## NUTRITIONAL STATUS AND LIFE SPAN OF HUMANS

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Social factors such as bad living conditions, harmful labor conditions, low quality of medicine, loss of social contacts, etc., and lifestyle factors such as mal- and over-nutrition, hypodynamia, bad habits, etc. are the main issues of premature ageing. In this article, the alimentary factor such as the risk of premature ageing has been considered from the point of view of over- and malnutrition (protein-energy undernutrition) and its influence on the rate of ageing. The effect of overnutrition has been examined in the literature review of Russian and foreign investigators. Scientific publications show that one alimentary factor can be used to produce a significant influence on life span and frequency of some degenerative diseases. The relationship between malnutrition in the older population and biological age has been evaluated. 408 those surveyed from the city of Voronezh aged 55 to 70 were included into the study. The examination was nonrecurrent. The biological age of those surveyed was determined using the method by V. P. Voitenko. Malnutrition was assessed with the MNA (Mini Nutritional Assessment) tool. Malnutrition is observed among 2.2% of elderly patients, 58.8% of those surveyed are at risk for malnutrition, whereas 39% of them have a normal alimentary status. It is established that the biological age is correlated with the alimentary status. Statistically significant differences are found in the mean group values of the biological age in the subgroup of people with a normal alimentary status in relation to the subgroup of people with a risk for malnutrition ($p<0.05$): the values were 56±1.7 and 64±1.4, respectively. The publication shows a direct and indirect influence of the alimentary status (both overnutrition, and malnutrition) on the rate of senescence.

**Keywords:** nutritional status, life span, nutrition, senescence (ageing), biological age

**Author contributions:** Skrebneva AV analyzed literature and planned the investigation, Vasil'yeva MV collected and processed the material, Skrebneva AV and Melikhova EP wrote the text, Skrebneva AV performed statistical processing, Melikhova EP was responsible for editing.

**Compliance with ethical standards:** the participation was voluntary. All participants signed the informed consent form prior to inclusion into the study.

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## ПИЩЕВОЙ СТАТУС И ПРОДОЛЖИТЕЛЬНОСТЬ ЖИЗНИ ЧЕЛОВЕКА

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Среди причин преждевременного старения на первом месте стоят социальные факторы (плохие жизненные условия, вредные условия труда, низкое качество медицины, потеря социальных контактов и многое другое) и факторы образа жизни: недостаточное или избыточное питание, гиподинамия, наличие вредных привычек и т. д. В данной работе такой алиментарный фактор, как риск преждевременного старения, рассмотрен с двух позиций: избыточного и недостаточного (белково-энергетическая недостаточность) питания и его влияния на темп старения организма. Влияние избыточного питания изучено в результате проведенного литературного обзора российских и зарубежных исследователей. Работы показывают, что при помощи одного алиментарного фактора можно в значительной мере воздействовать на продолжительность жизни и частоту некоторых заболеваний дегенеративного характера. Нами проведена оценка взаимосвязи между недостаточностью питания пожилых людей и биологическим возрастом. В исследовании приняли участие 408 респондентов в возрасте от 55 до 70 лет, проживающих в г. Воронеже. Обследование было единовременным. Биологический возраст респондентов оценивался методом В. П. Войтенко. Анализ недостаточности питания проводили с использованием анкеты «Краткая оценка питания» (MNA — MiniNutritionalAssessment). 2,2% пожилых людей имеют недостаточное питание, 58,8% респондентов — риск развития недостаточного питания, 39% — нормальный пищевой статус. Установлено, что биологический возраст коррелирует с пищевым статусом. Получены статистически значимые различия в среднегрупповых значениях биологического возраста в подгруппе лиц, имеющих нормальный пищевой статус по отношению к подгруппе лиц, имеющих риск развития недостаточности питания ($p<0,05$): показатели составили 56±1,7 и 64±1,4 года соответственно. В работе показано прямое или косвенное влияние пищевого статуса, причем как избыточного, так и недостаточного, на скорость процесса старения организма.

