<div style="text-align:center">**Original Article**</div>

# Monitoring and differentiation of the periods of the intensity of aging and death in the Ukrainian population

NATALIYA MAZUROK[1], OLEKSANDR PRYIMAKOV[2], MAREK SAWCZUK[3], OLEKSII TYMOSHENKO[4]
[1,2,3,]Centre for human structural and functional research, University of Szczecin, POLAND
[4]National Pedagogical Dragomanov University, UKRAINE

**Abstract.**
Building an evolutionary model of human physical state necessitates information about his/her life periodization according to a criterion that correlates with vitality, health level, and work capacity. Therefore, the ***objective of our study*** was to analytically describe and determine the duration and most typical and characteristic determinants of periods of adaptation, normal vital activity, aging and death based on the function of the intensity of aging and death of the population of Ukraine in 2020. It reflects clearly and informatively its vitality, health level, and physical work capacity. **Material and methods:** Periodization was carried out according to the age and cause of death of 616,835 people, of which 305,755 were men and 311,080 were women based on the methods of statistical analysis, approximation, and systematization using the "STATISTICA 13.5" program. ***Results:*** The average life expectancy of men 66 years, women 76 years, and both sexes 71 years was differentiated into periods of adaptation, normal vital activity, aging and death, and their duration was determined, which constituted 5 – 41 – 20, 5 – 43 – 28, 5 – 42 – 24, respectively. The main cause of death during the period of adaptation is the manifestation of certain conditions that arise in the perinatal period, whereas during those of normal vital activity and aging and death - external factors and diseases of the circulatory system, respectively. ***Conclusions:*** For the first time in 2020, an analytical model of the function of the intensity of aging and death was defined for the population of Ukraine, and according to the unified criterion of its speed change, life periods were differentiated and described by the superposition of exponents, their duration and the most typical and characteristic causes were determined.
**Keywords: intensity function, aging and death, periodization criteria, periods.**

## Introduction

In many scientific disciplines; biological, psychological, social, etc., when studying the evolution of human life, it is differentiated into periods or stages (Vasiliev, 2012; Gurov, 2018; Polishchuk, 2017; Khukhlaeva 2006; Shapovalenko, 2005).

For instance, building an evolutionary model of the human physical state necessitates information about the periodization of life according to criteria that would correlate with the level of somatic health (Apanasenko, 2016, 2017) and physical work capacity (Mikhailov, 2020).

At present, chronological differentiation in the most well-known periodization systems according to Erik Erikson, Elkonin, Vygotsky, Piaget, etc. is quite relative, since it is traditionally carried out according to non-unified criteria and is mainly descriptive and qualitative in nature (Shapovalenko, 2005; Khukhlaeva, 2006; Vasiliev , 2012; Polishchuk, 2017).

In addition, such periodization is practically neither updated for years nor specified by gender (Shapovalenko, 2005; Khukhlaeva, 2006; Vasiliev, 2012; Polishchuk, 2017).

According to various sources (State Statistics Service of Ukraine, 2020; World Population Aging 2020; Aging and health. © 2022 WHO; Nagorna et al., 2021), the state of health and demographic indices of the world and Ukraine change annually, which directly affects the change of the definition of periods.

Therefore, to obtain relevant and reliable information about life periodization, it is appropriate to determine it based on a statistical analysis of life expectancy and causes of death of the Ukrainian population in a single year. Such an analysis can be rationally made using the function of the intensity of aging and death, which clearly and informatively reflects the vitality of the population and thus its physical condition, including the level of somatic health (Apanasenko, 2016, 2017) and physical work capacity (Belozerova, 2008; Sirotin et al., 2009).

According to Belozerov (2008), Sirotin et al., (2009), Mikhailov (2020), the physical work capacity index is one of the key biomarkers of aging. Differentiation of vital activity into periods is expedient to perform according to the criterion of change in its speed, which, as opposed to traditional periodization, will allow analytical describing and analyzing the regularities of modern life and the specifics of individual age periods of adaptation, normal vital activity, aging and death, for men and women, as well as both sexes (Gnedenko et al., 1965; Mazurok 2011; Kyrylenko, et al., 2013).

