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Mortality Trends in Czechoslovakia

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FOREWORD

This report is part of a series of analytical studies to look into the problem of changing mortality trends observed in a number of countries. More specifically, it was hoped that this study, which was contracted with the Institute for Social Medicine and the Organization of the Health Services of Czechoslovakia, would shed some light on similar changes in trend observed in the United States.

Iwao M. Moriyama, Ph.D.
Director
Office of Health Statistics Analysis

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CONTENTS

IN THIS REPORT mortality trends in Czechoslovakia are discussed by sex, age, and cause of death for the years 1930-67. After a wartime peak in the death rate, a marked decline in the crude death rate was experienced in Czechoslovakia. This rapid postwar change was observed until the latter part of the 1950 decade after which the death rate began to level off. The movement of the crude death rate is now upwards.

Much of the postwar decline resulted from the drop in the death rates for the infective and parasitic diseases, and diseases of early infancy. Mortality from infective and parasitic diseases has now reached such a low level that further decline can have only a minor influence on the total death rate. On the other hand, the upward trends of death rates for diseases characteristic of old age are governing the movement of the death rate. It is therefore expected that the crude death rate will increase further.

With respect to the future, it is anticipated that the infant mortality rate will undergo further decline. The death rates for females 45 years and over will probably decrease some more whereas the death rates for females at other ages are expected to stabilize at a somewhat lower level. The death rates for males with the possible exception of that for the age groups 55-74 years are expected to stabilize at the present level.

The author has developed statistical models to depict the mortality situation in Czechoslovakia.

MORTALITY TRENDS IN CZECHOSLOVAKIA

Miloš Vacek, Ph.D., C.Sc.[1]

INTRODUCTION

The past 100 years of social progress in the developed countries of today resulted mainly from the rapid increase of the productive capacity which in turn was closely associated with progress in all branches of science and technology. The result was a general increase in living standards, improvements in living and working conditions, and elimination or substantial reduction of malnutrition. In this context shorter working hours, better housing conditions, and the provision of sanitary water and food may be mentioned.

On the other hand, there appeared--especially during the past few decades--several important noxious factors which have negatively influenced the population's health. These factors are, among others, air and water pollution, the increase of noise levels, the decline of physical activity, overnutrition and overweight, and the increase in stressing situations.

Along with the developments in science, medical and health services developed rapidly. Unprecedented progress was achieved, especially in diagnostics, immunology, surgery, and drug therapy. At the same time, there was a great increase in the number of physicians and hospitals, which increased the accessibility to health services. Best results were achieved in the control of infective diseases and perinatal mortality.

Over a long period of time, the positive aspects of this development outweighed the negative ones and this resulted in the continuous decline in the death rate and an increase in the expectation of life over the past 100 years. Figure 1 shows the decline in the crude death rate for Czechoslovakia. It can be seen that the decline was uninterrupted until 1960, except for stagnation or even a transient increase during both World Wars. A significant increase of the average life span was the consequence (table 1).

Similar developments have been described in many countries, starting earlier in some and later in others. This could be interpreted (and actually was) as a direct interdependence between the general level of living and progress of medical science and public health on the one hand, and the health status of the population (characterized by the morbidity and mortality) on the other. It was generally believed that the death rate would continue to decline so long as the standard of living increased and progress was made in the medical sciences and in the provision of health services.

Some doubts concerning the validity of these optimistic predictions could have arisen from the

Table 1. Expectation of life at birth, by sex: Czechoslovakia, selected years, 1869-1961

Period	Expectation of life in years	
	Male	Female
1960-61----------	67.64	73.12
1949-51----------	60.93	65.53
1937----------	54.92	58.66
1929-32----------	51.92	55.18
1909-12----------	42.24	45.19
1899-1902----------	38.36	40.99
1869-80----------	32.70	35.30