**Ключевые слова:** пищевой статус, продолжительность жизни, питание, старение, биологический возраст

**Вклад авторов:** Скребнева А. В., Васильева М. В. — анализ литературы, планирование исследования, Скребнева А. В., Мелихова Е. П. — сбор и обработка материала, написание текста, Скребнева А. В. — статистическая обработка, Мелихова Е. П. — редактирование.

**Соблюдение этических стандартов:** участие было добровольным, все обследуемые подписали информированное согласие перед включением в исследование.

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The issue of comprehending the nature of senescence, its warnings and possibility of life prolongation has been receiving the attention of revered scientists for a long time (I. I. Mechnikov, A. A. Bogomolets, A. Steinach, S. Voronov, V. N. Anisimov, V. N. Shabalin, V. Kh. Khavinson, O. N. Tkacheva, etc.) [1–6]. From the point of view of modern science, ageing should be considered as a constant and inevitable process, starting soon after the individual's growth is over, and in some cases even earlier. Ageing is not typical of the last third part of our life, as it is with us during the entire life. Morphological and

functional involution of many organs, occurring during the life, results in significantly decreased accustomization and reduced capability of regulatory mechanisms to support the internal environment consistency. A series of experiments has shown, that simultaneous to establishment of the general character of senescence phenomena, in some cases the rate of ageing can be significantly influenced and slowed down. Ecological factors capable to accelerate or slow down the ageing process are found.

Many degenerative diseases, which are currently manifested at a very early age, represent just premature ageing of certain systems of organs, which is just a reaction to modern conditions of life [7]. It is possible that the conditions stopped corresponding to the ecological optimum, to which a human was slowly adapted during the long-term evolution.

Nutrition is a factor that determines the life span. Non-rational nutrition is one of the basic reasons for an increased senescence rate of a body. Elderly people commonly consume less proteins and energy as compared to the younger ones. With age, the gastrointestinal tract undergoes certain changes such as reduced strength of contraction, failure of the sphincter to effectively relax for the intestine; atrophy, delay in motor activity, reduced gastric acid secretion for the stomach; malabsorption of D-xylose, large amount of fats, vitamin D, folic acid, calcium and zinc for the small intestine; atrophy of the muscle segment, increased amount of collagen and elastane, increased time of food transition for the large intestine; atrophy of the gland, increased diameter of the glands for the pancreas; reduced reaction to cholecystokinin, increased bile lithogenicity for the gallbladder. Consequently, individualized nutrition is required with age, taking into account metabolic profiles and condition of separate organs and systems [8].

According to A. Yu. Baranovsky and L. I. Nazarenko, in protein malnutrition of people over 60 years of age, the biological age can exceed the calendar one by 40% and more. In too high calorie diet predominantly due to carbohydrates in people aged over 60, the biological age can exceed the calendar one by 50% and more [9].

Thus, the purpose of our publication is to study the influence of mal- and overnutrition on human body ageing.

## MATERIALS AND METHODS

The study object includes population older than working age from the city of Voronezh. All study participants were informed about the purpose and course of the work. Those surveyed aged 55 to 70 who signed the informed consent were included into the study.

The study object is the alimentary status as the factor influencing life span. For the study, a sample size was calculated based on A. M. Merkov's formula (1962) with a known number of observations in a population:

$$n = \frac{(p \times q \times t^2 \times N)}{(N \times \Delta^2 + p \times q \times t^2)}, \text{ where}$$

n — the minimum sample size;
N — the number of a general population;
p — the probability value of the studied phenomenon (it is not known in this case, that's why it was estimated to be equal to the maximum possible value or 50%), the sign rate in the aggregate;
t — confidence coefficient (t=2 at p=0,05);
Δ — margin of a value error (5%);
q — the value of optionality (100-p).

The values of t and Δ are selected to follow the high confidence of survey results (95% cases in case of an admissible error of ±5%).

