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## INEQUALITY IN THE FACE OF DEATH UNDER COVID-19 IN UKRAINE

*If there is a decline in mortality, it is mainly in younger age groups. As a result, more and more deaths are occurring in older age groups. In advanced societies, therefore, people are becoming “more equal in the face of death”. A sharp increase in mortality, such as that caused by the Covid-19 pandemic, affects different age groups of the population to different degrees. It is therefore relevant to study the change in inequality of life expectancy under the conditions of a sudden shock. The purpose of this paper is to analyse the inequality of lifespan variation in Ukraine in 2020—2021 and to compare it with countries with different levels of mortality.*

*Previous studies of lifespan variation specifically devoted to Ukraine, or those that used data for Ukraine, were conducted or related to the pre-Covid period. The novelty of this work is the study of the behaviour of indicators characterising the inequality of lifespan before and during the two years of the epidemic, for which data are available. The demographic method for constructing life tables and statistical methods for calculating lifespan variation indicators were used. Those are: Gini coefficient, average inter-individual difference in length of life, lifespan disparity, entropy of the life table, standard deviation of age at death, coefficient of variation. These indicators were calculated for the period 1989—2021 for Ukraine, Poland, Sweden, Spain, Japan, and England and Wales. It was confirmed that life expectancy is generally inversely related to inequality in the life table. It was found that this rule can be violated during mortality shocks such as the Covid-19 pandemic. It is shown that male life expectancy and lifespan inequality in Ukraine decreased in 2020—2021. Average inter-individual difference in length of*

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life and lifespan disparity have decreased by 6.6—6.9 %. On the other hand, almost all indicators of inequality for women have increased. The life expectancy elasticity indicator (entropy of the life table) turned out to be the most sensitive, increasing to 4.9 %. At the same time, it is interesting to note that the standard deviation of age at death for women in Ukraine decreased by 1.8 %. The Covid-19 pandemic has affected inequality depending on sex and the country's pre-Covid level. Inequality indicators in Japan have hardly changed. Inequality rates rose in Spain and Sweden before returning to their previous downward trend. Available data for England and Wales suggest a continued slow trend towards greater inequality.

**Keywords:** *lifespan inequality, lifespan disparity, Gini coefficient, Covid-19.*

*'... of all the casualties of this existence upon earth,  
not one was dealt out with so unequal a hand as Death.'*

*(Charles Dickens, Hard Times)*

**Relevance of the research.** Charles Dickens, renowned for his powers of observation, noticed 170 years ago that deaths were distributed in society unequally. At the time, infant and child mortality was extremely high. One of the characters in Charlotte Brontë's novel says to a 5-year-old girl: "Children younger than you die daily." Life expectancy at birth, both period and cohort, conceal details of the distribution of mortality by age. Life expectancy at birth in England and Wales in 1840—1850 was 36.5—43.6. Cohorts born in that decade lived on average 38.9—44.6 years. By way of comparison, Robert L. Stevenson died at 44 and Elizabeth Gaskell at 55. But in the same era, Queen Victoria lived to almost 82, and Thomas Hardy died at 87. In other words, when a large proportion of people died in childhood, there were some persons who managed to live almost twice as long as the expected average.

Since then, the age structure of mortality has changed significantly: young children no longer die with the same intensity as they did a century and a half ago. The decline of infant mortality has been the main driver of the increase in life expectancy at birth. The age at which people die has gradually shifted to older age groups. This process formed an increasing concentration of deaths in an increasingly narrow age range. More and more people began to die at about the same age. Thus, people became more equal before death. Still, not everyone dies at the same age. Even in advanced countries, the risk of premature death is not equally distributed and varies according to social status, standard of living, and other related factors.

In Ukraine, life expectancy has undergone several sharp and multidirectional changes over the last half century. In some periods, the mortality rates of individual age groups changed in different directions at the same time. As a result, life expectancy at birth could hardly change, but the structure of mortality by age was redistributed again, as it was in 2000—2008. The Covid-19 pandemic led to a sharp decrease in life expectancy at birth in Ukraine. Mortality caused directly or indirectly by Covid-19 affected different age groups of the population unequally. It is therefore relevant to look more closely at how much inequality in life expectancy changed in Ukraine during the years of the Covid-19 pandemic.

