r/min, and adjust the resistance of the power bike according to the situation of the child to achieve moderate exercise intensity. Using the HR telemeter to monitor the exercise intensity, the HR target area that reaches the individual's moderate-intensity exercise load starts timing and exercises 30 minutes.

Executive function evaluation

The cognitive tasks designed by Chen Aiguo and others based on the classic Flanker task are used to measure children's executive function. There is a practice part before the test. When the subjects master it (the accuracy rate is ≥85%), they will enter the formal test. When the performance is response, the smaller the response time, the higher the level of children's executive function.

Rs-fMRI scanning and image processing

fMRI scan: The images were collected using a Siemens 3.0T magnetic resonance scanner from the Brain Imaging Center of the State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University. The scanning time of resting BOLED-fMRI is 8 min. The specific parameters are as follows: TR/TE=2000/30 MS, number of layers=33, layer thickness=3.0 mm, spacing=1 mm, flip angle 90°, acquisition matrix=64×64, FOV=200×200mm.

Image processing: rs-fMRI data pre-processing adopts DPARSF (software, the first 10-time images of each rs-fMRI data are removed to eliminate potential noise interference; time correction and head movement are performed on the remaining 230-time images Pre-processing for correction and spatial standardization. Head movement correction can obtain the horizontal head movement and rotation head movement pictures of the subjects in each time series. The data of the subjects whose translation range of head movement exceeds 2 mm or rotation exceeds 2 are excluded. The data of the subjects have not been removed. The spatial standardization uses the EPI standard template.

Local consistency (ReHo) analysis

In this study, DPARSF was used to filter the spatially normalized graphs, while removing linear drift, and calculating the KCC value of each voxel in the whole brain to obtain the KCC graph of each subject, that is, the ReHo graph. The KCC value of each voxel of the whole brain divided by the average value of the KCC values of all voxels of the whole brain was obtained to obtain a standardized ReHo chart, and then the normalized ReHo chart was smoothed by Gaussian half-height full width (FWHM=4mm) deal with.[2]

Assuming that there is a set of basis vectors in space R^N that is $\{\psi_i\}_{i=1}^{N}$. From the signal theory, any signal $X \in R^N$ can be linearly represented by this set of bases, namely:

$$X = \sum_{k=1}^{N} \psi_k S_k = \Psi S \qquad (1)$$

It can be seen from equation (1) that S is the projection of signal X on the Ψ domain, and it is another equivalent form of signal X. As shown in Figure 1. If there are only $K(K = N)$ coefficients in the S vector that are not zero or far greater than other coefficients, then X is said to K be compressible or sparse. At this time, K is the sparse transform domain of the signal, so the sparse expression $S = \Psi^T X$ of the signal X. Then, according to the non-correlation criterion in CS, design a measurement matrix Φ that is not related to the sparse domain Ψ, and then use this matrix to observe the sparse signal to obtain the measurement vector $Y = \Phi\Psi^T X$. Assuming $\Theta = \Phi\Psi^T$, then $Y = \Theta X$, and finally use the l_0 norm Solving X for number optimization problems, namely:

$$\min \left\| \Psi^T X \right\|_0 \; s.t. \Theta X = Y \qquad (2)$$

Because of $M < N$, this is an underdetermined equation. The solutions obtained for general underdetermined equations are not unique, but because X is sparse and Ψ and Φ satisfy the irrelevant nature, the original signal can be accurately recovered.

For simplicity, we first consider only those images that are sparse in the image domain itself, and measure their non-correlation. Suppose we sample the K space of the image to obtain the K space data set S. F_s represents the Fourier transform, and its adjoint matrix F_s^+ is a zero-filled inverse Fourier transform, then the point spread function is defined as

$$PSF(i,j) = F_s^+ F_s(i,j) \qquad (3)$$

At this time, the value of PSF at (i,j) indicates that the value of pixe i is interfered by the unit pulse pixel j during linear reconstruction. However, in fact, most MR images are not sparse in the image domain and need to be sparsely transformed. In this case, we use the TPSF concept, which is defined as:

$$TPSF(i,j) = \left(\Psi^+ F_s^+ F_s \Psi\right)(i,j) \qquad (4)$$

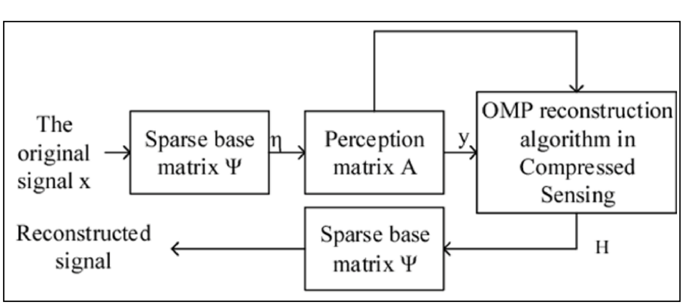

Figure 1. Schematic diagram of compressed sensing theory.

According to this concept, the correlation is given by the following formula:

$$\max_{i \neq j} \left| TPSF(i,j) \right| \qquad (5)$$

Obtain the maximum value of non-diagonal elements in TSPF and measure its non-correlation. As shown in Figure 2, a single non-zero point at position i in the wavelet domain, through multiple transformations, and finally back to the wavelet domain, this value becomes smaller and affects other values in the wavelet domain. Used to measure the non-correlation of the sampling trajectory. We want this value to be as small as possible, with statistics similar to noise.

Experimental procedures

This experiment is designed for complete subjects. All subjects need to participate in two experimental conditions, namely baseline and exercise. Baseline part: rest 20min, rs-fMRI scan, measure executive function. Exercise part: Perform a 30-min moderate-intensity bicycle exercise, rest, and when the HR recovers to within ±10% of the basic HR, perform an rs-fMRI scan to measure the executive function. Children complete the two-part experiment at the same time on different dates (interval time ≥ 7 days) to eliminate the effects of biological rhythm and sports fatigue. Children participated in the two-part experiment using the ABBA method to balance the potential sequence effects.

RESULTS

The brain regions are: the frontal lobe is mainly the left dorsolateral prefrontal lobe (DLPFC, peak MNI coordinate: 36, 12, 51; 29voxels, t=5.55), the left frontal medial gyrus (LM-FG, Medical Front Control, Dyna Map Norge, Root Map, Logic : 0, -18,48; 18voxels, t = 6.23); the main bilateral parietal back to the center (LPCG, Posterior Central Gyrus, peak MNI coordinate: -51, -18,45; 22voxels, t = 6.21), (LPCG, Posterior Central Gyrus, peak MNI coordinate: -48, -27,60; 27voxels, t = 7.39), (RPCG, Posterior Central Gyrus, peak MNI coordinate: 45, -24,66; 40voxels, t = 10.03); after bilateral cingulate cortex (LPCC, Posterior Cingulate Cortex, peak MNI coordinate: -9, -42, -12; 19voxels, t = 12.53), (RPCC, Posterior Cingulate Cortex, peak MNI coordinate: 12, -36, -18; 27voxels, t = 5.43); the temporal lobe is mainly the left midtemporal gyrus (LMTG, Middele Permall Gyrus, peak MNI coordinate: -63, -6, -9; 22 voxels, t=5.62), right supratemporal gyrus (RSTNet3, Calc3)., -6,3; 24voxels, t=6.27); the occipital lobe is mainly the left suboccipital gyrus (LIOG, Infinioir Occipital Gyrus, peak MNI coordinate: -39, -78, -9; 18voxels,) Lateral tongue gyrus (LLG, Lingual Gyrus, peak MNI cordionate: -18, -90, -12; 28voxels, t = 6.12. (Figure 3)

Changes of children's executive function before and after short-term moderate-intensity aerobic exercise

A paired sample t test was used to compare the differences in executive functions before and after exercise, and it was found that the measured value of the executive function after exercise (11.65±7.79) was significantly smaller than the measured value of the executive function before exercise (21.13±9. 72), t (9) =7.89, P<0.05, r2ppb=0.87.