On 01.01.2021, the general population (N) of the elderly from the city of Voronezh was 490 thousand people:

$$n = \frac{(50 \times 50 \times 2^2 \times 49000)}{(490000 \times 5^2 + 50 \times 50 \times 2^2)} = 400$$

Thus, the study can be considered representative, as the number of participating elderly people in the city of Voronezh was at least 400 people.

The biological age was determined using the method by V. P. Voitenko defining the ageing rate of a human being [10]. Certain measurements such as SBP, BP (with a tonometer), pulse pressure (PP) (difference between SBP and BP), body mass in kg, statistical balancing in seconds, and timed inspiratory capacity in seconds should be taken in the one surveyed. The heart rate (HR) is measured when standing on the left leg, with closed eyes, hands down, with no shoes (done thrice, the best option is chosen). During the breath-holding test a patient takes a deep breath and holds it; the results are measured in seconds. Consequently, the one surveyed fills in the Health Self-Assessment Inventory (HSAI), which has 29 questions. The obtained data are used to calculate the actual (ABA) and proper (PBA) biological age by formulas different for men and women (formulas 1–4).

$$ABA_{women} = -1.463 + 0.415 \times PP + 0.248 \times BW + 0.694 \times HSAI - 0.14 \times HR \quad (1)$$

$$ABA_{men} = 26.985 + 0.215 \times SBP - 0.149 \times IBH \text{ (inspiration breath hold)} + 0.723 \times HSAI - 0.151 \times HR \quad (2)$$

$$PBA_{women} = 0.581 \times RA \text{ (real age)} + 17.24 \quad (3)$$

$$PBA_{men} = 0.629 \times RA + 18.56 \quad (4)$$

The rate of human ageing is assessed based on the obtained results. Thus, if the difference between ABA and PBA is 0, then the ageing rate corresponds to statistical standards. If the difference exceeds 0, the ageing rate is increased (pathological type of ageing), if it is less than 0, then it is slowed down (decelerated type of ageing).

The Mini Nutritional Assessment (MNA) tool was used to assess malnutrition in participants. The questionary was utilized to assess the nutritional status recommended by the European Association of Clinical Nutrition (ESPEN), and to assess and screen patients with a risk for malnutrition in the elderly [11]. The questionary consists of two (screening and rating) parts. The screening part consists of 6 questions with 14 maximum score possible. The second part of the questionary, or the rating one, is used when the score is 11 or less. Taking into consideration the accumulated scoring, the nutritional status can be concluded. If the score is 24.0 or more, the nutritional status is normal, the score of 17.0–23.5 denotes the risk of malnutrition, whereas the score of 17.0 and less means insignificant (poor) nutrition.

Literature was reviewed to study the effect of the alimentary factor on premature ageing.

The data were processed using Microsoft Excel 2013. Correlation analysis of the interrelation between the biological age and nutritional status was performed.

To process the values, parametric methods estimating the validity of statistical study results were utilized based on the use of a mean deviation ($m = \frac{\sigma}{\sqrt{n}}$), mean error in the difference between the values of the two groups ($m_{differences} = \sqrt{m_1^2 + m_2^2}$) and estimation of the statistical significance between the mean group values based on Student's t-test.

## STUDY OUTCOMES

The influence of nutrition on the biological age of the elderly was assessed and analyzed. 408 of those surveyed from the city of Voronezh aged 55 to 70 participated in the study. According to the results obtained during the survey of the nutritional issue, it was found out that 2.2% of the elderly have insufficient nutrition, 58.8% are at risk for malnutrition, and 39% possess a normal nutritional status.

In the performed study it was found out that the biological age is correlated with the nutritional status. The lowest values of the biological age are typical of the people with a normal nutritional status. In the group with malnutrition, no significant difference in the values was found in the course of a statistical analysis due to a small sample (9 people), large variance and significant error of the mean (m±6.2).

Statistically significant differences in the mean group values of the biological age were obtained in the subgroup of people with a normal nutritional status as compared with the subgroup of people at risk for malnutrition ($p<0.05$): the values were 56±1.7 and 64±1.4, respectively (table).