**Literature review.** Inter-individual inequality in the life expectancy of the population of Ukraine was investigated by N. M. Levchuk and L. V. Luschik [1]. Using the Gini coefficient and the quartile range, they studied the process of mortality compression. Their work revealed a decrease in inter-individual inequality in length of life in Ukraine since the 2000s.

Indicators of the lifespan variation deepen the understanding of the dynamics of life expectancy during sharp shocks in mortality. In particular, absolute and relative indicators of variation have been used to study mortality during the famines of 1772—1773 in Sweden and 1932—1933 in Ukraine, the epidemics of 1808—1809 in Sweden and 1846 in Iceland [2]. This work also shows that during periods of sharp increases in mortality, relative indicators of variation in life expectancy increase, while their absolute counterparts decrease [2, p. 304—307].

J. M. Aburto and A. A. van Raalte [3] explored trends in lifespan variation in Central and Eastern European countries from 1960 to the beginning of the second decade of the 21st century using life disparity indicator. They identified five periods defined by trends in the coefficient of variation of male life expectancy [3, p. 2073]. The authors showed the heterogeneity of mortality patterns observed in this region and their differences from those observed in most developed countries. They also quantified the impact of large classes of causes of death on the life disparity trends for the period 1994—2010.

Overall, the interest in research on life expectancy inequality over the past two decades has been extraordinary. Life expectancy, like any other average, does not describe all the differences in the life expectancy across the population. Therefore, there has been a need for increased use and monitoring of indicators to measure lifespan variation, such as: Gini coefficient [4], standard deviation [5], life-years lost [6], life table entropy [7] etc. A detailed overview of the lifespan variation indicators and their properties can be found in the paper by A. A. van Raalte and H. Caswel [8].

Although the increase in life expectancy is mainly accompanied by a decrease in inequality, there have recently been reports of the possibility of a simultaneous increase in some countries or subpopulations [9, p. 5250]. This situation can be observed as a result of declining mortality in older age groups (above a certain threshold age) [10, p. 11].

The research of the burden of the *Covid-19* on life expectancy and lifespan inequality in England and Wales discovered a new, previously undocumented pattern, when these indicators decline simultaneously [11, p. 739]. This was due to the increased excess mortality in older age groups and a corresponding shift in the age distribution of deaths, which made the age at death more similar and reduced the variation due to the overall increase in mortality [11, p. 739].

**Novelty.** A system of indicators characterising lifespan variation in Ukraine during the *Covid-19* pandemic in comparison with the previous period and

several other countries was calculated. The behaviour of these indicators under the influence of abrupt shifts in mortality was studied.

**The aim of the article** is to study the change in lifespan variation with a sharp change in mortality. The analysis will provide a deeper understanding of the processes of transformation of the life expectancy regime in Ukraine.

**Data.** This study used data retrieved from the State Statistics Service of Ukraine [12], the Human Mortality Database [13], the SCB Statistical Database [14], Statistics Poland [15], and the Instituto Nacional de Estadística [16]. The invasion of Ukraine by the Russian Federation in 2014 resulted in incomplete registration of demographic events or the inability to obtain complete data on the population in certain regions of Ukraine. Therefore, the analysis of mortality in the period 2014—2021 covers only part of Ukraine. The full-scale war in 2022 caused a significant under-reporting of mortality and migration throughout Ukraine. There are also serious reasons to doubt the relevance of the current population estimates, which in turn distorts all demographic indicators whose denominator is population exposure. As a result, a detailed analysis of demographic processes in Ukraine is not possible from 2022 onwards. Therefore, the last available year for the analysis of the data series is 2021.

**Methods.** Several indicators are used to measure changes in lifespan variation. They have different mathematical properties and sensitivity to changes in mortality. This study analyses the dynamics of three absolute indicators of lifespan variation and their relative equivalents.

K. Hanada [17, p. 96] has proposed a variant of the Gini concentration ratio applied to life tables:

$$G_x = 1 - \frac{1}{e_x l_x^2} \int_x^{\omega} l_x^2 dx, \quad (1)$$

where  $e_x$  is the life expectancy at age  $x$ ,  $l$  is a survival function with the life table radix  $l_0 = 1$ , and  $\omega$  is the open age interval.