Corresponding Author: NATALIYA MAZUROK, E-mail: natprim75@gmail.com

-------------------------------------------------------------------------------------------------------------------------------

In this regard, the *objective of our study* was to analytically describe and determine the duration and most typical and characteristic causes of periods of adaptation, normal vital activity, aging and death based on the function of the intensity of aging and death according to the data of the State Population Statistical Service of Ukraine for 2020.

**Material & methods**

The study was carried out using official and reliable data on the age and cause of death of 616,835 people, including 305,755 men and 311,080 women. The data were obtained from the State Statistical Service of Ukraine for 2020 (State Statistical Service of Ukraine, 2020).

The study was conducted using:

- statistical analysis, which consisted in constructing a function of the intensity of aging and death.

The construction methodology is borrowed from the theory and practice of reliability, in which the function of the intensity of aging and failures is widely and effectively used to analyze the performance of various technical objects, assess the time of their failure-free operation, and identify the dominant causes of their failures in certain time periods (Gnedenko et al., 1965; Mazurok, 2011; Kyrylenko, et al., 2013);

- approximation of the function of the intensity of aging and death in certain time intervals and selection of the most adequate law for its description and determination of parameters (Laurent, 1975; Kononyuk, 2012);

- "STATISTICA 13.5" program based on which statistical analysis and approximation was made (Borovikov, 2018);

- systematization of the findings for the possibility of analyzing the data of a specific person as part of the whole system. Systematization was implemented by classifying the results into certain age intervals according to the criterion suggested in the work and establishing cause-and-effect relationships (Gnedenko et al., 1965; Warfield, 2006; Zhuravlev, 1989; Mazurok, 2011; Kyrylenko, et al., 2013) .

**Results**

The determination of the function of the intensity of human aging and death $\lambda(t)$ is associated with the lifetime (age) $t$ - the term from birth to death. From the angle of statistical analysis, lifetime is a random value with integral distribution $f(t)$.

The ratio of the number of dead people at age $t$ in a certain time interval $\Delta t$ to the total number of people who lived up to this age $n(t)$ determines the intensity of their aging and death (Gnedenko et al., 1965; Mazurok 2011; Kyrylenko, et al., 2013 ):

$$\lambda(t) = \frac{f(t)}{1 - \int_0^\infty f(t)} \approx \frac{n(t) - n(t + \Delta t)}{\Delta t n(t)}. \tag{1}$$

In 2020, 616,835 people died in Ukraine, including 305,755 men and 311,080 women (State Statistics Service of Ukraine, 2020). Based on the number of deaths at a certain age grouped into five-year intervals $\Delta t = 5$, the function of the intensity of aging and death for men, women, and both sexes of Ukrainians, respectively  was determined and depicted graphically in Fig. 1 and 2.
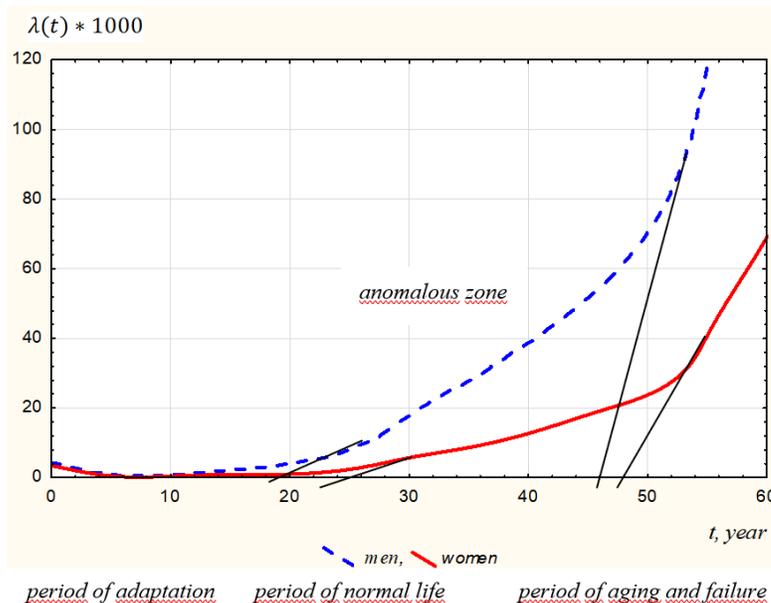


