CARDIOVASCULAR MONITORING IN THE TRAINING OF LONG-DISTANCE RUNNERS

MONITORAMENTO CARDIOVASCULAR NO TREINO DE ATLETAS CORREDORES DE LONGA DISTÂNCIA

MONITORIZACIÓN CARDIOVASCULAR EN EL ENTRENAMIENTO DE CORREDORES DE LARGA DISTANCIA

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ABSTRACT

Introduction: Strengthening research on cardiac function risk assessment in running sports is beneficial to prevent sport-related cardiovascular injuries and sudden deaths in sports. Objective: To study changes in cardiovascular response in athletes after long-distance running. Methods: Changes in cardiovascular response indicators of long-distance runners before and after the five-kilometer race were monitored. Analyzed indices included heart rate, blood pressure, hemoglobin, and a cardiac function index. Results: There were no statistically significant differences in heart rate, blood pressure, and hemoglobin levels before and after the long-distance run (P>0.05). There was no significant difference in the proportion of sinus arrhythmia before and after long-distance running (P>0.05). Conclusion: Long-distance running did not cause abnormal changes in blood indicators. No cardiovascular discomfort or changes in the electrocardiogram, heart rate, blood pressure, hemoglobin, and cardiac function index were reported. These young men were not enlisted, despite undergoing adaptive training. In conclusion, the five-kilometer run is safe for young men in the reserve. ***Evidence Level II; Therapeutic Studies - Investigating the result.***

Keywords: Running; Cardiology; Athlete; Sports.

RESUMO

Introdução: O fortalecimento da pesquisa sobre a avaliação de risco da função cardíaca nos esportes de corrida é benéfico para prevenir lesões cardiovasculares e mortes súbitas relacionadas com o esporte. Objetivo: Estudar as alterações na resposta cardiovascular dos atletas após corridas de longa distância. Métodos: Foram monitoradas alterações nos indicadores de resposta cardiovascular dos corredores de longa distância antes e depois da corrida de cinco quilômetros. Entre os índices analisados estão a frequência cardíaca, pressão arterial, hemoglobina e índice de função cardíaca. Resultados: Não houve diferenças estatisticamente significativas na frequência cardíaca, pressão arterial, e níveis de hemoglobina antes e depois da corrida de longa distância (P>0,05). Não houve diferença significativa na proporção de arritmia sinusal antes e depois da corrida de longa distância (P>0,05). Conclusão: A corrida de longa distância não causou mudanças anormais nos indicadores sanguíneos. Não foram relatados desconfortos cardiovasculares ou alterações em eletrocardiograma, ritmo cardíaco, pressão arterial, hemoglobina e índice de função cardíaca. Esses jovens não estavam alistados, apesar de passarem por treino adaptativo. Conclui-se que o treino em corridas de cinco quilômetros é seguro para homens jovens na reserva. **Nível de evidência II; Estudos Terapêuticos - Investigação de Resultados.**

***Descritores**: Corrida; Cardiologia; Atleta; Esportes.*

RESUMEN

Introducción: Reforzar la investigación sobre la evaluación del riesgo de la función cardíaca en los deportes de carrera es beneficioso para prevenir las lesiones cardiovasculares relacionadas con el deporte y las muertes súbitas en el mismo. Objetivo: Estudiar los cambios en la respuesta cardiovascular de los atletas después de correr largas distancias. Métodos: Se han monitorizado los cambios en los indicadores de respuesta cardiovascular de los corredores de larga distancia antes y después de la carrera de cinco kilómetros. Entre los índices analizados estaban la frecuencia cardíaca, la presión arterial, la hemoglobina y el índice de función cardíaca. Resultados: No hubo diferencias estadísticamente significativas en la frecuencia cardíaca, la presión arterial y los niveles de hemoglobina antes y después de la carrera de larga distancia (P>0,05). No hubo diferencias significativas en la proporción de arritmia sinusal antes y después de la carrera de larga distancia (P>0,05). Conclusión: Las carreras de larga distancia no causaron cambios anormales en los indicadores sanguíneos. No se registraron molestias cardiovasculares ni cambios en el electrocardiograma, la frecuencia cardíaca, la presión arterial, la hemoglobina y el índice de función cardíaca. Estos jóvenes no se alistaron, a pesar de que se sometieron a un entrenamiento de adaptación. Se concluye que el entrenamiento en carreras de cinco kilómetros es seguro para los jóvenes de la reserva. **Nivel de evidencia II; Estudios terapéuticos - Investigación de resultados.**