Average inter-individual difference in length of life, also known as absolute Gini is:

$$AID_x = G_x \cdot e_x. \quad (2)$$

Lifespan disparity, also known as e-dagger, is the average number of life-years lost as a result of death [6, p. 202]:

$$e_x^\dagger = -\int_x^{\omega} l_x \ln(l_x) dx = \frac{1}{2} e_\omega + \frac{1}{l_x} \sum_{y=x}^{\omega-1} d_y (e_{y+1} + 1 - a_y), \quad (3)$$

where  $d$  is the distribution of deaths in the life table population,  $a$  is the fraction of the last age interval of life (the average years lived in this interval by

those who died in this interval), and  $y$  is the mean age of persons who died in this interval. It is important, as in equation (1), that the radix of the life table is supposed to be 1.

Correspondingly, the relative counterpart is life disparity divided by life expectancy, also known as entropy of the life table or Keyfitz's  $H$  [9, p. 5254]:

$$H_x = -\frac{\int_x^\omega l_x \ln(l_x) dx}{\int_x^\omega l_x dx} = \frac{e_x^\dagger}{e_x}. \quad (4)$$

Another measure of lifespan variation is the standard deviation of age at death (also known as lifespan inequality):

$$SD_x = \sqrt{\frac{\sum_{y=x}^\omega d_y (\bar{y}_y)^2}{l_x} - (x + e_x)^2}. \quad (5)$$

Then the coefficient of variation is defined as:

$$CV_x = \frac{SD_x}{x + e_x}. \quad (6)$$

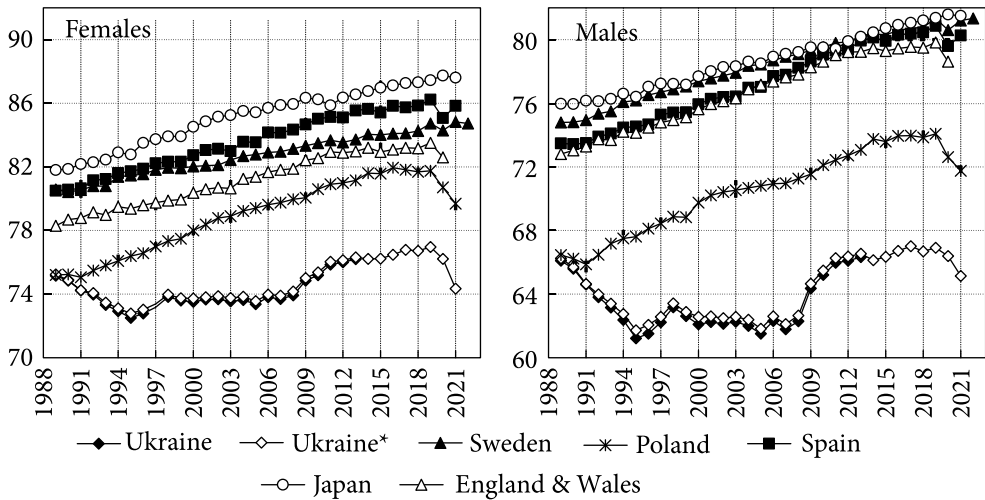
**The main results of the research.** As already mentioned, an increase in average life expectancy is usually accompanied by a decrease in mortality inequality. This makes sense because the decline in mortality is more pronounced and faster in the younger age groups, even if mortality is decreasing across the entire age profile. More and more people are living to a respectable age and dying in a narrower age range. In general, this process is shared by humans and other primates [18]. In advanced societies, the decline in mortality in the oldest age groups may exceed the progress in the middle age groups, resulting in a positive relationship between life expectancy and life inequality [19, p. 1002]. A third pattern of relationship between changes in life expectancy and life inequality is their simultaneous decline, found for England and Wales by Aburto et al. [11, p. 739].

Indeed, as was shown previously [20, p. 40], mortality during the Covid-19 epidemic in Ukraine in 2020–2021 resulted in a greater loss of life potential in older age groups than in younger ones.

This process can be clearly illustrated by the number of deaths in the male life table. As can be seen in Fig. 1, in 2021 there is a shift towards mode from both the younger and older age groups. The modal interval in 2021, together with the two adjacent ones, is higher and concentrates more deaths of the stationary popula-



**Fig. 1.** Life table deaths (dx) in Ukraine in selected years  
 Source: own calculation by the State Statistics Service of Ukraine data.



**Fig. 2.** Life expectancy at birth in several countries  
 Source: [12—16]; \*Ukraine — without data for AR Crimea, Donetsk and Luhansk oblasts, and the city of Sevastopol.

tion than the corresponding intervals in 2019, which preceded the epidemic. The plots for 1995, which had the lowest life expectancy for 1989—2021, show a distribution with a higher degree of inequality and lower life expectancy.