Fig.1 Intensity of aging and death of men and women

-------------------------------------------------------------------------------------------------------------------------------- 2191
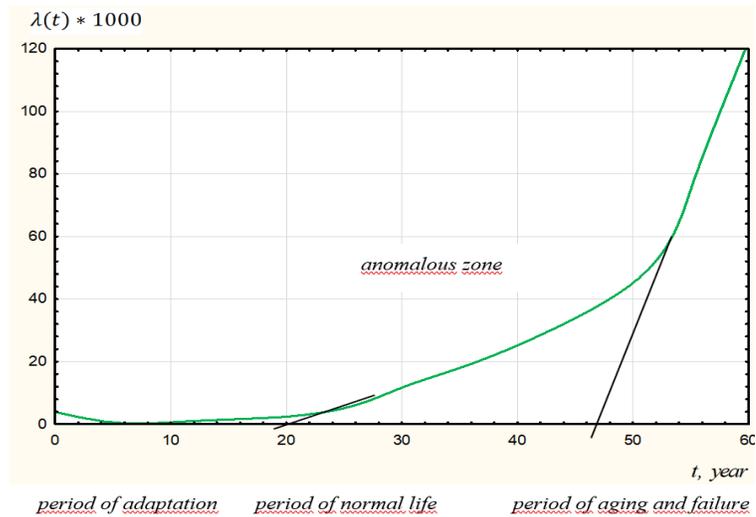
Fig. 2. Intensity of aging and death of both sexes of Ukrainians.

The analysis of the presented graphs demonstrated that the functions $\lambda(t)$ have a characteristic form of a "trough-like" curve, which initially declines, then stabilizes, and finally increases, that is, a certain part of the graphs fundamentally differs in the speed of the function of the intensity of aging and death $\frac{d\lambda}{dt}$.

This adherence to the principle allows the graphs of the functions $\lambda(t)$ of men, women, and both sexes of Ukrainians to be differentiated by the change in the speed of the function $\frac{d\lambda}{dt}$ into three periods: adaptation, normal vital activity, aging and death. The first period corresponds to a negative speed $\frac{d\lambda}{dt} < 0$, the second to a constant $\frac{d\lambda}{dt} = 0$, and the third to a positive $\frac{d\lambda}{dt} > 0$.

The change in the speed of $\frac{d\lambda}{dt}$ function, is due to the fact that the studied population of deceased persons is heterogeneous in terms of the causes of death, that is, it consists of a sum of subspecies, each of which has its "own" cause. It is noteworthy that peculiar for a certain age interval causes, one or several of which are dominant correspond to each period. These are the dominant causes that are responsible for the change in the speed of $\frac{d\lambda}{dt}$ and the formation of clear periods of intensity decline, stability, and increase (Gnedenko et al., 1965; Mazurok, 2011; Kyrylenko, et al., 2013). An adequate statistical description of the intensity requires finding the distribution law of the lifetime of the examined population as the sum of the distribution laws of each sub-population with account for its numerical proportion (Gnedenko et al., 1965; Mazurok, 2011; Kyrylenko, et al,. 2013).

Due to the lack of detailed information in the "age of the deceased - cause of death" system on the official website of the State Statistical Service it is impossible to determine the law of distribution of the lifetime of the deceased. Therefore, to describe the intensity, one may use the superposition of exponents and present each of the periods in the following form:

$$\lambda(t) = \lambda_0 \, e^{\frac{t}{\tau}}, \tag{2}$$

where $\lambda_0 > 0$, $\tau$ – some parameters. Parameter $\tau$ for the periods of adaptation, normal vital activity, aging and death will take on the following values $\tau < 0$, $\tau = 0$, $\tau > 0$.
The modulus of the parameter represents the relaxation time of the life period. Its double value approximately determines $t_n$ duration of the period (Gnedenko et al. 1965, Kyrylenko, et al. 2013, Mazurok 2011):

$$t_n \approx 2|\tau| \tag{3}$$

The duration of the periods can also be determined graphically by means of a tangent line drawn to the corresponding parts of the curve of aging and death intensity.