It was found that there was a significant correlation between the bilateral posterior buckle gyrus, bilateral parietal central posterior gyrus, and left dorsolateral prefrontal lobe ReHo enhancement and changes in executive function behavior performance. (Table 1)

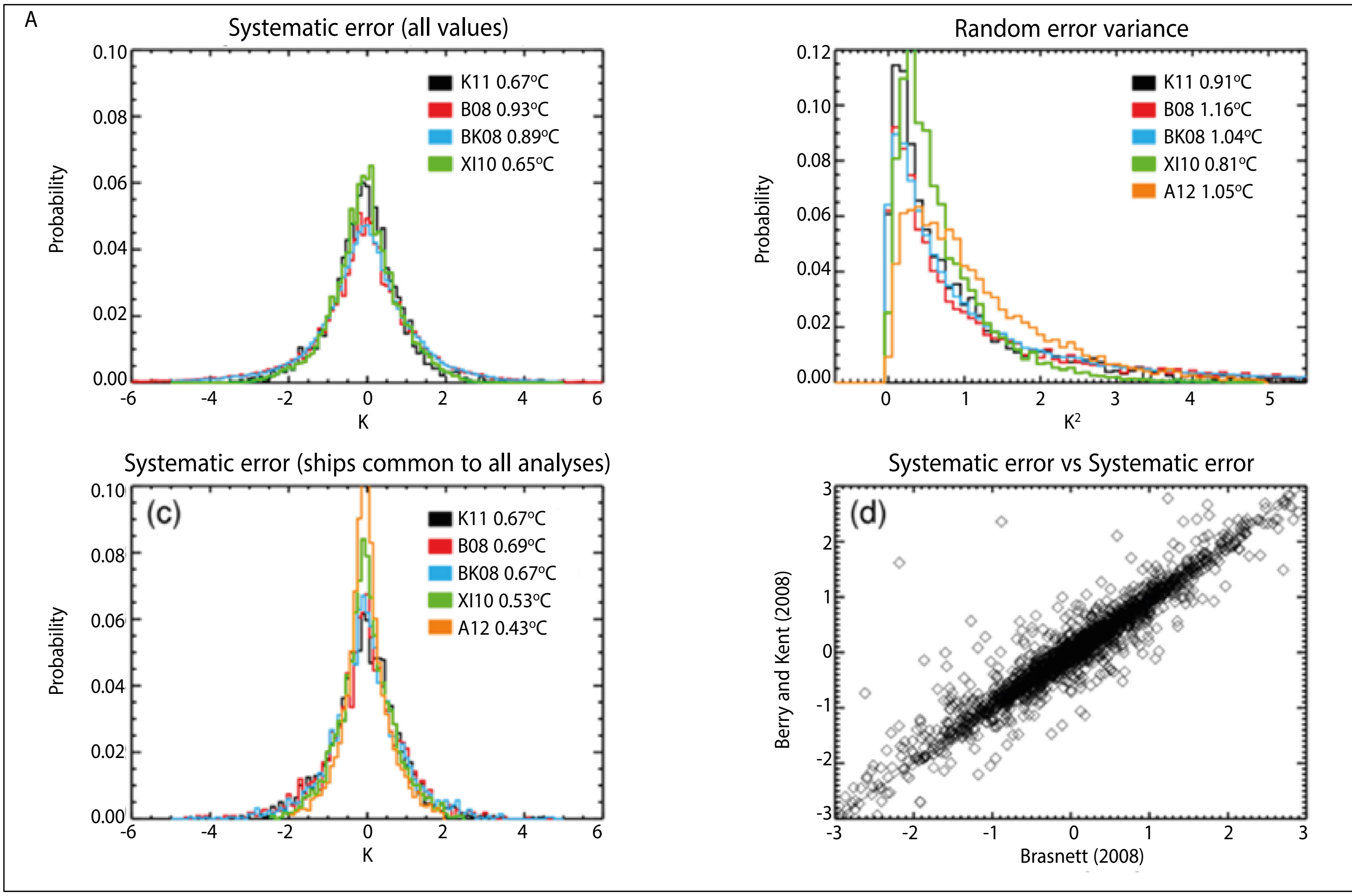

Figure 2. Measurement of non-correlation.