In 2019—2021, a reverse process of mortality decompression was observed for women. The mode of the life table deaths in 2021 became lower than in 2019, and in general the distribution shifted towards younger age groups. Although visually the 1995 and 2021 graphs almost overlap (Fig. 1, left panel), the latter is still more concentrated around the mode at 80—84 years and has a lower level up to 65 years. As a result, life expectancy in 2021 is still higher than in 1995 (Fig. 2).



The life expectancy of women in Ukraine is not only much higher than that of men, but also changes more slowly over time. This statement is also true for other populations. The exceptions are massive short-term mortality shocks, such as natural catastrophes (tsunami, cyclones) [21] or famine, which have a greater impact on women [2, p. 293]. For the case of Ukraine in particular, several studies have come to a similar result. Although in fact the female life expectancy remained higher, the decline in this indicator was faster for women than for men in 1932—1933 [22, pp. 35—36 & 23, pp. 65]. This was also the case this time. Ukrainian women were more vulnerable during the Covid-19 epidemic. In 2021 female life expectancy in Ukraine fell by 2.6 years compared to 2019, while male life expectancy fell by 1.8 years [20, p. 37]. This is not the case in Sweden, Spain, and Poland, where the decline in life expectancy was greater for men (Fig. 2).

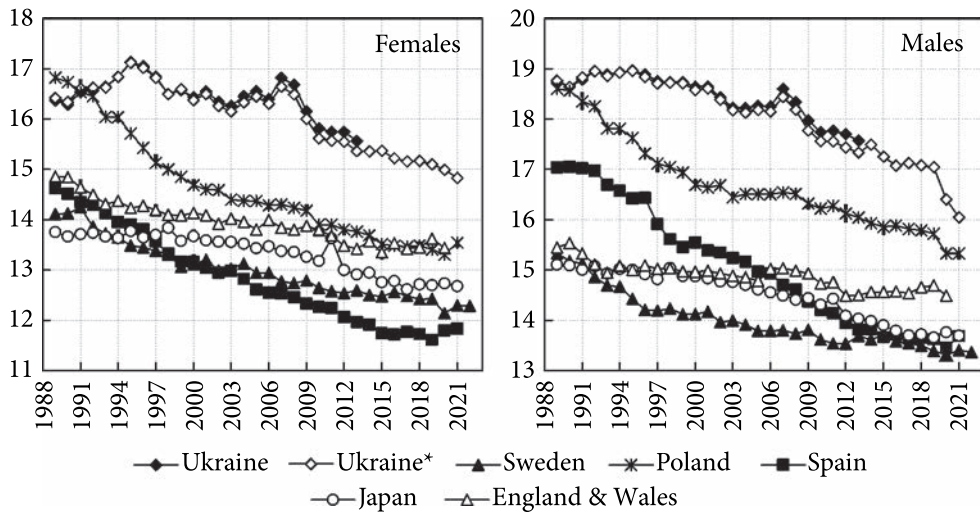
A likely explanation for this is the higher life expectancy achieved by European men compared to Ukrainian men. As shown earlier, Ukrainian men even experienced a decrease in mortality from external causes, as well as infectious and parasitic diseases due to the introduction of lockdowns and social distancing measures, which contributed to reducing the number of Ukrainian men exposed to potentially dangerous situations [20, pp. 38—39]. The male population in European countries had a lower mortality rates to begin with, which did not allow them to benefit from reduced exposure to dangerous situations under the Covid-19 restriction policy.

It should be noted that the life expectancy dynamics in the most advanced countries remained almost unchanged in 2020—2021 (Japan) or recovered quickly (Sweden). Even Spain, which was severely affected by Covid-19, with life expectancy falling by 1.2 and 1.3 years in 2020 (for women and men respectively) almost recovered the lost positions in 2021 (Fig. 2). Unfortunately, it was not possible to find data for England and Wales in 2021. Considering the problems of the British health care system [24], it would be very useful to draw comparisons and conclusions for the case of Ukraine.