The first period of adaptation is caused by direct and hidden defects and deviations in the development of children, which lead to their rapid death, mainly under the age of 1 year. The number of boys, girls, and both sexes constitutes 1,086, 902, 1,988 persona, respectively (State Statistics Service of Ukraine, 2020).
The intensity of this period decreases, that is, it has a negative speed $\frac{d\lambda}{dt} < 0$, and is described by the exponent for men (4), women (5), and both sexes (6), respectively:

$$\lambda(t) = 4.3 * 10^{-3} e^{-\frac{t}{2.6}} \tag{4}$$

with parameters $\lambda_0 = 3.8 * 10^{-3}$, $\tau = -2.6$;

$$\lambda(t) = 3.5 * 10^{-3} e^{-\frac{t}{2.5}} \tag{5}$$

with parameters $\lambda_0 = 3.5 * 10^{-3}$, $\tau = -2.5$;

$$\lambda(t) = 3.9 * 10^{-3} e^{-\frac{t}{2.56}} \tag{6}$$

with parameters $\lambda_0 = 3.9 * 10^{-3}$, $\tau = -2.56$.

The analysis of the parameters demonstrated that the first period of adaptation is characterized by decreasing intensity and its duration determined by the formula (4) lasts $t_n$=5.2 years, $t_n$=5 years, and $t_n$=5.1 years for men, women, and both sexes of Ukrainians, respectively. The value of the parameter $\lambda_0$ of the adaptation period corresponds to the intensity of newborn mortality. In recent years, the $\lambda_0$ parameter has reached minimum values of $\lambda_0$=$min$, which indicates a decrease in child mortality. This is due to the fact that over the past 10 years, the birth rate has decreased to 293,457 people, whereas the death rate has reached a maximum value of 616,835, that is, there are approximately two deaths per one birth, and therefore the main reason for the low value of $\lambda_0$ is just the low birth rate (State Statistics Service of Ukraine, 2020). Data analysis (State Statistics Service of Ukraine, 2020; Krinichko, F., 2020) showed that the cause of death of 60% of infants under 1 year was the manifestation of certain conditions occurring in the prenatal period, such as; disorders associated with the duration of pregnancy and fetus size; intrauterine hypoxia and asphyxia during an act of delivery; respiratory disorder in a newborn (distress); bacterial sepsis in a newborn; hemorrhagic and hematological disorders of the fetus and newborn, etc.

Congenital developmental disorders, deformities, and chromosomal abnormalities, such as congenital heart defects, Down's syndrome, and other chromosomal abnormalities caused the death of 22% of children (State Statistics Service of Ukraine, 2020; Krynychko, F., 2020). In the remaining 18% of children, various defects and deviations constituted the cause of death, each of which has a statistically insignificant contribution compared to the two previous ones, which led to the loss of 60% and 22% of children, respectively (State Statistical Service of Ukraine, 2020; Krinichko, F., 2020). The next period of intensity is the period of normal vital activity. It begins from the age of 5 and is characterized by an almost constant intensity $\lambda(t) \approx const$ and, accordingly, its speed $\frac{d\lambda}{dt} = 0$, and has a relatively low mortality rate: for men, women, and both sexes, the intensity of this period is almost similar and is determined by the pre-exponential parameter:

$$\lambda(t) - \lambda_v \approx 0.2 * 10^{-3}. \tag{7}$$

The cause of death in this period is mainly associated with random external forces and is not related to the processes of aging and diseases (Mazurok, 2011; Kyrylenko, et al., 2013; Nagorna et al., 2021).

External causes include; transport accidents; falls; accidental drowning and immersion in water; accidents caused by smoke, fire, and flame; accidental poisoning caused by poisonous substances; intentional self-harm; consequences of an attack with intent to kill or injure; cases of injury with an unspecified intention.

In Fig. 1, 2, for men from the age of 20, women from the age of 26, and both sexes from the age of 21, the period of normal vital activity has atypical for this period abnormal zone of increasing intensity, with a positive rate of $\frac{d\lambda}{dt} > 0$.

According to Table 1, this zone is mainly due to a high number of deaths in men, women, and both sexes related to external causes constituting 7%, 2%, and 5%, respectively, that is, the mortality of men is 5% higher than that of women.

