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S.I. Vdovenko

COMPARATIVE ANALYSIS OF EXTERNAL RESPIRATION SYSTEM OF THE NORTHERNERS IN THE AGE ASPECT

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This study aimed at the specific performance of respiration system based on the ontogeny. Four hundred and fifty-two male residents of Magadan aged 15-74 participated in a comprehensive age-associated survey that involved 4 groups: adolescents, early adults, workable men of mature age and the elderly. The lungs volumetric and velocity characteristics were analyzed using computer spirometry. Most indicators of external respiration proved to be significantly age specific. The maximum values were observed in the early adulthood followed by a fall in men of older age groups. The revealed changes indicated lowered reserve capabilities of the respiration performance with increasing duration of residence under the North conditions and suggested reduced adaptabilities of the body owing to the chronic adverse effects of natural and climatic environmental factors.

Keywords: North, adaptation, respiration system, men.

Introduction. Severe ecological and climatic factors of Russia's North-East are provided by not a long-term low atmospheric temperatures only, but a combination of abiotic environmental factors (the weather extremes, humidity and wind conditions, shifting daily and seasonal light periods, the influence of heliophysical effects, etc.). At the same time, this territory (Magadan Region, Chukotka, and Yakutia) receives the most dramatic climate changes [8]. Among all the body physiological systems, the external respiration is the first to face the outer environment and it experiences constant stress, due to continuous contact with natural extremes [9]. The increasing age results in pronounced changes in the breathing system, thereby aggravating the stress at various levels, from respiratory muscles to the conductive and convective zone of the lungs [2, 6, 12, 13]. Since the body experiences increased metabolic needs under the cold conditions, the optimal performance of the respiration system is the key to adequate oxygen supply and is crucial because of hypoxic changes in lungs resulting from a fall in the tissue respiration with increasing age [7]. Following on from the above, we see it is relevant to study changes in the respiration system functioning in men of different age groups – permanent residents of Magadan city.

Materials and Methods. Four hundred and fifty-two male residents of Magadan city, Caucasian by origin, participated in the survey. All subjects were divided into four groups based on their ages: adolescents, n = 85 (mean age 16.2±0.06 yrs, body height 179±0.75 cm, body mass 66.5±1.27 kg), young adults, n = 235 (19.2±0.5 yrs, 178.9±0.7 cm, 66.4±1.2 kg), mature men, n = 89 (37.1±0.59 yrs, 180.3±0.68 cm, 84.1±0.9 kg), and elderly men, n = 43 (65.6±1.09 years, 174.1±1.16 cm, 86.1±2.18 kg). The external respiration (or external breathing) function (EBF) of men was assessed by the standard and well-proven method of indexing volumetric pressure and pneumatic flow on a medical Diamant-C spirograph. All basic characteristics of the EBF were automatically compared with the proper values which are the values calculated for the population of residents of the Central part of Russia [5] We studied 21 indicators: vital and forced lung capacity (VC and FVC, l), forced expiratory volume in the first second (FEV_1, l), peak expiratory flow

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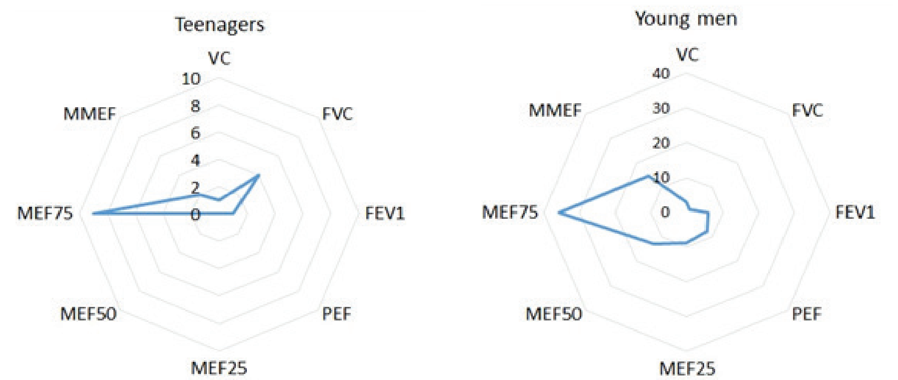
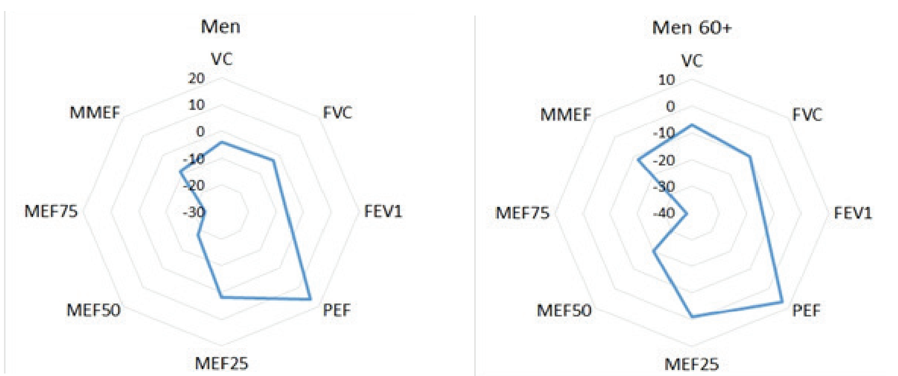
Indicators of external breathing function in males of different ages (M±m)