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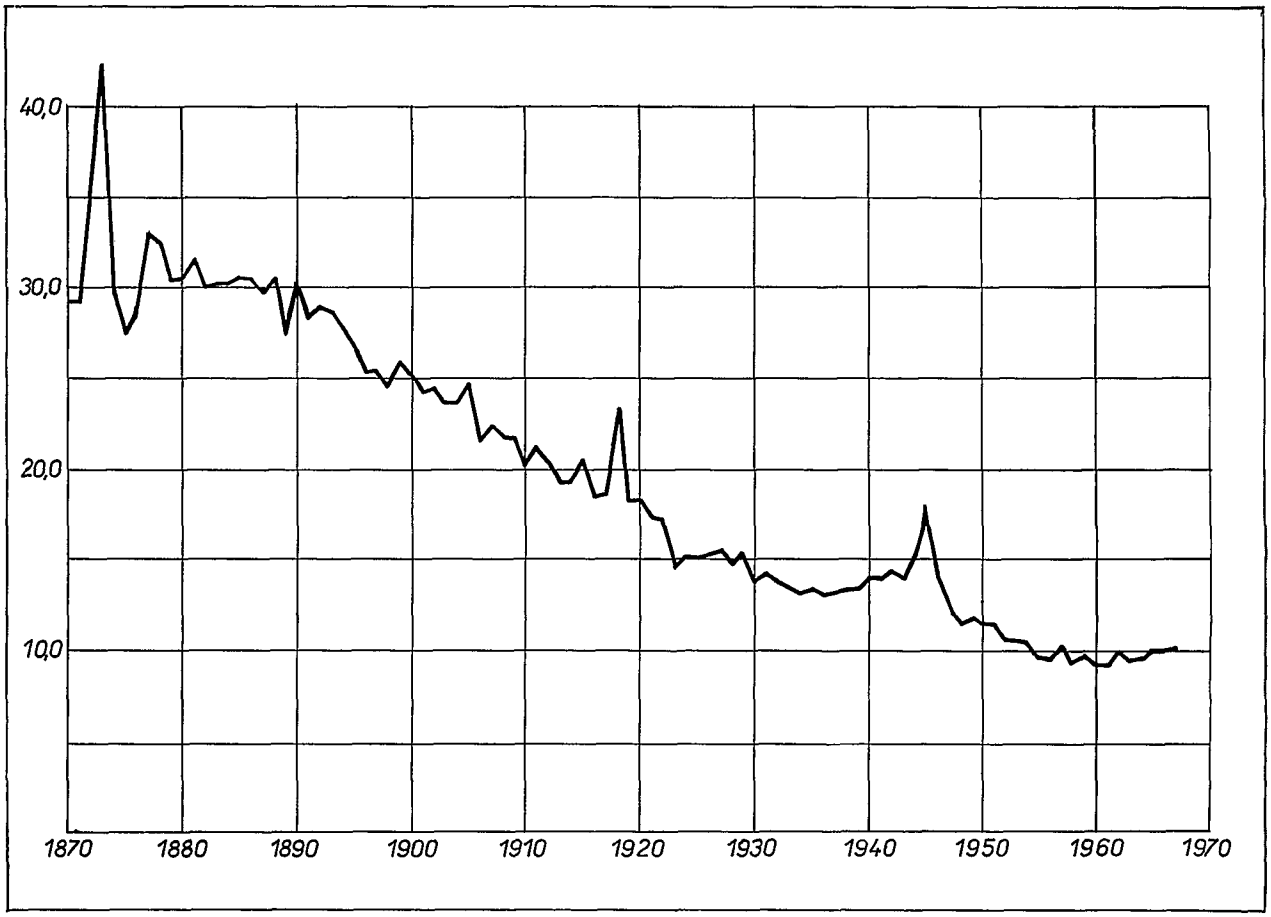


Figure 1. Crude death rate per 1,000 population: Czechoslovakia, 1870-1967.

well-known fact that the population's health is conditioned by a number of factors, some of which have a positive influence on health, others, a negative one. Many of these factors change rapidly in the course of time. This is especially true of some of the negative factors which have been increasing rapidly during the past several decades. In spite of all this, most specialists interested in population forecasts believed that further declines in the death rate would occur beyond any doubt, at least for a number of years.

Subsequent development in Czechoslovakia, as in many other developed countries, has not fulfilled these optimistic expectations (fig. 2). A considerable increase in mortality in 1962 could be explained as a direct consequence of a major influenza epidemic. In the following years, however, the low mortality level of 1960-61 was not reached again. On the contrary, there has been a manifest tendency toward further increase in the crude death rate, as well as in the age-adjusted death rate for males.

The situation with regard to the average life span since 1960 can be described as a stagnation with minor fluctuations around the value of 70.5 years (table 2). It will be shown below that this apparently stable state of the life span is the result of marked antagonistic trends in the development of certain causes of death.

The fact that a similar development was observed in many other countries attracted considerable attention and led to attempts to ascertain the underlying causes of this development. It seems very important to arrive at the correct solutions to this problem. If a new factor could