The increasing intensity of the abnormal zone is also subject to exponents for men (8), women (9), and both sexes (10), respectively:

$$\lambda(t) = 3.2 * 10^{-3} e^{\frac{t}{16.2}} \tag{8}$$

with parameters $\lambda_0 = 3.2 * 10^{-3}$, $\tau = 16.2$;

$$\lambda(t) = 0.7 * 10^{-3} e^{\frac{t}{13.6}} \tag{9}$$

with parameters $\lambda_0 = 0.7 * 10^{-3}$, $\tau = 13.6$;

$$\lambda(t) = 2 * 10^{-3} e^{\frac{t}{15.8}} \tag{10}$$

with parameters $\lambda_0 = 2 * 10^{-3}$, $\tau = 15.8$.

According to formula (3), the duration of the abnormal zone constitutes $t_n$=32.4 years, $t_n$=27.2 years, and $t_n$=31.6 years for men, women, and both sexes Ukrainians, respectively. This zone accordingly ends at the age of 52.4 years, 53.2 years, and 52.6 years for men, women, and both sexes, respectively.

Table 1. Number of deaths by main classes of causes of death and sex in 2020* (State Statistics Service of Ukraine, 2020)

| Causes | Men | | Women | | Both sexes | |
|---|---|---|---|---|---|---|
| | persons | % | persons | % | persons | % |
| I. Some infectious and parasitic diseases | 4941 | 2 | 2039 | 1 | 6980 | 1 |
| II. Neoplasms | 43295 | 14 | 34585 | 11 | 77880 | 13 |
| IX. Circulatory diseases | 182095 | 60 | 226068 | 72 | 408163 | 66 |
| X. Diseases of the respiratory system | 10619 | 3 | 5860 | 2 | 16479 | 3 |
| XI. Diseases of the digestive system | 14971 | 5 | 9196 | 3 | 24167 | 4 |
| XX. External causes of death | 22852 | 7 | 5783 | 2 | 28635 | 5 |
| XXII. Codes for special purposes | 11505 | 4 | 9779 | 3 | 21284 | 3 |
| Other unspecified causes | 15477 | 5 | 17770 | 6 | 33247 | 5 |
| In total | 305755 | 100 | 311080 | 100 | 616835 | 100 |

*Note: The data do not include the territory of the Autonomous Republic of Crimea and parts of the territories in the Donetsk and Luhansk regions.*

-------------------------------------------------------------------------------------------------------------------- 2193

*JPES ®*     www.efsupit.ro

-------------------------------------------------------------------------------------------------------------------------------

The duration of the period of normal vital activity characterizes the healthy period of human life. The longer the period, the healthier the population. For men, women, and both sexes, this period begins, as it was indicated, from the age of 5, but ends differently.

The end of the period of normal vital activity is masked by an abnormal zone. Therefore, it was defined as the point of intersection with the life time axis of the tangent line drawn to the rectilinear zone of the next period. Points of 46, 48, 47 years determine the end of the period of normal vital activity for men, women, and both sexes, respectively (Fig. 1, 2).

Thus, in 2020, the duration of normal vital activity period in men, women, and both sexes constituted 41 years, 43 years, and 42 years, respectively. In women, the second period was two years longer than in men.

The point of divergence between the tangent line and the third period of intensity also graphically determines the end of the abnormal zone of the second period. For men, women, and both sexes, it approximately constitutes 52-53 years, which practically coincides with the obtained above result of 52.4-53.2 years.

Data analysis indicated that the abnormal zone overlaps two periods of intensity and for men, this zone is 5 years longer than for women and begins 6 years earlier.

The end of the normal vital activity period is simultaneously the beginning of the last period for humans, that of aging and death. The intensity in this period increases rapidly, its rate is positive $\frac{d\lambda}{d\tau} > 0$. For men (11), women (12), and both sexes (13), the intensity is described by the exponent:

$$\lambda(t) = 0.4 * 10^{-3} e^{\frac{t}{10}} \qquad (11)$$

with parameters $\lambda_0 = 0.4 * 10^{-3}, \tau = 10$;

$$\lambda(t) = 1.9 * 10^{-3} e^{\frac{t}{14}} \qquad (12)$$

with parameters $\lambda_0 = 1.9 * 10^{-3}, \tau = 14$;

$$\lambda(t) = 0.8 * 10^{-3} e^{\frac{t}{12}} \qquad (13)$$

with parameters $\lambda_0 - 0.8 * 10^{-3}, \tau - 12$.

