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FEATURES OF HAEMODYNAMICS INDEX CHANGES DURING RESPIRATORY CYCLE IN MEN

The changes of R-R interval duration and stroke blood volume were measured during respiratory cycle at rest in prone position, at orthostatic test, with physical and mental loading among 157 healthy men aged 18-23. Significant inter-individual differences of shifts of stroke blood volume and R-R duration during respiratory cycle were found at rest and with loadings. The important aspect for assessing respiratory arrhythmia of R-R interval duration and stroke blood volume is the consideration of amplitudes of decreasing the level of these indexes on inhalation.

***Key words**: respiratory sinus arrhythmia*

A factor stipulating cycle processes in haemodynamics is periodical respiratory movements and changes in central link of controlling these movements [2], afferent impulsation from the receptors of external respiration organs [1], inflow of venous blood to the heart [9], the level of blood filling of the lungs herewith [7]. The most well-known phenomenon of respiration influence on heart activity is the phenomenon of respiratory sinus arrhythmia which is regular acceleration of the heart rate on inhalation and deceleration – on exhalation. A number of surveys [2, 8, 10] considers the publications studying this phenomenon. RSA is found in newborns, children, adults, and different species of vertebrates [4].

At the same time, the features of changes in stroke blood volume (SV) during breathing cycle are studied less. Moreover, practically, there are no works determining the amplitude of phase shifts of respiratory arrhythmia (in the broad sense of this phenomenon), their time parameters. There is a lack of research of individual reactivity of respiratory waves of haemodynamics with different loadings.

The goal of the research is to find the change features of stroke blood volume and R-R interval duration (t-R-R) during respiratory cycle in men at rest, at orthostatic test, with dosed neuro-dynamics and physical loadings.

Methods

The measurements were conducted on 157 healthy young men aged 18-23. The investigation was carried out in compliance with the main provisions of the European Convention on Human Rights and Biomedicine (04.04.1997), Helsinki Declaration of the World Medical Association on ethical principles of scientific medical research involving human (1994-2008).

5-minutes registration of electrocardiogram and differentiated impedance rheogram from rheo-analizer RA-5-01(Kyiv Research Institute of Radio Measuring Equipment) were made after 15-minute rest in prone position in the morning (from 8 till 11). The similar records were made at orthostatic test (7 minutes), with neurodynamics loading according to the test of M.V. Makarenko and physical exercise with capacity of 1 W per kg of body weight. Systolic blood volume was calculated by the signal of differential impedance rheogram; R-R interval duration - according to the signal of ECG for all implementations for 5-10 minutes [5]. Pneumogram signal was received from piezoelectric sensor placed in front of the nose nostrils of the examined person.

The level of sinus respiratory arrhythmia was determined by the method proposed by S.O. Kovalenko and V.O. Tsybenko [6] (Fig.1). The method is as follows: having recorded or being recorded time series consisting of successive R-R interval durations and spirocycles are analyzed.

Since the beginning of each inhalation before the next inhalation, the duration of cardio-intervals was interpoled starting with “0” point – the beginning of inhalation and after a certain period of time (0.1 sec. in our research).Interpolation was performed analytically. Such a transformation is performed owing to the relatively random character of time realization of the beginning of cardio-cycles. After that, the duration of cardio-intervals at appropriate points of each spirocycle is summed; their average values are found. The obtained data are analyzed: maximum and minimum average duration of cardio-cycle (and their deviation from the value on inhalation: RSA_{min} and exhalation: RSA_{max}), that determine the value of respiratory sinus arrhythmia (RSA) and time interval between these values and inhalation start ($tRSA_{min}$ and $tRSA_{max}$).