***Descriptores:** Carrera; Cardiología; Atleta; Deportes.*

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INTRODUCTION

Many colleges and universities have successively canceled 3km and 5km long-distance running and other high-volume sports in recent years. The reason is to prevent the occurrence of sudden sports deaths.[1] This has caused widespread concern in society. Sudden exercise-induced death is a non-traumatic death that occurs during or immediately after exercise and occurs within 6 hours. Groups younger than 20 and 20-29 years old have a high incidence of sudden exercise-related deaths in China. Most of the sudden death athletes abroad are younger than 35 years old. The sports of sudden sports death are mainly running and military training. About 80% of sudden exercise-related deaths are sudden cardiac deaths, and the cause is closely related to exercise-related cardiovascular damage. Autopsy reports from the sports and military systems show that most of the sudden exercise deaths do not have organic heart disease. Therefore, strengthening the research on the risk assessment of cardiac function for running-based sports is beneficial to prevent sports-related cardiovascular injury and sudden sports death.[2] Brain natriuretic peptide (BNP) is currently the most important marker for understanding heart function. Cardiac troponin I (cTnI) has good sensitivity and specificity in detecting exercise-related myocardial injury, and it is widely used to assess this type of myocardial injury. Electrocardiogram (ECG) is the most commonly used and basic testing method for checking and evaluating heart function. This study observed the changes in blood BNP and cTnI levels and ECG of 63 young people before and after the 5km long-distance running and conducted medical observations.

METHOD

Research object

The article focuses on 63 young men who participated in a 5km long--distance race. There was no fever, diarrhea, or training injury within 2 weeks. The age ranged from 18 to 35 years old, with an average of (23.9±4.3), 17 people under 20 years old, 28 people 21-25 years old, 11 people 26-30 years old, and 7 people 31-35 years old. On the afternoon of June 15, 2020, a 5km long-distance race will be carried out according to the daily training status.

Determination of plasma BNP and serum cTnI

10 mL of venous blood was drawn for testing 10 minutes before the long-distance running and 5 minutes after the long-distance running.[3] We use the chemiluminescence method to measure BNP level (normal value 0-263μg/L). The level of cTnI was determined by the immunofluorescence method (normal value 0-0.4μg/L).

ECG inspection and analysis

The standard 12-lead ECG in the supine position was recorded with a 12-lead electrocardiograph 10 minutes before and 5-10 minutes after the long-distance running.[4] ECG measurement, diagnosis, and analysis by a dedicated person according to diagnostic criteria, including heart rate, sinus bradycardia, sinus tachycardia, sinus arrhythmia, and ST-segment depression.

Medical observation

Record the number and time of chest tightness, chest pain, palpitations, dizziness, headache, syncope, and fatigue during exercise and 1 day after exercise.

Modeling of Coronary Circulation in Heart Disease

The relationship between blood pressure and volume of the ventricle is usually used to describe the systolic function of the ventricle. The mutual capacitance $E(t)$ represents myocardial elasticity when building the left ventricular analog circuit model. $E(t)$ is defined as the ratio of intraventricular pressure to volume, a time-varying elastic function.[5] The time-varying elasticity function is mainly composed of the active elasticity $E(t)$ and the passive elasticity E_p of the left ventricle. The active elasticity $E_a(t)$ of the left ventricle can be obtained by the following equation according to the work of *Suga* et al.:

$$
\begin{aligned}
&t_n = \frac{t}{0.2 + 0.1555 \times T_{cycle}} \\
&E_n(t_n) = 1.553\,174 \times \frac{(t_n/0.7)^{1.9}}{1+(t_n/0.7)^{1.9}} \times \frac{1}{1+t_n/(1.173\,474)^{21.9}} \\
&E_a(t) = E_{\max} \times E_n(t_n)
\end{aligned} \tag{1}
$$