The last period of intensity for men, women, and both sexes begins at the age of 46, 48, and 47 years, respectively, and according to formula (3) lasts an average of 20, 28, and 24 years.

According to our data, the average life expectancy of men is 66 years, whereas that of women 76 years, that is, women live 10 years longer than men and the last period of their life begins two years later. The average life expectancy for both sexes of Ukrainians is 71 years.

The cause of death during this period is irreversible physiological processes that lead to deterioration of health, aging, and natural end of life (The top 10 causes of death. © 2022 WHO; World Population Aging, 2020).

Table 1 shows the most statistically significant causes of death (The top 10 causes of death. © 2022 WHO; State Statistics Service of Ukraine, 2020). Their analysis showed that in 2020, the cause of death of 66% of Ukrainians of both sexes was diseases of the circulatory system, namely ischemic heart disease - 46% and cerebrovascular diseases - 13%. Moreover, the number of women who died as a result of circulatory system diseases was 12% higher than that of men and constituted 72% and 60%, respectively.

The next 13% of Ukrainians lost their lives as a result of neoplasms, of which malignant neoplasms constituted 12%, including those of digestive organs - 4% and those of respiratory and thoracic organs - 2%. Mortality due to neoplasms in men was 3% higher than in women.

The remaining 21% of Ukrainians died of a variety of less statistically significant causes, such as diseases of the digestive system; respiratory diseases; codes for special purposes (COVID-19); symptoms, signs, and deviations from the norm, detected during clinical and laboratory tests, not classified in other headings; some infectious and parasitic diseases (tuberculosis, diseases caused by human immunodeficiency virus); diseases of the nervous system; endocrine diseases, nutritional and metabolic disorders (diabetes); diseases of the genitourinary system; mental and behavioral disorders, etc.

It should be noted that among the listed less statistically significant causes of death, COVID-19 ranks first and accounts for 5% of the total number of dead Ukrainians in 2020.

**Discussion**

Built on the statistical analysis of official data on the age and causes of death of 616,835 people, the analytical model of the function of the intensity of aging and death is an integral function of the "unhealthiness" of the population of Ukraine in 2020.

A change in its speed is a criterion for differentiating human life into periods in which the vitality of the population fundamentally changes due to internal and external causes along with its level of physical condition, including somatic health (Apanasenko, 2016, 2017) and physical work capacity ( Mikhailov, 2020).

Thus, during the first period from 0 to 5 years, mortality due to internal causes drops to a minimum level, and the vitality of the population in the second period reaches a maximum and stable value.

In the third period, due to the irreversible processes of body aging and degradation, mortality increases and, accordingly, the vitality of the population (functional capacities, level of health, physical development) drops to a minimum value. The presence of an abnormal zone from 20 to 50 years leads to an increase in mortality and a decrease in the vitality of the population due to external causes.

2194 -------------------------------------------------------------------------------------------------------------------

*JPES* ®    www.efsupit.ro

--------------------------------------------------------------------------------------------------------------------------

Graphs of the function of the intensity of aging and mortality illustrate the effect of the main causes of the "unhealthiness" of the population on its vitality during the period of adaptation, normal vital activity, and aging and death of men, women, and the entire population of the country in one year. The significant difference between the maximum intensity values in the first and last period visually emphasizes the low potential vitality of the population, which is due to the existence of a disproportion between birth and death rates over the last three decades. From 1993 to 2020, the population decreased from 51,870,400 to 41,732,779 people, which constitutes approximately 10 million people (State Statistics Service of Ukraine, 2020).

The analytical model of aging and death intensity developed on actual, reliable, and modern data can be recommended for increasing the reliability and relevancy of existing and developing new diagnostic and prognostic models of both the intensity of aging and death, as well as the level of somatic health and physical work capacity for the population of Ukraine ( Krinichko, L.., 2020; Krinichko, F., 2020; Nagorna et al., 2021). As for the principle of its building. it can be useful for specifying such models for other countries (World Health Organization 2021; Aging and health. © 2022 WHO).