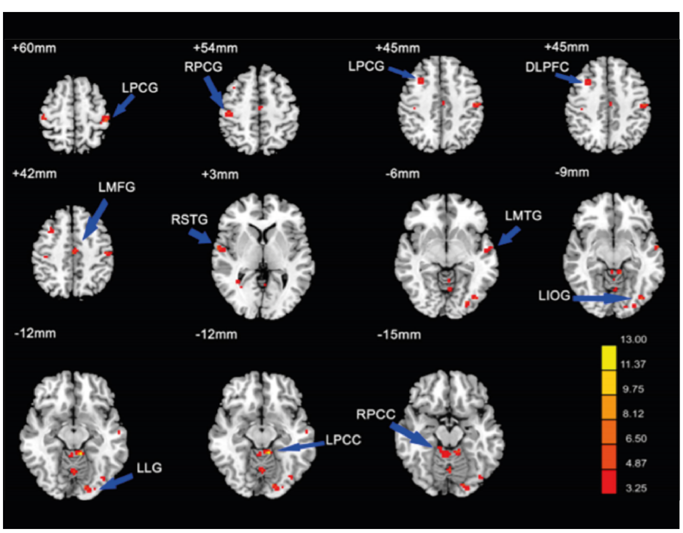

Figure 3. The results of the comparison between the children's resting state brain consistency in the post-test and pre-test of this study.

DISCUSSION

The effect of short-term moderate-intensity aerobic exercise on children's ReHo and executive function

This study found that children's performance in post-exercise exercise is significantly better than pre-test, indicating that the exercise intervention used in this study improves the child's executive function; this result is consistent with existing views in the field. The results of the study found that one 20-min moderate-intensity aerobic exercise (running table) had a positive effect on the executive function of normal and ADHD children. Studies have shown that short-term basketball dribbling training with different intensities can affect children's executive function.[3,4]

Table 1. List of relevant analysis results of brain regions with increased ReHo value caused by short-term moderate-intensity aerobic exercise and changes in executive function.

Prefrontal lobe	Dorsolateral prefrontal lobe (9)	left	36	12	51	29	5.55	0.74**
Top leaf	Central back (4)	right	45	-24	66	40	10.03	0.84**
Top leaf	Central back (4)	left	-51	-18	45	22	6.21	0.92**
Buckle back	Rear buckle leather (30)	left	-9	-42	-12	19	12.53	0.87***
Buckle back	Rear buckle leather (30)	right	12	-36	-18	27	5.43	0.76*

Relationship between ReHo change and executive function change

The increase in the ReHo value of the brain area can be regarded as a sign of the maturity and perfection of the brain neural network to which it belongs. Therefore, the brain functions involved in these brain neural networks are better. Studies have shown that the level of spontaneous neural activity at rest can predict the executive function of an individual. Compared with individuals with poor executive function, individuals with better executive function have a higher level of control and attention network activity at rest.[5]

The relationship between short-term moderate-intensity aerobic exercise, ReHo enhancement and children's executive function improvement .Short-term medium intensity aerobic exercise can improve the performance of children. Is it a brain mechanism related to the REHO signal with the brain area of the function network? Existing brain plasticity theory improves cognition of exercise indicates that the knowledge of cognitive improvement is the result of the plasticity of the relevant brain regions caused by the movement. Research on short-term aerobic exercise supports this theory.[6,7]

CONCLUSION

A 30-minute moderate-intensity aerobic exercise increased the local consistency of brain function in children at rest, improved brain plasticity and improved executive function. The results of the study provided a new experiment to fully reveal the relationship between sports and the plasticity of children's brains. evidence.

All authors declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: Each author made a significant personal contribution to the manuscript. Feng Wang analyzed and explained the impact of short-term moderate-intensity aerobic exercise on the local consistency of resting children's brain function, and provided new evidence for clarifying the relationship between physical exercise and children's brain plasticity. Ailuan Huang uses the standard FMS test to collect data, and uses the receiver's operating characteristics to track the biological image data (ROC) curve of Chinese rugby players' non-contact injury, probability (OR) and other statistical methods to evaluate FMS test related indicators, and it is The main contributor to the manuscript. The final manuscript read and approved by all authors.

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