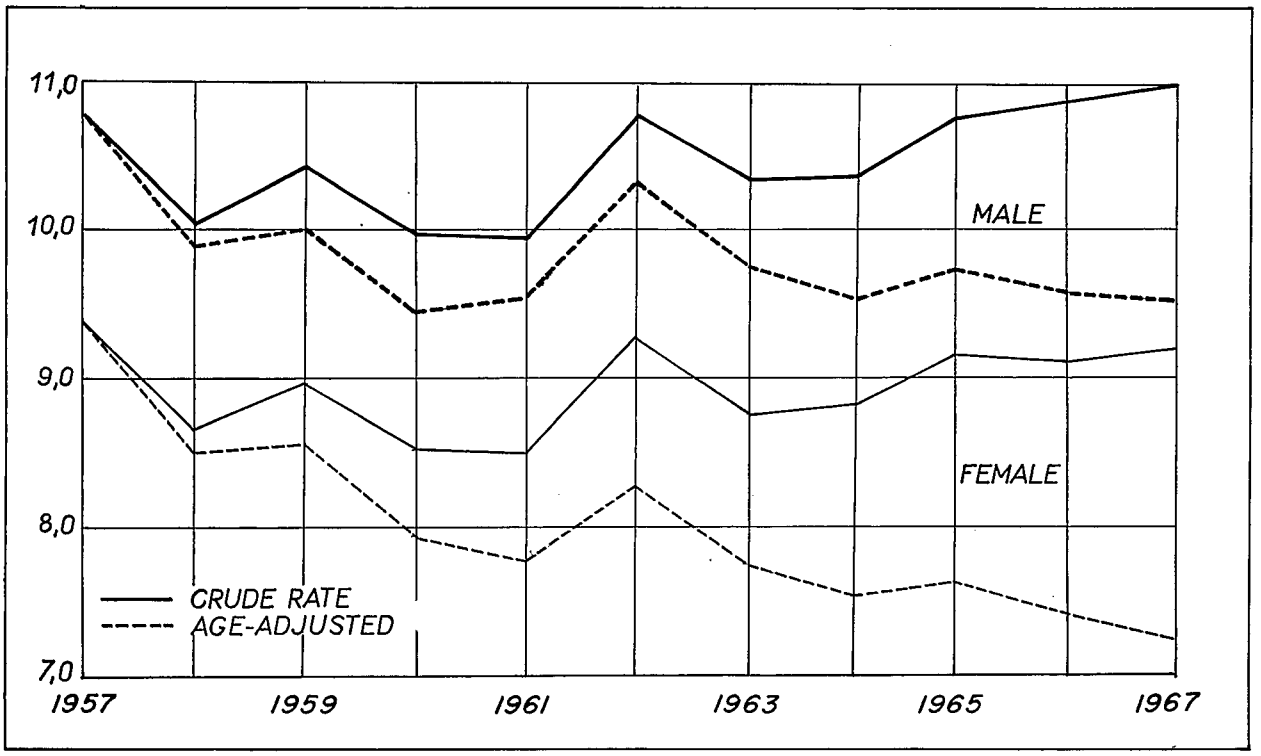


Figure 2. Crude and age-adjusted death rates per 1,000 population, by sex: Czechoslovakia, 1957-67.

be found which has in recent years changed the trend of the death rate, it would be a task of vital importance to locate this factor and then to eliminate it or at least to neutralize its influence. On the other hand, if no such factor exists, that is to say, if the recent development could be explained as the result of longstanding trends of known causative factors, it would lead to a better understanding of the interplay of these factors and consequently to more reliable forecasts of the future development of mortality.

Some of the factors conditioning the health of the population change very slowly, e.g., genetic factors or the influence of climate. Recent changes in mortality, however, have taken place within a comparatively short period of time. It is therefore possible and expedient to focus attention on factors which recently have undergone considerable changes.

Unusually rapid changes have been recorded in the structure of causes of death. Some of them are steadily declining (infections, infant mortality, etc.), primarily as a consequence of new methods of prevention and treatment. The increase in death rates for other causes of death was probably due to changes in living conditions (environmental factors, habits, etc.) during several past decades.

These conditioning factors can be followed only indirectly. For example, no precise data are available on smoking habits, obesity, or physical

Table 2. Expectation of life at birth: Czechoslovakia, 1960 and 1962-67

Year	Expectation of life in years
1967	70.5
1966	70.4
1965	70.2
1964	70.7
1963	70.4
1962	69.9
1960	70.5

activity among people of a certain age and sex group who survive and those who die within a certain time interval. Some of these factors and their effects on health and on the death rate have been studied only on a limited scale in epidemiological studies. The results of these studies will be taken into consideration in this assessment. However, our main basis of analysis will be the demographic data for Czechoslovakia for the period 1930-67. These data have been collected by the same method over a long period of time and are virtually complete.

The report is organized as follows. First, some background information on Czechoslovakia is given, mainly for the purpose of international comparisons. This is followed by a discussion of mortality trends according to age and sex. Two subpopulations (regions) are compared for the purpose of assessing the effect of those factors which influence the mortality in both regions with differing intensity. Analysis of cause of death includes a critical evaluation of validity of these data for Czechoslovakia, a brief look at the cause-specific mortality for the entire country, and a more detailed examination for the Czech regions and for the period 1949-67. The report ends with a general presentation of some models of trends in heterogeneous populations, an application of results on the mortality in the Czech regions, a discussion of some problems of mortality prediction, and a summary of the results.