Due to the possibility of obtaining operational information for any period of time on the basis of an analytical model, it is possible to evaluate the effectiveness of the measures taken to improve the physical condition, health, and physical work capacity of the population of Ukraine, and, if necessary, implement their correction (Aging and health. © 2022 WHO; Krinichko, L., 2020; Krinichko, F., 2020; Word Health Organization, 2021). In addition, this possibility fundamentally distinguishes the suggested periodization from the traditionally accepted ones, in which, despite the change of factors (demographic, biological, social, psychological, etc.) that directly impact the determination of the duration of vital activity periods, the information is neither confirmed nor updated decades if necessary (Shapovalenko, 2005; Khukhlaeva, 2006; Vasiliev, 2012; Polishchuk, 2017).

Some studies show that human biological age is significantly associated with physical work capacity (Moore et al., 2012). Thus, according to Moore et al., (2012), a higher level of physical activity ≥450 min./week, which clearly exceeded the minimum international recommendations of WHO in 2010 (150 min./week), was associated with higher life expectancy The principle of building an analytical model with the determination of periods of their duration and reasons in any time intervals can be extended to the study of evolutionary processes, gender differences, both for Ukraine and other countries (World Health Organization, 2021).

**Conclusions**
Based on systematization and statistical analysis of data of 616,835 people of the Ukrainian population in 2020:
- the function of aging and death of the Ukrainian population was described for the first time by an exponential law;
- as opposed to traditional approaches to human life periodization, according to the unified criterion of changes in the intensity of aging and death, the average life expectancy of men, women, and both sexes equal to 66, 76, and 71 years, respectively were for the first time differentiated into periods of adaptation, normal vital activity, and aging and death;
- the duration of the periods of adaptation, normal vital activity, and aging and death for men, women, and both sexes constitutes 5 – 41 – 20, 5 – 43 – 28, 5 – 42 – 24 years, respectively;
- the main cause of death during the adaptation period is the manifestation of certain conditions, which arise in the perinatal period, whereas during those of normal vital activity and aging and death  – external factors and diseases of the circulatory system, respectively;
- the mortality of men due to circulatory system diseases is 12% lower than that of women.
- it was established for the first time that the duration of an abnormal zone for men, women, and both sexes constitutes 20 – 52; 26 – 53; 21 – 53 years, respectively;
- the main cause of abnormal zone is the mortality rate due to external factors, which is 5% higher in men as compared to women.
**Conflict of interests.** The authors declare that there is no conflict of interests.

**References:**
Aging and health. © 2022 WHO (2022).  https://www.who.int/ru/news-room/fact-sheets/detail/ageing-and-health
Apanasenko G.L. (2016).  Biological degradation of homo sapiens: motor activity as a major counteraction way / G. L. Apanasenko // Physical culture, sport, health and longevity: collection of materials of the fifth All-Russian scientific conference with international participation. - 2016. - P. 23-29.
Apanasenko G.L. (2017). Laws of thermodynamics and human health. *Sechenovskiy vestnik*, 2(28): 61-66. UDC 612.014.1:613:536.12.
Belozerova L.M. (1998). Method of determining biological age according to work capacity. *Clinical gerontology,* 2: 34-38. (in Russian).
Borovikov V.P. (2018). Popular introduction in modern data analysis and machine teaching on STATISTICA. M.: STI «Hot line – Telecom». - 354 p. - ISBN 978-5-9912-0738-6. (in Russian)
Gnedenko B. V., Belyaev Yu. K., Solovyov A. D. (1965). Mathematical methods in reliability theory. The main characteristics of reliability and their statistical analysis. Moscow: Science, 1965. - 524 p.  (in Russian)

Gurov V.A. (2018). Chronobiology. Age periodization. *Universum: Chemistry and biology: electron.sci.journal*, 4(46). URL: http://7universum.com/ru/nature/archive/item/5703  (in Russian)

Khukhlaeva O.V. (2006) Development psychology. Youth, adulthood, old age.  Moscow: Academy, 208 p. ISBN 5-7695-2635-1 (in Russian).