The obtained data require a subsequent analysis of the condition of those participants with the risk of malnutrition in order to find the reasons for its development and possible successful correction.

Thus, malnutrition produces an influence on a human's life time. The elderly people with a catabolic stress due to chronic diseases, traumas and age, reduced physical activity and sarcopenia have a critical need in increased and optimized consumption of proteins.

However, the results obtained during the analysis of scientific data from Russian and foreign studies have shown that an excessive amount of food is a factor of premature ageing.

## DISCUSSION OF RESULTS

In his works examining the effect produced by the alimentary factors on life span of rodents, the American scientist McCay shows the correlation between the amount of food, on the one hand, and the rate of growth, life span and rate of some degenerative diseases, on the other hand.

McCay compared two groups of rats of the same line, fed and grown under the similar conditions during the entire life. The only difference was that the control animals were fed ad lib, whereas the experimental animals had a quantitatively limited, but fortified foods. If in control rats, the growth of skeleton stopped when they were 175 days old, and they died at the age of 2.5 years, then the experimental rats continued their slow growth until they were 300, 500, 700 and even 1000 days old, depending on the age when they were given a regular diet. It is extremely important to notice that the growth arrest due to caloric reduction was always accompanied with distinctly increased life span in animals. In the first experiment, one experimental rat held the record for longevity (1.421 days). In other words, its life span was twice as high as the average life span of the control animals. In the second experiment, when all the control animals have already died, the experimental animals, who have reached the age of 1.000 days, started growing again [12].

It is equally important that slow ageing is accompanied with a reduced rate of degenerative diseases. Lymphatic sarcomas, commonly occurring in control animals aged over 400 days (54%), were found less frequently in the experimental group (6%) and developed much later (aged above 800–1000 days). Another example is as follows. Nephrosclerosis, which is the most frequently occurring degenerative disease in rats of this strain, was almost lacking in animals with retarded growth (2 of 197 of the studied animals). The cited facts confirm that no distinction can be drawn between the physiological and pathological ageing, as both categories of events are inseparably associated. Thus, pathological ageing of any system is virtually an intensification of a common physiological process.

From the physiological point of view, rats with retarded growth occupy an intermittent position between the control animals of the same age and younger species. Their activity and metabolism are decreased, whereas the reproductive ability is manifested only when the food is not restricted any longer.

McCay's data are confirmed in the works by Riesen, Herbst, Walliker, Elvehjem, who worked with rats; and Robertson, Marston, Wolter, Ball, Barner, Visscher, who used mice [13,14].

The study data demonstrate that one alimentary factor only can significantly influence life expectancy and rate of some degenerative diseases in mammals. It has long been known, that life span of poikilothermic vertebrates strongly varies depending on metabolism and growth rate, it was difficult to imagine that a similar dependence can be observed in superior vertebrates, who are less dependent on changes in the environmental conditions.

All the data obtained in tests with mice and rats can't be applicable to a human being. It is known that the rodents are more flexible than carnivores and primates. Thus, rats have no ossification of epiphyseal plates even when the bones stop growing.

Though the values of mortality and reasons for people's death are examined rather well, we still have no proof that the life span of people (like the life span of rodents) has a direct dependence on the amount and quality of food. The issue has so many variables that its statistical analysis is rather difficult.

However, a set of data about some groups of population in Europe and America shows that nutrition and a way of life produce a clear influence on the length of the coming adult life,

**Table.** Estimation of the difference in the biological age in population older than the working age depending on the nutritional factor

| Estimation of the nutritional factor | Estimation of nutrition | | | Biological age | |
|---|---|---|---|---|---|
| | M±m | max÷ min, число лиц | % | M±m | max÷ min |
| Malnutrition (less than 17 б) | 14±0.8 | 13.5÷15 (9) | 2.2 | 58±6.2 | 58÷69 |
| Risk of malnutrition (17–23.5 б) | 21±0.3 | 17÷23.5 (240) | 58.8 | 64±1.4 | 55÷70 |
| Normal nutritional status (24 and over) | 26±0.3 | 24÷30 (159) | 39 | 56±1.7 | 55÷69 |

Note:* — significant difference in the value as compared with the subgroup of those with a normal nutritional status ($p<0.05$).

and occurrence of degenerative diseases at a younger age. The diseases should be considered as bad cases of normal ageing.