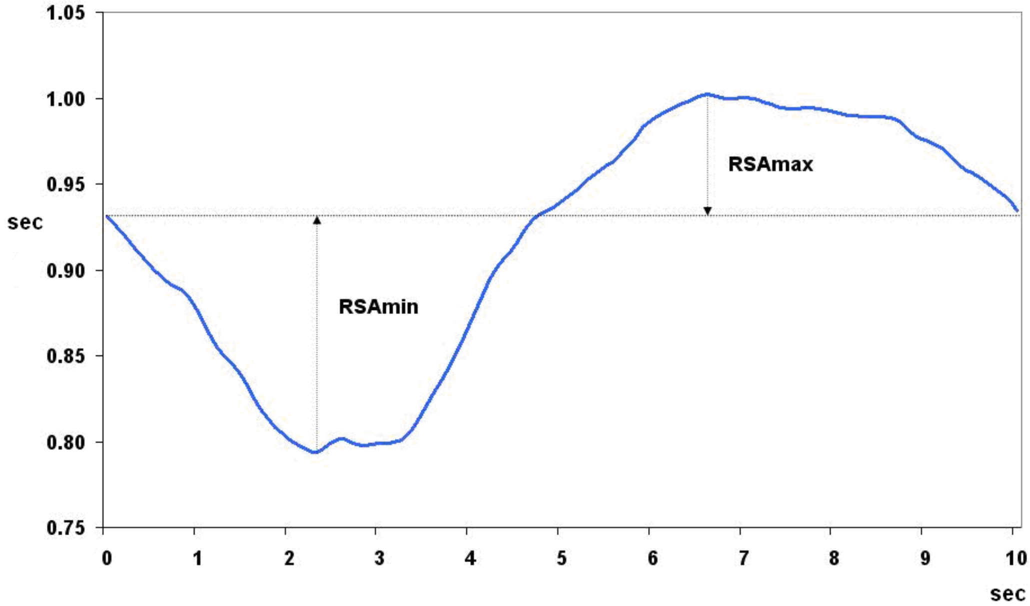

Fig. 1. Calculation of Respiratory Sinus Arrhythmia

Similarly, the changes of SV during respiratory cycle with the determination of minimum (RA_{min}) and maximum (RA_{max}) values and the time of their origin are analyzed.

Statistics data analysis shows their medians, limits 25 and 75 percentiles; the probability of differences is assessed by the method of pair comparison Wilcoxon in the program Statistics for Windows-5.

Results and their Discussion

The oscillation level of R-R interval duration during respiration cycle was 76 [55; 140] мs at rest in prone position. The median amplitude of this indicator decrease on inhalation (RSA_{min}) was significantly higher (-59 [89; -37] ms) than the increase on exhalation (RSA_{max}) (19 [5; 41] ms) (Table. 1). The reverse trend was observed concerning respiratory changes of cardiac output (RA): the decrease of SV on inhalation (RA_{min}) was lower (-1.2 [-3.4; -0.4] ml) than its increase on exhalation (RA_{max}) (12.1 [8.8; 17.4] ml).

Maintaining rather sustainable level of cardiac output on inhalation may be owing to a significant increase in heart rate. The lungs are stretched during inhalation and the level of their relative blood filling is reduced. It may lead, first, to the decrease of blood flow to the left ventricle and, consequently, the strike blood volume reduces; second, to the deterioration of gas exchange in the lungs. Increased heart rate helps to restore the blood filling level of the lungs and eliminates the above mentioned changes in cardiac output and gas exchange. In this situation, the level of cardiac output is a stable homeostatic constant; and the heart rate is an indicator that supports the constant. This assumption is confirmed by the analysis of time parameters of respiratory arrhythmia of SV and R-R (Table 2).

Table 1

Respiratory Arrhythmia Indicators of SV and R-R at Rest and Orthostatic Test (n=88)

Indicators	In prone position	Orthostatic Test	Reactivity (%)	P
RSA, ms	76 [55; 140]	61 [48; 103]	-17 [-52.5; 23.7]	0.003
RSA_{min}, ms	-59 [-89; -37]	-39 [-55; -23]	-34 [-58.4; 5.7]	0.000
RSA_{max}, ms	19 [5; 41]	21 [8; 48]	20.3 [-60.7; 279.1]	0.244
RA, ml	14.9 [10.8; 20.6]	8.7 [6.8; 12.4]	-34.7 [-60.2; -12.3]	0.000
RA_{min}, ml	-1.2 [-3.4; -0.4]	-1.7 [-3.7; -0.8]	49.8 [-58.4; 269.2]	0.456
RA_{max}, ml	12.1 [8.8; 17.4]	6.7 [4.9; 9]	-44.7 [-67; -15.7]	0.000

Table 2

Spiro-Cycle Duration and Time Indicators of Respiratory Arrhythmia of SV and R-R at Rest and Orthostatic Test (n=88)

Indicators	In Prone Position	Orthostatic Test	Reactivity (%)	P
Msp, ms	4206 [3615; 4910]	4419 [3689; 5280]	5.6 [-9.2; 20.8]	0.036
$tRSA_{min}$, sec	2.2 [1.9; 3.3]	3.2 [2.4; 4.3]	37.8 [0; 89.7]	0.000
$tRSA_{max}$, sec	4.2 [2.4; 5.5]	5.2 [1.9; 6.5]	27.5 [-9.8; 69.8]	0.009
tRA_{min}, sec	0.9 [0.5; 3.7]	1 [0.5; 4.6]	5.6 [-9.2; 20.8]	0.074
tRA_{max}, sec	2.4 [2; 3.5]	2.6 [1.9; 5.6]	18.3 [-48.2; 209.2]	0.012