Kirilenko V.M., Mazurok N.S. (2013). Physical and statistical models of reliability of heterogeneous items degradating by the diffusion mechanism. Energy*, XXI (2): 13 - 18. (in Russian).

Kononyuk A.E. (2012). Generalized modeling theory. Beginnings. B.1. P.1. «Education of Ukraine». – 602 p. ISBN 978-966-7599-50-8. (in Russian)

Krinichko, F.R. (2020). Evaluating children mortality status as a constituent of state policy in the field of public health. *Economics, management and administration*, 4(94): 150–159. https://doi.org/10.26642/ema-2020-4(94)-150-159 (in Ukrainian).

Krinichko, L.R. (2020). Evaluating current health status of Ukrainian population. *Economics, management and administration*, (4(94): 142–149. https://doi.org/10.26642/ema-2020-4(94)-142-149 (in Ukrainian).

Kvyetnyy R. (2007). Basics of Modelling and Computational Methods. Vinnytsia: VDTU. 147 p. (in Ukrainian)

Laurent P.J. (1975) Approximation and optimization. Moscow: Mir. - C. 496. (in Russian)

Mazurok N.S. (2011). Physical substantiation of the failure rate of products with the diffusion degradation mechanism. *Electronics, coll. mat. IV Intern. sci.-tech. conf.young sci., 29 - 31 March. 2011, Kyiv. P. 1*. M-ry of Education and Science of Ukraine, NTUU «KPI». P. 156-161. (in Russian).

Mikhailov P.V. (2020). Age changes of physical performance, hemorheology and microcirculation in persons with different levels of motor activity. Diss. Doc. Biol. Sci.  Yaroslavl: 297 p.

Moore, S.C., Patel A.V., Matthews C.E. et al.  (2012). Leisure time physical activity of moderate to vigorous intensity and mortality: a large pooled cohort analysis. *PLoS Med*., 9(*11*).  P. e1001335.

Nagorna A.M., Basanets A.V., Kononova I.G., Medvedovska N.V., Gvozdetsky V.A. (2021). Health status of working age population and the efficiency of Ukrainian health care system functioning. *UKRAINE. HEALTH OF NATION, 1(63)*. ISSN 2077-6594. http://healty-nation.uzhnu.edu.ua/article/view/227145 (in Ukrainian).

Polishchuk V.M. (2017) Age periodization and classification. *Naukovyi visnyk Khersonskoho derzhavnoho universytetu.Series Psychological sciences*, Iss. 1, Vol. 2: 103 – 108. (in Ukrainian).

Shapovalenko I.V. (2005). Age psychology (Development and age psychology). Moscow: [Electronic resourse]. http://www.alleng.ru/d/psy/psy014.htm    (in Russian)

Sirotin, A.B. Belozerova L.M., Shchepina G.M. (2009). Motor activity impact on aging of middle age men. *Remedial gymnastics and sports medicine,* 6: 21–24.

The top 10 causes of death. © 2022 WHO (2022).  https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death .

Vasiliev Ya.V. (2012) Futurreal age periodization of personality development and self-development. *Theory and practice of modern psychology,* Iss. 5: 63-67. http://nbuv.gov.ua/UJRN/tpcp_2012_5_13 . (in Ukrainian)

Warfield J.N. (2006). Introduction to Systems Science. Singapore: World Scientific.

World Population Ageing 2020: Highlights (2020). United Nations Department of Economic and Social Affairs 2020. https://www.un.org/development/desa/pd/news/world-population-ageing-2020-highlights.

Zhuravlev Yu.I. (1989). Identification. Classification. Prediction. Mathematical methods and their usage. Iss.2. Moscow: Science. (in Russian)

State Statistics Service of Ukraine (2020).  http://database.ukrcensus.gov.ua/PXWEB2007/  (in Ukrainian).

On the way to healthier Ukraine. Progress in achieving the objectives of steady state development of health care field – 2020. WHO | World Health Organization (2021). https://apps.who.int/iris/bitstream/handle/10665/340956/WHO-EURO-2021-1523-41273-58139-ukr.pdf (in Ukrainian).