Based on the available data we can confidently conclude that the majority of the richest people suffer from excessive nutrition and restricted muscular activity. The people's weight is ultimately above the line. In a number of works, a negative influence of adiposity on life time has been stressed.

In the research by Dublin and Marks it has been shown that among those of 50–59 years old with the weight exceeding the normal value by 15–24%, the mortality rate was 17% higher than the respective value for the entire population. If the weight was exceeded by 25–34%, then the mortality rate was higher by 41%. Among those who were 20 to 59 years old, a higher weight made a higher mortality rate [15]. In subsequent studies it has been found out that the mortality rate of obese people was higher than the one of those with a normal weight irrespective of their gender. Besides, there is a higher risk that young people (20 to 30 years old) suffering from obesity can die as compared to people aged 40 to 64. The mortality of obese men aged 20 to 29 is higher than the one of those with a normal weight by 80%, whereas in people aged 50 to 64 the excess makes 31% [16].

It is important to notice that the increased mortality rate is mainly associated with the increased rate of degenerative cardiovascular and renal diseases, which is a kind of premature ageing of separate organs.

Excessive amount of food can't be the only factor of premature ageing of those people who consume excessive amount of food in a limited physical activity. The type of food and too high content of animal fat in the diet should be taken into account.

It is known that the rate of atherosclerosis and one of its most dangerous manifestations such as myocardial infarction is various in different populations. It must be accepted that the criteria, that form the basis of the statistical collection, are not always comparable. The anatomical criterion is the best one. However, the studies are time-consuming, difficult and rarely conducted. Clinical criteria such as the electrocardiographic ones are not that valuable, but allow to collect a vast amount of data.

Nevertheless, the revealed differences between separate groups of population with a different way of life are so great, that they can't be attributable to imperfect methods of material collection only.

The influence of different aspects of a mode of life on the span of life was found in the last century. Thus, based on the results obtained during the examination of 10,000 people and analysis of 1,000 cases of necropsy, Kimura concluded that in Japan, the coronary arteries were affected 10 times less frequently than in the USA [17]. According to the statistical data of that period, the mortality rate due to coronary atherosclerosis is 231.8 (per 100,000 of population) for men aged 45 to 49 in the USA, and only 24.1 in Japan. The mortality rate is 637.9 and 60.3 for men aged 55 to 59, and 1,402.8 and 125.1 for men aged 65 to 69. Significant differences were found when diets of these groups were compared. According to Keys etc., fats constitute only 9% of calories in Japan and 40–43% in the USA [18]. Significant differences in serum total cholesterol were discovered as well: 141.5±3 mg/% in those from Japan (men aged 40–49) and 242.5 mg/% in those from the USA, who were of the same age.

The differences are not due to racial features, but due to a different type of nutrition. In the Japanese Americans aged 40–49 with 39% of fat in the diet, total cholesterol is 246.2±5.8 mg/% [18]. Consequently, they have a higher infarction frequency as compared to those who live in Japan.

Thus, the results show that along with other factors, both malnutrition, and overnutrition produce a huge influence on duration of life.

## CONCLUSIONS

The work deals with direct and indirect influence of the alimentary status on the rate of ageing. It is demonstrated that people leading a sedentary life consume much more food than it is needed to satisfy their caloric requirements. Besides, the type of diet was changed as well. Today people eat more meat, sausages, dairy cream and butter than fifty years ago, whereas the share of fresh vegetables significantly dropped. This resulted in an increased consumption of animal fat, leading to premature ageing of the cardiovascular system.

Thus, leading a healthy way of life, satisfying all hygienic requirements to rational nutrition at an early age belong to an important principle of premature ageing prevention.

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