CARDIOVASCULAR RESPONSE TO VESTIBULAR STIMULATION IN CYCLIC, SITUATIONAL AND STEREOTYPICAL COMPLEX COORDINATION KINDS OF SPORTS

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Abstract. The aim of the work is the study of the dependence of cardiovascular system reaction to the vestibular stimulation on the peculiarities of movements in the above-mentioned kinds of sports. Vestibular reactions of 108 males were studied, 93 of which were involved in cyclic (middle and long distance jogging, cross-country skiing, swimming), situational (sports game) and difficult to coordinate movements of stereotypical sports (gymnastics). The above facts indicate that sports contribute to the adaptation to vestibular load and, as a consequence, the development of less severe autonomic reactions to vestibular stimulation. It is essential that the vestibular resistance develops not only in those sports in which the motor activity abounds in a corner acceleration but also in those species sports where such similar accelerations are minimal. The influence of the specifics of the motor activity in some sports is reflected in the value of response in tests with a change of a head position.

Key words: vestibular stimulation, responses of the cardiovascular system, types of sport

Introduction

Functional development of the skeletal system and its regulatory centers is directly related to the system of balance, which is closely related to the vestibular system (Zlatev et al. 1989). Therefore, in many sports, vestibular apparatus has a leading role as the informant of the gravitational vertical position when moving the body and providing orientation and redistribution of muscle tone (Zhilina 1986). In addition, upon stimulation of the vestibular apparatus many autonomic functions change, in particular, the function of the circulatory system. Investigation of connections between the vestibular and the cardiovascular systems is essential to assess the general condition and fitness of athletes.

Research aimed at studying the effect of individual sports on the formation of vestibular function athletes and, on the contrary, the functional state of the vestibular system in the expression of their motor capabilities, were made by many authors (Kiryalanis et al. 2002; Chinkin and Khusnullina 2008). However, studying the literature, we found no work aimed at investigation of the dependence of the reaction of the cardiovascular system to vestibular stimulation on the specific motor activity of sportsmen specializing in cyclic, situational and complex coordination stereotypical sports, significantly different in size and diversity of addressed vestibular apparatus influences.

The aim of the work is the study of the dependence of cardiovascular system reaction to the vestibular stimulation on the peculiarities of movements in the above-mentioned kinds of sports.

Methods and organization of the research

Vestibular reactions of 108 male were studied, 93 of which were involved in cyclic (middle and long distance jogging, cross-country skiing, swimming), situational (sports game) and difficult to coordinate movements of stereotypical sports (gymnastics). When the sports experience is not less than 5 years, they have sports qualification from the first grade to the master of sports in Russia. The team sports group includes hockey, volleyball, football, basketball, and badminton. The control group consisted of students, not related to sports (15 students). All analyzed students were basically healthy and did not have any restrictions associated with the vestibular system.

The studies were conducted in the competitive period of one year training cycle. To examine the response of the cardiovascular system, the rotational vestibular irritation test V.I. Voyachek was used. The sample was taken with a student sitting in a Barany chair, eyes closed, his head bent forward at 90º. In such circumstances, 5 rotations of a chair at 180º/s (1 turn in 2 seconds) were done. After stopping the test seat in 5 seconds, the vertical position of the head was restored. The sample combines irritation of semicircular canals during a chair rotation and a statoconia apparatus when they subsequently restore the vertical position of the head. According to the heart rate (HR) and blood pressure (BP), obtained before and after the rotational tests, the reactions of the cardiovascular system were assessed. Repeated surveys to change the composition of annoyed receptors located throughout the semicircular canals, as well as rotations with a head tilt to the left and right were used; and to enhance the impact of rotational loads on the vestibular Voyachek - test duration was twice increased (10 rotations in 20 seconds).

The results are represented as mean ± SEM. Data were initially analyzed for normality (Shapiro-Wilk). All variables analyzed presented normal distribution. Differences between groups were tested by independent Students t-test. P values < 0.05 were accepted as statistically significant with a confidence level of 95%.

Results

The initial heart rate of gymnasts and athletes of cyclical and situational sports was 64.80 ±0.83, 55.65 ±0.79 and 59.68 ±0.52 bpm, respectively ($p < 0.01$–0.001). The control group students heart rate was higher – 68.13 ±1.19 bpm ($p < 0.001$).