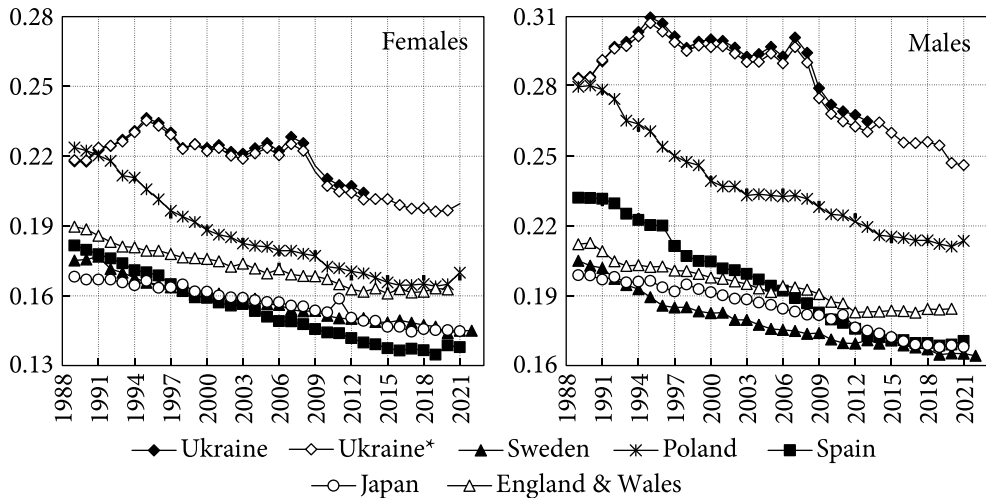
Therefore, a research question arises: how unequal became lifespan variation in 2020—2021 in Ukraine and how does it compare with other countries?

A common summary measure of age at death variation is the standard deviation (5). Calculations show that female lifespan inequality in Ukraine continued its slow decline (Fig. 3) during the 2020—2021 epidemic period (by 1.8 %). For men inequality decreased significantly — by 5.9 %. There was also a noticeable decrease in the standard deviation for men in Poland — by 2.5 %. Women in Poland and Spain experienced an increase of 1.0 and 1.9 % respectively (Fig. 3).

Previous research on lifespan variation shows that when there is a significant increase in mortality, “absolute and relative variations present contrasting dynamics: the former decreases during the crisis, while the latter increases” [2, p. 304]. Obviously, it depends on the ratio of the increment of the numerator and the denominator in equation (6). If standard deviation decreases faster than life



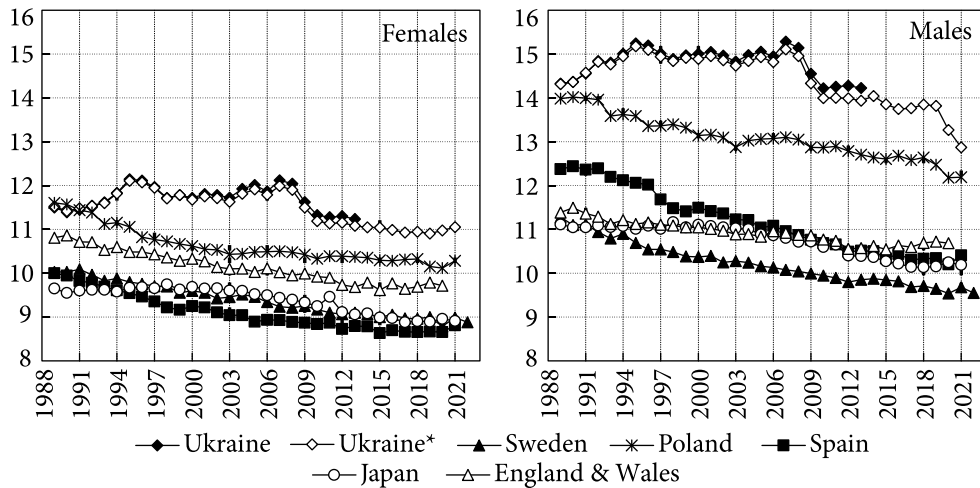
**Fig. 3.** Standard deviation (lifespan inequality) of age at death  
 Source: own calculation by data from various sources [12—16].



**Fig. 4.** Coefficient of variation  
 Source: own calculation by data from various sources [12—16].

expectancy, coefficient of variation also decreases. This can be seen in the data for Ukrainian men. In 2021 the Ukrainian males' coefficient of variation not only decreased since the pre-Covid period, but became the lowest for the last decades (Fig. 4). As noted before, in 2021 Ukrainian males' life table deaths became more concentrated, i.e. more equal (Fig. 1). The situation is different for Ukrainian women. Female standard deviation decreased very little (Fig. 3), while life expectancy decreased much more than that of Ukrainian males (Fig. 2).