Indicators	Examined Groups				The level of significance of the differences					
	Adolescents (1)	Young adults (2)	Mature men (3)	Men over 60 (4)	1-2	1-3	1-4	2-3	2-4	3-4
Tvc (s)	1.95±0.07	1.88±0.04	2.31±0.09	2.1±0.12	p=0.39	**p<0.05**	p=0.29	**p<0.001**	p=0.09	p=0.17
VC (l)	4.97±0.07	5.03±0.04	5.1±0.07	3.8±0.08	p=0.46	p=0.2	**p<0.001**	p=0.47	**p<0.001**	**p<0.001**
VC (%)	101±1.69	103±0.75	96±1.01	93±1.99	p=0.29	**p<0.05**	**p<0.05**	**p<0.001**	**p<0.001**	p=0.19
Tfvc (s)	1.92±0.08	1.42±0.03	3.15±0.1	3.2±0.21	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	p=0.83
FVC (l)	4.93±0.06	4.84±0.05	5.03±0.08	3.6±0.13	p=0.26	p=0.33	**p<0.001**	p=0.07	**p<0.001**	**p<0.001**
FVC (%)	104±1.44	101±0.81	97±1.24	90±2.38	p=0.08	**p<0.001**	**p<0.001**	**p<0.01**	**p<0.001**	**p<0.05**
FEV_1 (l)	4.2±0.07	4.43±0.04	4.03±0.07	2.8±0.11	**p<0.01**	p=0.01	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
FEV_1 (%)	101±1.6	106±0.73	94±1.34	86±2.55	**p<0.01**	**p<0.01**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.01**
Tpef (s)	0.16±0.01	0.17±0.01	0.12±0.01	0.1±0.01	p=0.49	**p<0.01**	**p<0.001**	**p<0.001**	**p<0.001**	p=0.17
PEF (l/s)	8.87±0.18	9.68±0.1	11.13±0.18	8.4±0.32	**p<0.001**	**p<0.001**	p=0.21	**p<0.001**	**p<0.001**	**p<0.001**
PEF (%)	100±2.05	108±0.97	116±1.8	107±3.18	**p<0.001**	**p<0.001**	p=0.07	**p<0.01**	p=0.77	**p<0.05**
$MEF_{25\%}$ (l/s)	7.91±0.19	8.73±0.1	8.97±0.22	7.2±0.33	**p<0.001**	**p<0.001**	p=0.07	p=0.33	**p<0.001**	**p<0.001**
$MEF_{25\%}$ (%)	100±2.37	109±1.32	102±2.35	99±3.88	**p<0.01**	p=0.55	p=0.83	**p<0.05**	**p<0.05**	p=0.51
$MEF_{50\%}$ (l/s)	5.52±0.16	6.38±0.09	4.94±0.15	3.7±0.3	**p<0.001**	**p<0.01**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
$MEF_{50\%}$ (%)	100±2.94	113±1.54	82±2.37	80±4.94	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	p=0.72
$MEF_{75\%}$ (l/s)	3.03±0.1	3.78±0.06	2.1±0.08	1.2±0.1	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
$MEF_{75\%}$ (%)	109±3.69	136±2.3	76±2.7	62±5.57	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.05**
$MMEF_{25-75\%}$ (l/s)	5.5±0.14	6.24±0.08	5.34±0.14	4±0.23	**p<0.001**	p=0.43	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
$MMEF_{25-75\%}$ (%)	102±2.54	115±1.29	91±2.22	88±4.14	**p<0.001**	**p<0.01**	**p<0.01**	**p<0.001**	**p<0.001**	p=0.53
FEV1/VC, %	84±1.04	88±0.53	78±0.83	71±1.55	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
FEV1/FVC, %	85±1.07	92±0.45	80±0.77	78±1.77	**p<0.001**	**p<0.001**	**p<0.01**	**p<0.001**	**p<0.001**	p=0.31

