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Short Communication

Effect of Exercise Intensity on Human Immune System under Different Environments

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ABSTRACT

The objective of this study was to explore the influence of exercise intensity on human immune system under different environments. Sixty physical education students were enrolled as research objects and divided into control group (normal oxygen group), hypoxia group, and high-altitude group. Each group was given the same exercise intensity. Venous blood was collected before and after each test to determine changes in Immunoglobulin A (IgA), immunoglobulin G (IgG), immunoglobulin M (IgM), IL-2, WBC, natural killer (NK) cell activity, C3, C4, CH50 and body weight. We found that the levels of IgA, IgG, and IgM in the three groups decreased; while IL-2 levels increased, and the order can be ranked as control group>hypoxic group>high altitude group ($P<0.05$). Moreover, WBC, C3, C4, CH50, and NK cell activity of three groups decreased, and the comparison result was control group>hypoxia group>high altitude group ($P<0.05$). The body weight also decreased but followed the gradation of the high-altitude group>hypoxic group>control group ($P<0.05$). We conclude that different oxygen environment exercise intensities have different effects on different immune functions under the basic state, and have significant and independent effects on the activities of WBC and NK cells, which can be used as for monitoring of effective immune indicators.

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Immunoglobulin plays a crucial role in the immune system. As an animal protein with antibody activity, it neutralizes the toxicity of bacterial toxins, blocks the invasion of pathogens, binds to viral antigens and makes the virus lose its ability to infect host cells, and can cross the mucosa to stimulate specific immune responses (Feng *et al*., 2013; Yi, 2004). Studies have reported that different ambient temperatures have a key regulatory effect on the body's immune system. Cold stimulation to the human body will lead to vasoconstriction and blood pressure increase, restrict oxygen delivery, and damage the lethality of multinucleated cells, eventually leading to immunosuppression (Yu, 2020). High and low-intensity exercise affects the body's immune system to varying degrees. The combination of temperature and intense exercise may amplify the body's immunosuppressive effects. Immunosuppression is the cause of athletes' diseases, and one of the main reasons why fatigue is difficult to eliminate is that the production of athletes' immune suppression system will affect the training effect and the development of competition level (Zhang and Liu, 2019; Zhang *et al*., 2019). Therefore, this research takes steps to determine the immunoglobulin A (IgA), immunoglobulin G (IgG), immunoglobulin M (IgM), IL - 2, the change of the WBC, natural killer (NK) cell activity, C3, C4 and CH50 and weight change under different temperature, and explores the effects of different exercise intensity on the body's immune system, in order to provide theoretical reference for its sports.

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Materials and methods

In this study, 60 physical education students in the university were selected as research objects and randomly divided into control group, hypoxia group and high-altitude group, each containing 20 cases. The training time exceeded 5h per week. Inclusion criteria were good health, no respiratory or cardiovascular diseases, no endocrine system diseases. The exclusion criteria were heart disease, renal complications, long-term smoking and other bad habits. The basic information of research objects is shown in Table I.

For studying the effect of intensity exercise, strenuous exercise or intake of alcohol, coffee and drugs were avoided within 24h before the test. Each test was conducted 2h after breakfast. No fluid infusion was allowed during the test. The room temperature was controlled at 12±1°C and the humidity was controlled at 40±3% for each test. During the experiment, subjects in each group were managed in a centralized and closed way. Activities such as diet, accommodation, living time and even leisure time were maintained consistently in each group to reduce differences between groups. In addition, the enrolled subjects played games (mainly board games) in their spare time to keep them happy. The experiment was conducted six days a week, for four consecutive weeks. The total amount of exercise per day was 5h, including walking slowly for 1h from 7:30 to 8:30 AM, exercising for 2h from 10:00 to 12:00 AM, and exercising for 2h from 03:00 to 05:00 PM. Exercise methods included fast walking, jogging, table tennis, badminton, swimming, aerobic exercise, strength cycling and so on. Exercise intensity control: During exercise, heart rate was monitored every 10 min to assess exercise intensity and control the range of exercise intensity rates within the target heart. Target heart rate range during exercise was determined according to Karvonen formula:

Target heart rate range = resting heart rate + heart rate reserve * exercise intensity range

heart rate reserve = maximum heart rate - resting heart rate

maximum heart rate = 220-age

The exercise intensity chosen for this study was 40% heart rate reserve, corresponding to low-intensity aerobic endurance training.