The basic variant of V.I. Voyachek sample of the heart rate change of swimmers (without regard to its direction) was 2.64 ±0.45 bpm, which is considerably lower than that of the runners (4.27 ±0.79 bpm) and skiers (3.92 ±0.75 bpm). The average response of cyclic sports athletes is 3.62±0.40 bpm, which is slightly higher than of the game sports athletes – 2.80 ±0.21 bpm ($p > 0.05$) and gymnasts – 2.67 ±0.29 bpm ($p > 0.05$), but about two times lower than that of non-athletes – 6.47 ±0.69 bpm ($p < 0.001$).

There are other features of the reaction of the heart, not only related to the nature of motor actions of athletes, but also to the position of the head at the rotational sample. The main feature is that the response of the heart in the rotation with a head tilt to the right and to the left is significantly different, and, in general, in the first case, it is somewhat smaller (2.90 ±0.15 bpm) than the second one (3.13 ±0.18 bpm, $p > 0.05$). Table 1 shows that the more it is typical for sports, which movements and/or basic productive actions are performed using hands and upper body (badminton, hockey, volleyball, skiing, swimming), the difference in the magnitude of responses in these sports is average 0.81 ±0.22 bpm ($p < 0.01$). It could be due to the asymmetry of movements and the position of the head when doing the main elements of an exercise using hands. In these sports, a right arm and a right shoulder of right-handers (these are the overwhelming majority) carry a greater load and to a greater extent determine their effectiveness during basic actions. Moreover, they also determine the position of the head necessary for the optimal distribution of muscle tone during these actions (Magnus 1962). Therefore, vestibular adaptation to rotational loads develops more with the head tilted to the right than when tilted to the left. This assumption is confirmed by the fact that, in those sports, where arms exertion is less important, and movements occur mainly in the vertical position of the head (running, soccer), the values of heart rate response to the rotation of the head at different positions do not differ (0.11 ±0.39 bpm, $p > 0.05$).

However, the predominance of the heart reaction with the head tilted to the left is not typical for representatives of all sports. So, for basketball players and gymnasts, it is lower when the head is tilted to the left (2.17 ±0.21 bpm) than when it is tilted to the right (2.96 ±0.23 bpm, $p < 0.05$). This may be due to the fact that in these sports turns and rotations of the right-handed tend to be in the right direction, which requires an advanced head turn to the left, and this, in turn, may contribute to the development of a predominantly left-sided to adaptation angular accelerations.

Table 1. Changes in heart rate of athletes and control students at different positions of the head (mean ± SEM, bpm)

Sports	5 rotations/10 seconds	
	inclination to the left	inclination to the right
The control group (n = 15)	5.73 ±0.79	5.40 ±0.46
Athletes (all groups) (n = 93)	3.13 ±0.18	2.90 ±0.15
Running, football (n = 19)	3.68 ±0.44	3.58 ±0.32
Hockey, badminton, volleyball, skiing, swimming (n = 51)	3.30 ±0.24	2.49 ±0.21*
Basketball, gymnasts (n = 23)	2.17 ±0.21	2.96 ±0.23*

* – $p < 0.05$ (significance of differences between the indicators for a head tilt to the right and left).

The reaction of the heart rate during the rotational load of different duration also varies. Table 2 shows that after increasing the duration of vestibular stimulation twice, it has increased by an average of 52.6%, but was not proportional to the reaction of 5 rotations of a chair. On the contrary, the dependence was reversed: the smaller the reaction with 5 rotations, the bigger the increase with its 10 rotations. So, when badminton players, basketball players, hockey players, swimmers and gymnasts had 5 rotations of chairs, the chronotropic response of the heart was on average 2.65 ±0.29 bpm, when 10 rpm - it increased by 1.87 ±0.25 bpm (70.58 ±9.52%). Football players, volleyball players, skiers and runners had 3.85 ±0.34 and 1.36 ±0.42 bpm (35.32 ±10.98%), respectively. Therefore, the relative increase of the heart reaction of the first was twice higher than that of the latter ($p < 0.05$). This may mean that the second group had a higher capacity to the mobilization of functional reserves of the heart under the influence of the stimulus and their more economical use, when increasing its duration.