Thus, registration time of SV minimum during respiratory cycle (tRA_{min}) was 0.9 [0.5; 3.7] sec from the start of the inhalation and was significantly less than the time of RSA minimum ($tRSA_{min}$) – 2.2 [1.9; 3.3] sec. The time of SV maximum from the beginning of the inhalation was almost similar to tRA_{min} and, quite possibly, reflects the introduction of compensatory shifts of heart rate. It is interesting to note that $tRSA_{max}$ is almost equal to spirocycle duration showing the slow increase of t-R-R in the second phase of RSA. And, even with the start of inhalation due to the inertia of regulatory processes, the duration of R-R interval may continue to increase that may lead to some distortion of classical picture of RSA during short period of respiratory cycle.

At the same time, rather wide range is characteristic for the level of respiratory arrhythmia indicators of both SV and t-R-R. The histograms of RSA, RSA_{max}, RA and RA_{min} distribution are presented on Fig.2. RSA and RA distributions have some peaks with considerable variations, which may show the availability of typological groups. RSA_{max} and RA_{min} distributions are also characterized with several peaks. The charts of RSA_{max} and even more RA_{min} distributions show the highest and dominant peak in the range of small amplitude changes. Thus, we may suppose that rather small range of SV decrease on inhalation can be stipulated at the expense of significant variability of both the level of RSA and particularly t-R-R changes in the first reflex stage of respiratory sinus arrhythmia.

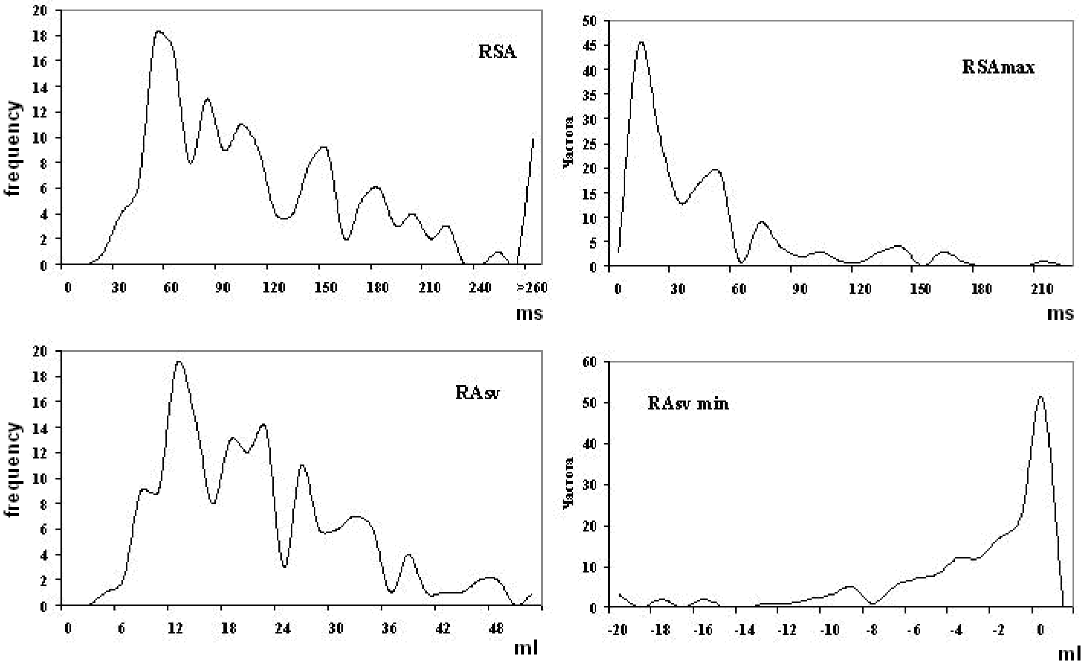

Fig. 2. Charts of Indicator Distribution of Respiratory Arrhythmia at Rest, in Prone Position (N=157)

The change of the body position into the vertical one resulted in the significant decrease of the level of respiratory arrhythmia of R-R interval duration and, to a larger extent, SV (Table 1). At the same time, similar changes were stipulated with multi-directed shifts of two phases of respiratory arrhythmia. For t-R-R, the amplitude decreased in the first phase of RSA; the increase value almost did not change in the second one; for SV, conversely, RA_{max} decreased reliably, RA_{min} shifts were not reliable. RA_{max} shifts are quite natural since the change of body position results in significant decrease of SV and, definitely, the level of all the indicators stipulated by it. In case of RA_{min}, the SV decrease can somewhat neutralize the reactions of its amplitude increase.