The enrolled students were divided into control group (referred to as the constant oxygen group), hypoxia group (referred to as the low oxygen group), and plateau group (referred to as the plateau Group at an altitude of about 2300m in Toba National Plateau Sports Training Base in Qinghai), according to different oxygen environments. The experiment lasted for 4 weeks, with 5h of exercise per day, 6 days of exercise per week. The constant oxygen group exercised and lived in the plain environment every day. The hypoxic group lived in a hypoxic environment simulated at an altitude of 2300m from 19:00 to 7:00 the next morning, and exercised for 2h in the hypoxic environment simulated at an altitude of 2300m during the day. The other arrangements were the same as that of the control group. The plateau group exercised and lived every day in Toba National Plateau Sports Training Base in Qinghai province.

Height was measured by a tester (XinDongHuaTeng GJ-II, Beijing). Body weight was measured by an electronic scale (OMRONHBF-356, Japan). Immunoglobulin IgG, IgA and IgM were determined by immunoturbidimetry (Hitachi, 7180, Japan). The activity of NK cells was determined by lactate dehydrogenase release method. Plasma level of IL-2 was measured by immunoradiometric analysis (SN-69B type intelligent free γ measurement instrument). White blood cell count (WBC) Advia 120 Hematology System (Shanghai Bayer Company) was used for blood cell detection.

All experimental data were statistically processed by SPSS 17.0 software. The measurement data were expressed as θ, ANOVA was used for comparison among the three groups, SNK-Q test was used for pair-wise comparison among the groups, and repeated measurement data were analyzed by repeated measurement analysis of variance. The difference was considered statistically significant when $P<0.05$.

Results and discussion

Table II shows the effect of different oxygen levels on IgA, IgG, IgM, WBC, NK, C3, C4, CH50, and IL-2 levels of patients and their body weights in the three groups. The comparison of levels of all parameters among the three groups showed the gradation high altitude group<hypoxic group<control group (P<0.05).

Immunoglobulin is a kind of protein that is formed after the body is stimulated by an antigen substance and has a specific binding reaction with the antigen. Its electrophoretic movement is mainly located in the γ region. There are five categories of human Ig, namely IgA, IgG, IgM, IgE and IgD (Su *et al*., 2012; Meng, 2018). Since IgA, IgG and IgM account for a large proportion, clinical testing of IgA, IgG and IgM is also a commonly used indicator in sports training. IgA accounts for 10%~20% of the serum Ig content. As IgA mainly exists in external secretion, it plays an important role in the first line of anti-infection defense, which can be called local antibody. IgG is the most abundant immunoglobulin in the serum, accounting for about 3/4~4/5. According to the difference of antigenicity of heavy chain (γ chain), IgG is the main antibody against bacteria, antivirus and antitoxin in the serum, and can fix complement C3, C4 and CH50. IgM accounts for 6% of the serum Ig content. Regarding its structure, two heavy chains and two light chains to form a monomer, and then five monomers to form a pentamer macromolecule. This molecular form makes IgM more superior than other Ig classes in binding complement, and it has a strong ability to activate the traditional complement pathway after binding with antigen, thus contributing to a strong cytotoxic activity and cytolysis activity (Han *et al*., 2017; Wang and Hao, 2012; Gleeson *et al*., 2012; Cui *et al*., 2013). IgM is mainly found in the blood vessels. It is the first line antibody against intravascular infection and plays an important role in preventing sepsis. A considerable amount of IgM is often present in the secretion. This study mainly focuses on the effect of exercise intensity on human immune system in different environments.

Table I. Basic information of research objects.