Table 2. Changes in heart rate (mean ± SEM, bpm) of athletes and control students with different duration of rotational tests (neck down)

Sports	5 rotations/10 seconds	10 rotations/20 seconds	Increase
The control group (n = 15)	6.47 ±0.69	8.53 ±0.73	2.07 ±0.70*
Badminton, basketball, hockey, swimming, gymnasts (n = 54)	2.65 ±0.19	4.52 ±0.22	1.87 ±0.25#
Football, volleyball, cross country skiing, running (n = 39)	3.85 ±0.34	5.21 ±0.32	1.36 ±0.42*

* – $p < 0.01$; # – $p < 0.001$.

Systolic arterial pressure of gymnasts and athletes of game and cyclic sports was the same – 112.07 ±0.71; 111.95 ±0.55 and 111.76 ±0.79 mm Hg respectively. The highest average, as well as of the heart rate, was detected in a control group – 117.20 ±1.25 mm Hg ($p < 0.01$–0.001), which conforms with the idea of developing a moderate hypotension in sports (Karpman and Lyubina 1982).

In response to the rotational load, the main reaction of the systolic arterial pressure at all positions of the head was increasing. Only 13% of the surveyed showed a slight decrease (mainly 1–2mm Hg). In contrast to the heart rate, the increase of the systolic arterial pressure of gymnasts and representatives of cyclic and team sports, as well as of the control group, was almost identical – 3.93 ±0.86; 3.68 ±0.56; 3.77 ±0.40 and 3.80 ±1.08 mm Hg respectively. Such stability of the reaction of arterial pressure to rotation, in fact, was preserved when comparing this index by different positions of the head. Differences between groups in this case can be viewed as no more than a tendency.

By the double duration of the rotational load, the increase of the systolic arterial pressure of athletes had an average of 1.52 ±0.45mm Hg (39.4%), which is more than with the 10-second load, but the correlation between these parameters were not found. The systolic arterial pressure growth by the double duration of the rotational load of the control group is much more – 5.00 ±1.01mm Hg (131.58%, $p < 0.01$) than that of the athletes.

The diastolic pressure of vestibular load of the representatives of game sports, cyclic sports and gymnastics, as well as the systolic arterial pressure, did not differ – 69.44 ±0.75; 69.89 ±0.68 and 69.93 ±1.21mm Hg respectively. Diastolic pressure does not irritation on vestibular stimuli of athletes playing sports games ($p > 0.05$). The athletes of cyclical sports had the increase of the diastolic pressure - an average of 1.53 ±0.47mm Hg, but the gymnasts had the highest – 3.33 ±0.60mm Hg ($p < 0.05$).

This dynamics of the diastolic pressure affected the nature of the changes in pulse pressure as a response to vestibular stimulation. The changes of individual parameters in the control group were different and were generally unauthentic – 1.20 ±1.31mm Hg ($p > 0.05$), while in cyclic and team sports highly significant increase of pulse pressure was revealed - up to 2.15 ±0.45 and 2.98 ±0.54mm Hg respectively ($p < 0.001$). In this case, there was a tendency that high qualified athletes pulse pressure was higher. If we consider that the pulse pressure is associated with the stroke volume (Karpman and Lyubina 1982), the reaction of the heart to vestibular stimulation and exercise of the athletes is aimed at a greater increase of the heart rate than of the stroke volume. This is more typical for sports, when developing stamina. Thus, in cyclic sports the correlation of the coefficient between the indices with a negative sign reaches 0.5. At the same time, the gymnasts whose trainings are much less focused on improving functional characteristics of the heart in response to the rotational load, the pulse pressure has increased slightly, but overall turned out authentic – 0.60 ±0.69 mm Hg ($p > 0.05$). This pattern was to some extent reflected in the changes of an endurance factor (Nazarenko 2009), which, according to its calculation formula, represents the ratio of the heart rate and pulse pressure (Balandin 1975).