Time-varying elastic function:

$$E(t) = E_a(t) + E_p \tag{2}$$

In the above formulas, t_n is the normalized time. T_{cycle} is the cardiac cycle. $E_n(t_n)$ is the normalization function of $E_a(t)$. $E_{\max}$ is the maximum active elasticity of the left ventricle. The following formula can calculate the left ventricular pressure at different volumes:

$$P_{1v} = E(t)(V_{1v} - V_d) - E_p(V_0 - V_d) \tag{3}$$

V_0 is the tension-free end-diastolic volume of the left ventricle and V_d is the tension-free end-systolic volume of the left ventricle.

Statistical methods

We use the CHISS2004 version of statistical software for data analysis, and the measurement data conforming to the normal distribution are expressed as mean ± standard deviation.[6] Paired t-test was used. Non-normally distributed, the median represents measurement data. Wilcoxon signed-rank test with the paired design was used. The count data is expressed as a percentage, and the χ2 test is used. P<0.05 indicates that the difference is statistically significant.

RESULTS

Blood BNP and cTnI levels of young men before and after long-distance running

The blood BNP level of each youth before and after the long-distance running was lower than 263μg/L, and the blood cTnI level was lower than 0.4μg/L (Table 1).

Comparison of ECG results of young men before and after long-distance running

The heart rate increased significantly after long-distance running (P<0.01) (Table 2). There was no atrial or ventricular arrhythmia and heart block in the ECG before and after the long-distance running, and no left ventricular high voltage and high T wave.

Medical observation

Sixty-three youths had no chest tightness, chest pain, palpitations, dizziness, headache, fainting, and fatigue during exercise and 1 day after exercise.

DISCUSSION

BNP mainly comes from the ventricle. Because the nucleic acid sequence of BNP contains the unstable TATTTAT sequence and its messenger RNA

Table 1. Comparison of blood BNP and cTnI levels of young men before and after 5km long-distance running.

Project	BNP (μg/L)	cTnI (μg/L)
Before running	15.90 (8.40, 34.85)	0.010 (0.005, 0.040)
After running	20.30 (11.40, 30.40)	0.020 (0.007, 0.050)
u value	0.481	0.895
P value	0.631	0.371

Table 2. Comparison of electrocardiogram results of young men before and after 5km long-distance running.

Project	Before running	After running	t/χ2 value	P
Heart rate (times/min)	61.7±8.6	103.1±11.4	23.021	<0.001
Sinus bradycardia [n (%)]	25(39.7)	0	31.188	<0.001
Sinus tachycardia [n (%)]	0	29(46.0)	37.670	<0.001
Sinus arrhythmia [n (%)]	3(4.8)	0	1.366	0.243
ST segment moves down [n (%)]	0	1(1.6)	0.000	1

switches faster. This allows BNP to be synthesized instantaneously. BNP in the blood can reflect the ventricular volume and pressure load proportionally. And it can sensitively and specifically reflect the degree of ventricular dysfunction.[7] In this study, the median blood BNP level was 15.90μg/L before long-distance running and 20.30μg/L after. This shows that the 5km long-distance running did not cause abnormal blood BNP levels in 63 young people. Cardiac troponin (cTnI and cTnT) is a protein present in atrial and ventricular myocytes. It is only expressed in the myocardium and has a high degree of tissue specificity. In this study, the median cTnI level was 0.010μg/L before long-distance running and 0.020μg/L after long-distance running.