Group	Number of cases	Sex (n%)		Average age (year)	BMI (kg/m^2)	Body weight (Kg)	Weekly training h (h)
		Male	Female				
Control group	20	12(74.42)	8(25.58)	21.16±0.34	21.52±2.26	70.52±3.25	7.95±0.98
Hypoxic group	20	14(79.07)	6(20.93)	21.82±0.41	22.01±3.33	69.08±2.94	8.08±1.02
High altitude group	20	13	7	21.54±0.28	21.98±3.15	71.05±3.51	7.69±0.57

Table II. Effects of different oxygen environments on immunoglobulin.

		Control group	Hypoxic group	High altitude group	P
IgA(g/L)		2.93±0.81	2.54±0.68	2.04±0.21$^{*\#}$	0.001
IgG(g/L)		14.92±2.31	13.35±2.19	12.28±1.98$^{*\#}$	0.001
IgM(g/L)		1.41±0.82	1.29±0.71	0.71±0.62$^{*\#}$	0.007
WBC(×10^3个/μl)		14.03±3.98	12.62±2.47	10.38±1.08$^{*\#}$	0.001
Natural killer cells (%)		32.24±10.57	28.61±5.69	20.39±1.46$^{*\#}$	0.001
IL-2(ng/ml)		4.03±0.97	3.12±0.74*	2.31±0.29$^{*\#}$	0.001
C3(g/L)		1.46±0.24	1.42±0.18	1.27±0.07$^{*\#}$	0.003
C4(g/L)		1.37±0.98	1.02±0.54	0.46±0.21$^{*\#}$	0.001
CH50(U/L)		97.31±2.13	96.78±1.61	95.32±0.69$^{*\#}$	0.001
Body weight	Before exercise	90.02±16.37	89.34±17.09	91.47±14.93	>0.05
	After exercise	85.91±14.46$^{\$}$	79.61±16.84$^{\$}$	76.61±12.06$^{\$}$	0.001
	Decrement	7.36±2.39	8.69±2.65	10.89±2.71$^{and@}$	0.001
	Decreasing amplitude	8.42±1.28	10.08±1.07^{and}	12.04±1.16$^{and@}$	0.001

Compared with control group, $^{*}P<0.05$; Compared with the hypoxic group, $^{\#}P<0.05$. Compared with situation before exercise, $^{\$}P<0.05$; compared with the control group, $^{and}P<0.05$; compared with the hypoxic group, $^{@}P<0.05$.

Known as natural killer cells, NK cells are important immune cells in the body. NK cells morphologically belong to large granular lymphocytes, which are derived from bone marrow and are the third group of lymphocytes besides T cells and B cells, accounting for about 15% of all immune cells (white blood cell count) in the blood. NK cells are the core cells of the natural immune system and are mainly distributed in peripheral blood, liver and spleen. NK cells are the main "fighters" in the body responsible for killing abnormal cells such as aging, virus infection and tumor (Qiu *et al*., 2011; Chang *et al*., 2002; Yu *et al*., 2016). Unlike more than 150 other white blood cells in the body, NK cells do not need special instructions from the immune system or coordination from other cells. They can recognize and attack foreign cells, cancer cells and viruses on their own. Circulating NK cells are usually dormant. Once activated, they infiltrate into tissues and secrete perforin and tumor necrosis factor, attacking virulent cells and so on. The most important feature of the immune response of the body after exercise is leukocytosis in peripheral blood, that is, the increase in the total number of white blood cells indicates an inflammatory response of the body to exercise stress (Blegen *et al*., 2008). The results of this study showed that the IgA, IgG, IgM, C3, C4 and CH50 levels of patients in the three groups were significantly different. Compared with the control group and the hypoxia group, the weight loss in the plateau group was more significant (Xie *et al*., 2018). It suggests that under different oxygen environments, moderate intensity exercise can improve serum IgG, IgA and IgM levels, improve immunity and reduce the risk of infection. Exercise intensity is a key factor in the change of NK cells during exercise, and there are many studies on the impact of acute exercise on cells, showing consistent results (Wen *et al*., 2017).

Conclusion

To sum up, exercise intensity in different oxygen environments has different effects on different immune functions, and has significant effects on IgA, IgG, IgM, WBC, NK cell activity, C3, C4 and CH50, which can be used for monitoring of effective immune indexes.

Statement of conflicts of interest

The author has declared no conflict of interest.

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