Time parameters of respiratory arrhythmia at orthostatic test (Table 2) mostly increased reliably. The largest amplitude of such shifts was for $tRSA_{min}$ – 37.8%. Such changes of the indicator can be explained with the influence of several factors: the first one is the increase of spirocycle duration; the second one is the post-action increase of the second phase of RSA reflex on the course of the first phase; the third one is the tonus changes of various parts of the vegetative nervous system.

Reactivity analysis of respiratory arrhythmia indicators at orthostatic test showed that they were characterized with a wide deviation both in direction and the value of their changes. It concerned, to the greatest extent, those parameters that had unreliable shift, RSA_{max} and RA_{min}.

Mental loading also caused significant changes in amplitude and time parameters of SV and t-R-R changes during respiratory cycle. With such a loading, RSA amplitude, RSA_{min}, and RA_{min} decreased significantly, RA_{min} increased. The factor caused it might be reliable decrease of spirocycle duration to 2917 ms. $tRSA_{min}$ decreased significantly and reliably to 1.5 [1.3; 3] s and tRA_{min} to 0.95 [0.5; 2.7] s. Thus, reaction time of SV decrease and t-R-R on inhalation were reduced that was displayed on their amplitude.

Reactivity to mental loading was characterized with the high level of inter-deviance according to the amplitude of changes and their orientation for RSA (-28 [-44; 17] %) ,

RSA_{max} (-10 [-63; 359] %), RA_{max} (-11 [-62; 180] %). The reactions of decreasing these indicators dominated mostly for RSA_{min} (-36 [-53; -10] %), RA^{sv} (-51 [-75; -16] %), RA_{min} (-66 [-83; -36] %).

Further decrease of RSA , RSA_{min}, RA_{min} amplitude and significant increase of RA and RA_{max} were observed with dosed physical loading. tRA_{min} was significantly decreased to 0.3 [0.2; 0.6] s. At the same time, spiro-cycle duration was somewhat higher (3191 ms) than with mental loading. The dynamics of DSA changes may be influenced by the increase of respiratory volume with physical exercise, the decrease of t-R-R, the tone changes of parasympathetic link of VNS. The significant increase of SV changes amplitude during respiratory cycle may be explained by the dynamics of respiratory volume changes and the availability of artifacts in determining SV with the movements of a person.

Conclusions

1. Both at rest and with loadings, there are significant inter-individual differences of strike blood volume and t-R-R shifts during respiratory cycle.
2. Considering the decrease amplitude of these indicators level is important for the assessment of respiratory arrhythmia of R-R interval duration and strike blood volume.

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Анотація. Коваленко С.О., Завгородня В.А. Особливості змін гемодинамічних показників упродовж дихального циклу у чоловіків. *На 157 здорових молодих чоловіках віком від 18 до 23 років проведені вимірювання змін тривалості інтервалу R-R, ударного об'єму крові упродовж дихального циклу у спокої лежачи, при ортопробі, розумовому та фізичному навантаженнях. Показано, що як в стані спокою, так і при виконанні навантажень існують суттєві міжіндивідуальні відмінності зрушень ударного об'єму крові та т-R-R впродовж* *дихального циклу. Важливим для оцінки дихальної аритмії тривалості інтервалу R-R та ударного об'єму крові є врахування амплітуд зниження рівня цих показників на вдиху.*

Ключові слова: *дихальна синусова аритмія*

Аннотация. Коваленко С.А., Завгородняя В.А. Особенности изменений гемодинамических показателей на протяжении дыхательного цикла у мужчин. *На 157 здоровых молодых мужчинах в возрасте от 18 до 23 лет проведены измерения изменений длительности интервала R-R, ударного объема крови на протяжении дыхательного цикла в покое лежа, при ортопробе, умственной и физической нагрузках. Показано, что как в состоянии покоя, так и при выполнении нагрузок существуют межиндивидуальные отличия сдвигов ударного объема крови и m-R-R на протяжении дыхательного цикла. Важным для оценки дыхательной аритмии длительности интервала R-R и ударного объема крови является учет амплитуд снижения уровня этих показателей на вдохе.*

Ключевые слова: *дыхательная синусная аритмия*

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