ECG is an objective indicator that reflects the production, conduction, and recovery process of heart excitement, and its detection results can effectively reflect the basic functions of the heart. Sinus bradycardia is common in healthy young people. Sinus bradycardia is often accompanied by sinus arrhythmia.[8] Healthy people may have sinus tachycardia during physical activity. In this study, the proportion of young men with sinus bradycardia after 5km of long-distance running was lower than before (P<0.01). The reason is the adaptable physiological changes of the heart to long-term training. Sinus bradycardia is caused by increased vagus nerve tension. The heart rate increased significantly after long--distance running, and the proportion of sinus tachycardia was higher (P<0.01). The reason is that exercise leads to increased heart rate and sinus tachycardia caused by the excitement of the sympathetic nervous system, which is a normal physiological change of the human body.

Although there is no precise definition of myocardial injury caused by high-intensity exercise, many sports medicine studies have confirmed the myocardial injury caused by strenuous exercise. Inappropriate exercise can adversely affect the cardiovascular system. Mainly include arrhythmia, myocardial damage, changes in the shape and structure of the heart, heart failure, coronary artery disease, and even death.[9] The occurrence of cardiac events, including sudden death, has caused irreparable losses and serious adverse effects on the country, collectives, families, and individuals.

At present, there is still a lack of unified understanding of the early diagnosis criteria for sports-related cardiovascular injuries. Based on the monitoring of cardiovascular function, there are two traditional methods for timely detection of sports-related cardiovascular injuries: 1) Subjective assessment of fatigue from work. Among them, chest tightness, shortness of breath, palpitations, headaches, nausea, and other uncomfortable symptoms may also be normal reactions during exercise. 2) Objective evaluation methods include blood pressure, heart rate, blood oxygen, ECG, and cardiac ultrasound monitoring.[10] The changes in cardiac structure and function caused by training include changes in heart rate, high left ventricular voltage, abnormalities in cardiac repolarization, ischemic changes, abnormalities in the origin of agitation, and myocardial wall thickening. Whether physiological changes or pathological changes are difficult to define, these methods have failed to achieve satisfactory results in timely detection of exercise-related cardiovascular injuries and the prevention of cardiac events. New myocardial injury markers represented by blood BNP and cTnI have the advantage of early assessment of changes in cardiac function and myocardial micro-injury. This has become an important indicator of exercise-related cardiovascular injury.

How much long-distance running may cause, damage to the heart has been the focus of sports medicine in recent years. Some scholars compared the blood BNP levels of 60 healthy soldiers before and after 10km long-distance running and found that the blood BNP levels increased significantly immediately after training. Some scholars have found that 70% of young athletes' cTnT after 21km runs is higher than acute myocardial infarction's diagnostic value. Some scholars reported that 40% of 60 adult athletes had blood cTnT levels exceeding the critical diagnostic value of myocardial infarction after a marathon. Some scholars tested the blood BNP and blood cTnT levels of 10 athletes before and after completing the 50km ultra-long marathon and found that the blood BNP and blood cTnT levels increased significantly after the exercise. And the difference of BNP before and after exercise is positively correlated with the difference of cTnT. These studies show that running more than 10km may lead to increased blood BNP and cTnT levels.

In addition, lack of adaptive exercise is an important factor in sports-related cardiovascular injury. Some scholars have reported that the recruits may have ECG abnormalities in the first 5km trail running. The content includes arrhythmia and ST-T changes. The blood cTnI of some recruits increased immediately after a 5km physical training and 4h after exercise. In comparison, the test soldiers did not experience obvious heart damage after 1 week of adaptation and then 5km physical training. The reason is the lack of adaptive exercises among the newly enlisted soldiers and the incoordination of the body's sympathetic and vagus nerves. This leads to dangerous electrical activity of myocardial cells and increases myocardial vulnerability.

CONCLUSION

The 5km long-distance running did not cause abnormal changes in the three objective indicators of blood BNP, cTnI and ECG, and did not cause discomfort in the cardiovascular system. The reason is that the young and middle-aged in this study did not have newly enlisted soldiers, and they had all undergone adaptive training. The young man's mental reserve can meet the exercise load of a 5km long-distance running.

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