Discussion

The predominant reaction of heart rate on vestibular irritation, of both the athletes and the control group, was its promotion. Only 10% of the students detected the heart rate decrease. Generally, it was observed with the same subject examined at different positions of the head and with double duration of vestibular stimulation and, obviously, is the type of individual reactions of these athletes. Among the representatives of some sports, this type of reaction was not available. The exceptions were the swimmers – the reduced by 1–3 bpm heart rate was observed in almost half of them. Moreover, when there is a rotational load of the tilt of the head to the left and right, and at twice its length, such reaction is detected in 55–64%, and the average index was equal to a zero or had a negative value. In contrast to single cases among the athletes of other sports, the negative reaction of the heart of swimmers seems acquired and can be caused by frequent contacts with water, which is a non-specific irritant of the vestibular system (Fedchin and Belousova 1988). The formation of this type of swimmers reaction may occur through the implementation of a well-known reaction of a rate control that takes place when a person immerses in water while swimming, and combines it with the rotation of the head. However, the role of these factors is not clear and needs a special study.

So, practicing sport games, gymnastics and swimming, in which rotational movements are greatly represented, helps to minimize hearts reaction on vestibular stimulation irritation.

It should be noted that the vestibular resistance develops when you do those sports in which the elements of the rotational motion and angular accelerations are represented in small amounts. Both semicircular canals and vestibule receptors are stimulated in all motions. However, in various forms of rotational movements a part of elements and their orientation, as well as irritation and subsequent adaptation of the semicircular canals of different receptors are significantly different. Therefore, an adaptation measure of vestibular of an athlete, which is proportional to abundance of rotational components in exercises of some chosen sport, can serve a total (average) value of the reaction of the heart to the vestibular stimulation at different positions of the head.

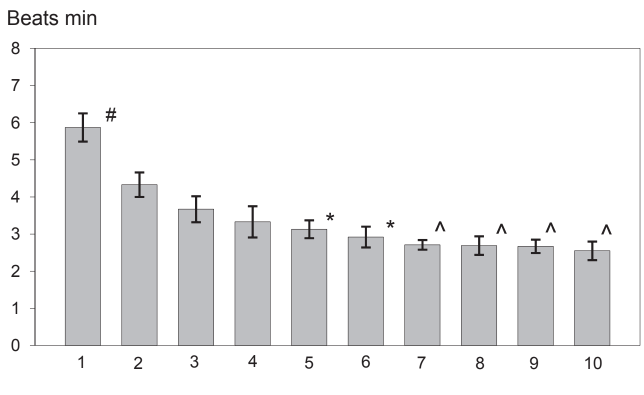

Figure 1. The mean strength of the chronotropic response of the heart to rotational load in tests with three positions of the subject's head in athletes specializing in different sports. Significant differences from: # athletes ($p < 0.01–0.001$); * runners ($p < 0.05–0.001$); ^ runners and ski racers ($p < 0.05–0.001$). The abscissa shows the groups of subjects: (1) control, (2) runners, (3) ski racers, (4) badminton players, (5) volleyball players, (6) soccer players, (7) basketball players, (8) hockey players, (9) gymnast, and (10) swimmers

Indeed, Figure 1 shows that runners and skiers showed the highest response of the heart to the rotational load; their movements have mostly straight linear orientation. The reaction of badminton and volleyball players, who face more angular accelerations than the runners and skiers, is lower. However, due to the lack of direct contact with players of competing the saturation of their movements with rotation elements rotation is lower than that of the contact sports, which include football, hockey and basketball. Accordingly, the reaction of the heart is much lower. It is comparable with that of gymnasts and swimmers: the first have many twists and complex rotations while exercising; for swimmers an additional irritant is the aquatic environment.

Conclusions

The above facts indicate that sports contribute to the adaptation to vestibular load and, as a consequence, the development of less severe autonomic reactions to vestibular stimulation. It is essential that the vestibular resistance develops not only in those sports in which the motor activity abounds in a corner acceleration but also in those special sports where such similar accelerations are minimal. The influence of the specifics of the motor activity in a sport is reflected in the value of response in tests with a change of a head position. However, this reaction change concerns only the heart rate. The reactions of different components of the arterial pressure, with the exception of the pulse pressure, in fact, are not connected with the specifics of movements in different sports.

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