(PEF, l/s), time of achieving the VC, FVC, PEF (s), maximal expiratory flow values at 25%, 50%, and 75% of FVC ($MEF_{25\%}$, $MEF_{50\%}$, $MEF_{75\%}$, l/s), mean maximal expiratory flow ($MMEF_{25-75\%}$, l/s), as well as two indices of bronchial obstruction, Gensler and Tiffeneau which are FEV_1/VC, FEV_1/FVC. The data obtained were processed using an applied statistical analysis package. The processing results are presented as an average value (M) and an arithmetic mean error (±m). The statistical significance of the differences was determined with the Scheffe criterion. The critical significance level (p) in the research was assumed to be 0.05; 0.01; 0.001. The research was carried out in accordance with the principles of the Helsinki Declaration, the research protocol was approved by the local bioethics commission of the Scientific Research Center "Arktika" FEB RAS. Prior to the breathing tests, all participants were given a detailed explanation of all the upcoming studies and provided written informed consent for voluntary participation.

Results and Discussion. The Table shows age dynamics of the respiration system variables in the range from adolescents to the elderly men and in the figure there is a relative (in %) deviation from the required values. The greatest number





Subjective positive and negative dynamics in indicators of external breathing, %

of differences existed between young adults and men of workable age and the elderly, and the least between men of the two older age groups. For all the examined groups, significant differences were found in terms of the forced exhalation indices in the first second, patency of small bronchioles and the Tiffeneau bronchial obstruction index. If to consider some indicators of external respiration, we can see similar trends for the time of normal and forced exhalation: the minimum values in both cases were typical for young adults, and the maximum values for men of workable and older ages. The indicator of the lung vital capacity which, due to its reproducibility [4]. is an informative physiological indicator for assessing the lung tissue condition, in real (l), and relative (%) values, proved to be significantly lower in older men as compared to other age groups. The same pattern was found for the forced lung capacity: adolescents and young adults exhibited the highest values and no significant intergroup differences. These were generally consistent with the data of L.B. Kim (2010) who reported age-associated reduction in VC. In our case, however, this occurs in a wider age period and somewhat later, not from 30 to 50, but from 35 to 65 years [6].

Interestingly, all the numerous expiratory volume flow values of bronchopulmonary indicators showed significant intergroup dynamics. The amount of forced exhalation in the first second is the most important indicator, since it is first to indicate possible obstructive pulmonary patency disorders, and normally it should be at least 0.8 of the vital lung capacity [17]. The FEV_1 values significantly raised up to 106% in young adults, then dropped to 94% and 86% in men of the middle and older age groups, respectively. The time to reach the peak expiratory flow also shortened from young adults to the elderly men. The initial part of the expiratory curve (25-33% of lung volume) depends more on the applied muscular effort, rather than the mechanical properties of the lung tissue [10]. In our studies, the peak expiratory flow (PEF), as the initial component of this curve, reached its highest values in absolute and relative values in men of workable age. In this case, it can be assumed that it is the greatest development of expiratory muscles in men of workable age that contributes to achieving the maximum PEF value in this group. We could see a similar pattern of changes with age in the patency of large, medium and small bronchi since the young adults demonstrated highest values compared to adolescents; then the indices gradually decreased to the group of the elderly. It is noticeable that in adolescence, the values of bronchial patency mainly corresponded to age standards whereas young male adults experienced dilation of the airways, and the elderly men developed a significant bronchial constriction. High subjective Tvc and Tfvc values in these groups indicated increased resistance to expiratory flow. Reduced pulmonary function with increasing age was also reported by other authors [14, 15]. It is caused by changes in both the lung tissue and in the respiratory muscles, thereby affecting the lung function.