**Fig. 5.** Lifespan disparity (e-dagger)

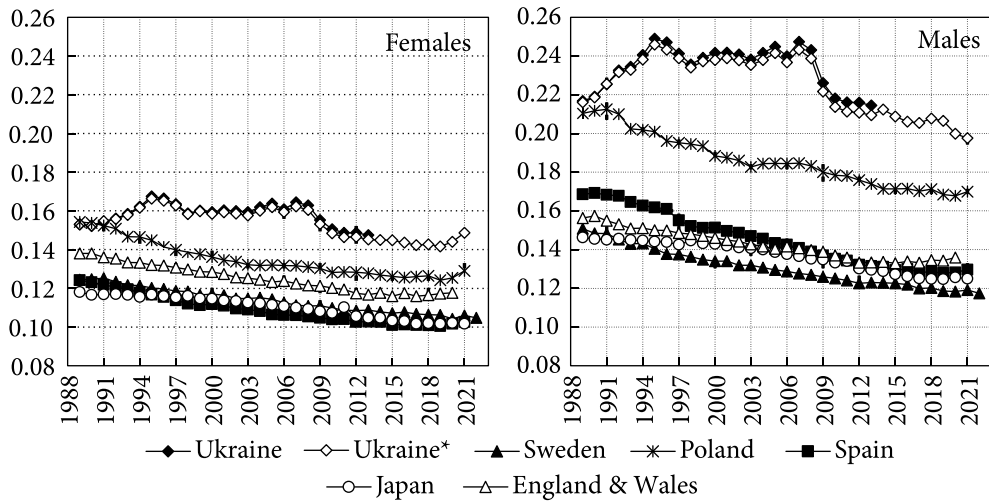
Source: own calculation by data from various sources [12—16].

Thus, female coefficient of variation in Ukraine increased by 1.7 % in 2021 compared to 2019 (Fig. 4). The increase for women in Poland is even higher, at 3.6 %. Coefficient of variation in life expectancy and the standard deviation in England and Wales has remained at around the same level since 2012. Women's coefficient of variation in Spain increased slightly more than men's. Coefficient of variation in Sweden and Japan remained almost unchanged in 2019—2021 (Fig. 4).

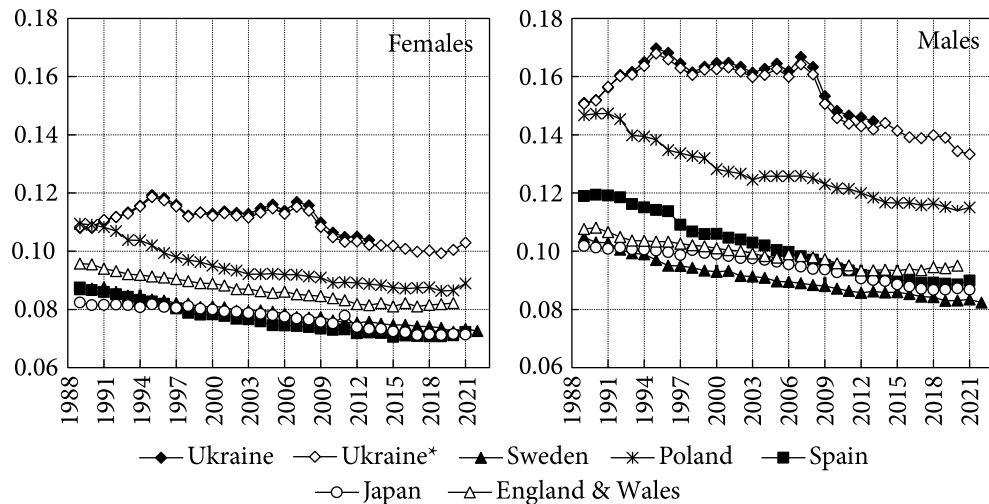
Another consequence of the more equal distribution of male deaths in Ukraine is a significant decrease in the lifespan disparity. This measure decreased by more than 0.9 year (–6.9 %) during 2020—2021 (Fig. 5). Men in Poland also experienced a decrease (–2.3 %). The other countries considered show almost no changes. Women, on the other hand, show a slight increase during this period, ranging from around 1.3—1.6 % in Poland and Ukraine to 1.6 % in Spain. In Sweden, in 2022, both women and men resumed their previous downward trend in the lifespan disparity (Fig. 5).