The $MEF_{50\%}$ and $MEF_{75\%}$ indicators, with their isolated picture of a decrease, can be an early sign of bronchial obstruction [11]. At the same time, the smaller the pulmonary structures, the more dramatically the intergroup bronchial patency came down. The patency index of small (distal) bronchioles tended to be most variable with the range of deviations up to 74%, with a maximum shown by young adult men and a minimum in older men. Normally $MEF_{75\%}$ reflects the opening of small bronchioles, contributing to an increase in residual volume and growth in the amount of warm air in the pulmonary ways after exhalation [3]; thus the discovered fact of a significant fall in this indicator values with increasing age serves as a message of concern. J.F. Morris et al. (1975) reported a negative correlation existed between the patency index of bronchioles of this type and age [16]. In addition to the well-known fact of an age-related decrease in vagal nerve tone, I.V. Averyanova (2023) observed the similar picture for northern men who reduced the activity of the parasympathetic link of the ANS, which shifted the sympathetic-vagal balance to a relative condition of sympathetic activity [1]. In this aspect, the esTableished change in bronchial patency cannot be explained in terms of a shift in the ANS balance since a 20-40% narrowing of the bronchi lumen clearly contradicts the idea of the influence of age-associated sympathicotonia. It is obvious that the causal relationships of such pulmonary dynamics lie in the complex intersystem mechanisms of adaptation. This provides the priority and will be given emphasis in our further research. The intergroup dynamics of bronchial obstruction indices (FEV_1/VC, FEV_1/FVC) had a similar picture of a significant increase up to maximum levels which could be seen from the group of adolescents to young adults with a further gradual decrease to the elderly.

Conclusion. This study showed pronounced intergroup dynamics in the bronchopulmonary performance in Northerners of workable and older ages owing to the violation in the patency of the bronchi of various diameters as risks of developing bronchoobstructive disorders and weakened adaptabilities of the body. Along with constant adverse effects of natural and climatic environmental factors, these changes indicate age-related tension in the lung functioning which is increasingly stressed in small bronchioles and can cause restriction of access of the oxygen-enriched air mixture to the distal parts of the lungs where the main part of gas exchange occurs in the acinus's perfused alveoli. Such a picture may be a consequence of overstrain in the pulmonary function (after reaching maximum in early adulthood) which develops misalignment and weakening of regulatory mechanisms. Social relevance of the condition requires further detailed research.

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SCIENTIFIC REVIEWS

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MODERN METHODS OF EXPERIMENTAL EVALUATION OF BIOMECHANICAL PROPERTIES

The review presents a description of methods and results of various experimental studies of corneal biomechanical properties: the technique of tensile testing, the indentation method, and atomic force microscopy. Corneas of experimental animals and humans (in particular, donor eyes and material obtained as a result of keratoplasty) are considered as "sources" of samples. Selective evaluation of individual corneal structures using classical mechanical tensile tests is limited to a certain extent due to the rather small thickness of these structures and, as a consequence, difficulties in fixing the specimen. In real practice, it remains promising to use indentation and AFM, which are more adapted for such studies, on the one hand, eliminating the need for mechanical fixation of the specimen, and on the other hand, providing the possibility of studying various areas and surfaces of the latter.

Keywords: cornea, biomechanical properties, methods of experimental evaluation.

The encyclopaedic interpretation defines biomechanics as "a section of biophysics that studies mechanical properties of biological tissues, individual structures and organs on the basis of models and methods". From the point of view of the tasks to be solved, biomechanical research can be divided into fundamental and applied. In the first case it is a question of determining various indices characterising mechanical properties of tissues, and in the second case - in addition to that, about clinical significance of these properties in terms of potential influence on pathogenesis, methods of diagnostics and treatment of various diseases.

The cornea, being a part of the outer fibrous membrane of the eye, in addition to conducting and refracting light rays, provides the function of maintaining a certain shape of the eyeball, primarily related to biomechanical properties. Besides, it is the cornea that is the zone of "application" of the most widespread in clinical practice aplanation methods of intraocular pressure measurement and the determined indices can also depend on the "biomechanics" of the cornea. Thus, in relation to the cornea, the applied direction of biomechanical research is connected with solving the problems of diagnostics and monitoring of glaucoma, as well as pathological changes in its thickness and shape induced by diseases and surgical interventions [2-3, 5, 14, 15, 22, 26-27, 32, 37, 44].

Methods for assessing the "biomechanics" of the cornea are divided into clinical and experimental methods. Clinical or lifetime (i.e. in vivo) methods are based on the analysis of changes in the corneal shape as a result of some effect, for example, using a McLakov tonometer of different masses or an air jet (elastometry and bidirectional corneal pneumoaplanation, respectively). Experimental methods are based on mechanical tests of isolated corneal specimens (i.e., ex vivo) obtained from experimental animals, from human donor eyes, and as a result of any corneal surgery [74].

To characterise the biomechanical features of a material, such an index as Young's modulus (modulus of elasticity), which characterises the material's resis-

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