Another dimension of lifespan variation is shown by the life table entropy. This indicator depends on the dynamics of both lifespan disparity and life expectancy according to equation (4). Women in Ukraine and Poland experienced an increase in lifespan disparity (Fig. 5), while life expectancy decreased significantly (Fig. 2). The entropy of the life tables for Ukrainian and Polish women increased by 4.9 and 3.9 % respectively (Fig. 6). Women in Spain showed a slight increase of 2.1 %, while Spanish men showed an increase of 1.4 %. Only Ukrainian men showed a notable decrease of 4.3 %. The rest showed almost no change (Fig. 6). Data for Sweden in 2022 show a continuation of the downward trend.

As mentioned above, the dynamics of the Gini coefficient in Ukraine has already been studied [1]. However, this was done a few years before the outbreak



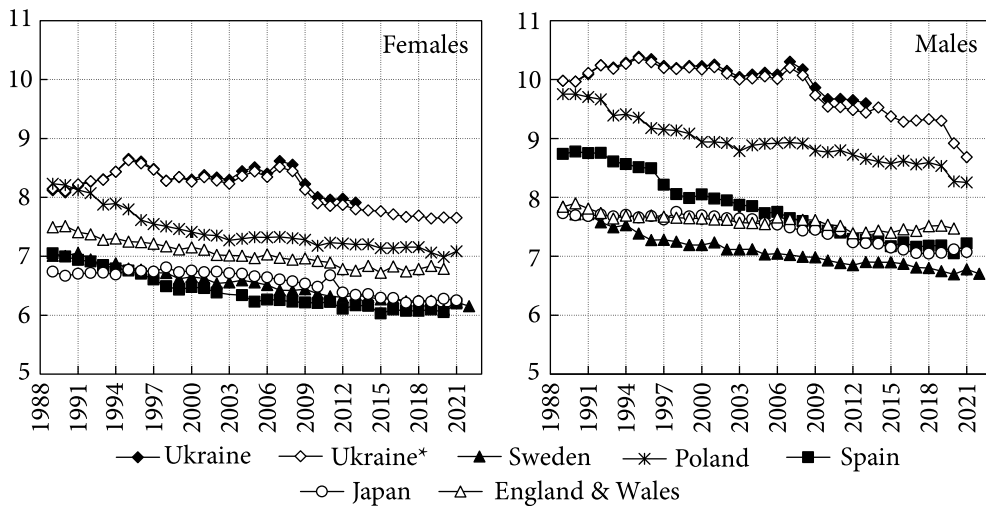
**Fig. 6.** Entropy of the life table (Keyfitz's H).  
 Source: own calculation by data from various sources [12–16].



**Fig. 7.** Gini coefficient  
 Source: own calculation by data from various sources [12–16].

of the Covid-19 pandemic. Therefore, this study provides some new insights into the behaviour of this indicator during an abrupt increase in mortality.

Like most other indicators of inequality, the Gini coefficient for men and women in Ukraine shows a different direction. While this indicator decreases by 4.1 % for men in 2021 compared to 2019, it increases by 3.7 % for women over the same period (Fig. 7). In Sweden this indicator continues its gradual movement towards greater equality in 2022 (Fig. 7).



**Fig. 8.** Average inter-individual difference in length of life  
 Source: own calculation by data from various sources [12–16].

The average inter-individual difference for women in the period 2019–2021 did not change much, except in Spain, where the indicator increased by 1.7 %, almost reaching the level of the corresponding indicators for Sweden and Japan (Fig. 8). In the more developed countries, the average inter-individual difference for men also changed by less than 1 %. On the other hand, the average inter-individual difference in life expectancy for men in Poland and Ukraine fell quite sharply — by 3.2 and 6.6 % respectively (Fig. 8), which is consistent with other indicators (Figs. 3 and 5).

A limitation of this study is the long absence of a population census in Ukraine. This may affect the relevance of the current population estimate and, consequently, affect the accuracy of the calculated indicators. The advantage is the short period of the epidemic considered — 2 years. Therefore, it can be hoped that the error of the current population estimate in 2021 will not differ much from the error of such an estimate in 2019.

**Conclusion.** Calculations over a 30-year period confirm that life expectancy tends to be inversely related to inequality in the life table. The Covid-19 pandemic has affected this rule in different ways, depending on sex and the country's pre-Covid level.

Both absolute and relative measures of the lifespan variation for women in Ukraine in 2021 compared with 2019 have mostly increased slightly. Only the standard deviation of age at death decreased slightly. For men in Ukraine, the decrease in life expectancy was accompanied by a decrease in all inequality indicators. This is confirmed by a clear concentration of deaths around the modal interval.

Lifespan variation in Sweden and Japan barely felt the shock of Covid-19. In Spain, these indicators had already started to return to the pre-crisis trend by 2021. Most indicators of mortality inequality converged in these countries, despite some differences in life expectancy. The indicators in England and Wales continued their slow drift towards higher inequality. It is therefore important to avoid the mistakes of the British model when reforming the health care system in Ukraine.

Looking ahead, it would be advisable to analyse the lifespan variation by region in Ukraine. This will shed more light on the regional variation in mortality in Ukraine, its spatial and temporal differences. Such a study would contribute to a deeper understanding of the change in the spatial gradient of mortality in Ukraine over the period 1989—2021.

Unfortunately, the full-scale war unleashed by the Russian Federation makes it impossible to obtain complete demographic data for the next few years (2022 and beyond). It is unlikely that they will be of high quality for the period of hostilities. Therefore, this study can be used as a reference point for investigating trends in life expectancy and lifespan variation after the restoration of statistical observations and the conduct of a census in the post-war period.

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## НЕРІВНІСТЬ ПЕРЕД ЛИЦЕМ СМЕРТІ ПІД ЧАС COVID-19 В УКРАЇНІ

Якщо відбувається зниження смертності, це насамперед позначається на молодших вікових групах. Тому все більше смертей концентрується в старшому віці. Таким чином, у більш розвинених суспільствах люди стають «більш рівними перед обличчям смерті». Різке зростання смертності, як, наприклад, спричинене пандемією Covid-19, різною мірою зачіпає різні вікові групи населення. Тому актуальним є дослідження зміни нерівності в очікуваній тривалості життя в умовах раптового шоку. Метою цієї роботи є аналіз нерівності за очікуваною тривалістю життя в Україні у 2020—2021 рр. та порівняння її між країнами з різним рівнем смертності населення. Попередні дослідження нерівності очікуваної тривалості життя, спеціально присвячені Україні, або ті, що використовували дані щодо України, були проведені або стосуються доковідного періоду. Новизна цієї роботи полягає у вивченні динаміки показників, що характеризують нерівність очікуваної тривалості життя до і протягом двох років епідемії, за які є доступні дані. Використано демографічний метод побудови таблиць смертності та статистичні методи розрахунку показників варіації тривалості життя: коефіцієнт Джині, середню міжіндивідуальну різницю у віці смерті, середню кількість років утраченого життя, ентропію таблиці смертності, стандартне відхилення віку смерті, коефіцієнт варіації. Показники нерівності в очікуваній тривалості життя розраховано за статтю за період 1989—2021 рр. для України, Польщі, Швеції, Іспанії, Японії, Англії та Уельсу. Підтверджено, що середня очікувана тривалість життя загалом обернено пропорційно залежить від нерівності в таблиці життя. Виявлено, що під час шоків смертності, таких як пандемія Covid-19, це правило може порушуватися. Показано, що середня очікувана тривалість життя при народженні чоловіків та нерівність за тривалістю життя в Україні у 2020—2021 рр. зменшилися. Зокрема, середня міжіндивідуальна різниця в тривалості життя та нерівність тривалості життя зменшилися на 6,6—6,9 %. З іншого боку, майже всі показники нерівності жінок зросли. Найбільш чутливим виявився показник еластичності очікуваної тривалості життя (ентропія таблиці смертності), який збільшився до 4,9 %. Цікаво, що стандартне відхилення віку смерті для жінок в Україні зменшилося на 1,8 %. Встановлено, що пандемія Covid-19 вплинула на нерівність залежно від статі та досягнутого рівня смертності в країні до пандемії. Показники нерівності в Японії майже не змінилися. В Іспанії та Швеції показники нерівності зросли, а потім повернулися до попередньої тенденції до зниження. Наявні дані щодо Англії та Уельсу свідчать про продовження повільної тенденції до зростання нерівності.

**Ключові слова:** нерівність тривалості життя, коефіцієнт Джині, Covid-19.