BACKGROUND INFORMATION

The Czechoslovak Socialist Republic (or more briefly, Czechoslovakia) is situated between 12° 03'20" E. longitude and between 51° 03'26" and 47° 43'53" N. latitude. The elevation of the country can be seen from the following:

	Percent of area
Under 200 meters	11.8
200 to 500 meters	53.5
500 to 1,000 meters	32.0
1,000 meters and above	2.7

The climate is intermediate between Atlantic and Continental. The average temperature in Prague is 9.4° centigrade. The yearly average of sunshine at different places extends from 1,632 to 2,144 hours.

The area of Czechoslovakia on March 1, 1961 (census year) was 127,860 square kilometers; the number of inhabitants on that day was 13,741,529, or a population density of 107 per square kilometer.

In spite of industrial progress and urbanization, 45.3 percent of the population lived in small communities up to 1,999 inhabitants. A considerable part of this population, however, commutes to and from work in nearby towns. Only 18.5 percent of the population lived (on March 1, 1961) in towns of more than 50,000 inhabitants.

The number of people working in agriculture (including their family members) has been decreasing. In 1930, the agricultural population amounted to 25.3 percent of the total population; in 1961 to 15.9 percent.

In the period under consideration the land area of Czechoslovakia as well as the population underwent a major change. The area of Carpatho-Ukraine with a population under 1 million was part of Czechoslovakia until 1939, that is, before World War II. All data given here refer to the territory excluding the Carpatho-Ukraine.

After World War II, in connection with territorial changes in Eastern Europe, a transfer of the population was carried out, which involved a major part of the German population in Bohemia and Moravia. The comparability of demographic data from the periods 1930-38, 1939-44, and 1945-67 was not seriously affected, because the death rate of the German population in Bohemia and Moravia was not significantly different from that of the Czech population.

The period of World War II was, for many reasons, exceptional and the statistical data for this period should be judged with appropriate reserve. This applies particularly to the years 1944 and 1945, when operations of war affected the territory of Czechoslovakia.

In the period 1930-67, many changes took place in the economic field. The number of peasants and workers in agriculture steadily declined. On the other hand, the number of industrial workers, technicians, research workers, and

administrative workers increased considerably. The largest increase was recorded in the mining industry, metallurgy, and chemistry. The number of employed women greatly increased.

The birth rate declined; the abortion rate increased considerably during the period under observation.

A dense communications network has been developed. At present, even the most remote village is easily accessible by buslines. This is a prerequisite for the proper functioning of the health services. The number of physicians declined during World War II, but this loss was more than compensated for after 1945. The number of hospital beds also increased. Since 1950 all health services have been provided free of charge and are accessible to everybody. Any employee who is unable to work is eligible for sickness benefit or disability pension. A small "social pension" is granted even to invalid citizens who have never been employed. In this way, at least the most serious consequences of ill health such as pauperization, privation, and especially malnutrition have been almost completely wiped out.

Against these positive influences stand the well-known noxious factors of any industrialized society, such as air and water pollution, lack of physical exercise, obesity, and many others. Rapid industrialization together with changes in the traditional ways of life has brought about also a large amount of discomfort, stress, and conflict situations.

It is worth noting that all these changes in Czechoslovakia lag somewhat behind similar developments in the most advanced industrial countries. Almost all factors influencing health in a negative way have a delayed, cumulative effect on health. The primary causes of contemporary development should therefore be sought in the past. Changes taking place within very short time intervals usually cannot be accepted as an explanation of slowly progressing changes in mortality.

On the other hand, it seems highly improbable that factors with a delayed effect extending over a number of years could explain rapid changes in the death rate such as have taken place in the last decade, especially around 1960. These problems will be discussed in more detail in the following chapters.

MORTALITY

National Trends by Age and Sex

The statistical data on trends of age- and sex-specific death rates can be taken as accurate. They cannot answer the question as to how the changes in mortality trends came about, but they do show the changes which were most marked.

The trends of age- and sex-specific death rates in Czechoslovakia during the years 1930-67 are illustrated in figure 3. The main features of these trends can be summarized as follows. In all age and sex groups there was a declining trend. In all age groups the decrease was less marked among males. In both sexes the gradient of decline was much steeper among children and diminished with increasing age.

The general tendencies can be seen in figure 4 where the average death rates for the period 1960-66 are compared with the average death rates for the decade of 1930-39. The decrease of death rate

by (percent)	will be denoted as
more than 75	very pronounced
50-75	pronounced
25-50	intermediate
less than 25	minor

The distribution of *males* by the rate of decrease is shown in figure 4. The results can be summarized as follows.

Decrease in death rate	Age group	Actual range of decrease (in percent)
Very pronounced--------	0-14	82-78
Pronounced-------------	15-44	59-51
Intermediate-----------	45-54	37
Minor------------------	55+	16-7

Among females the decrease in the death rate was more marked for all age groups. Here, too, the decrease diminished with increasing

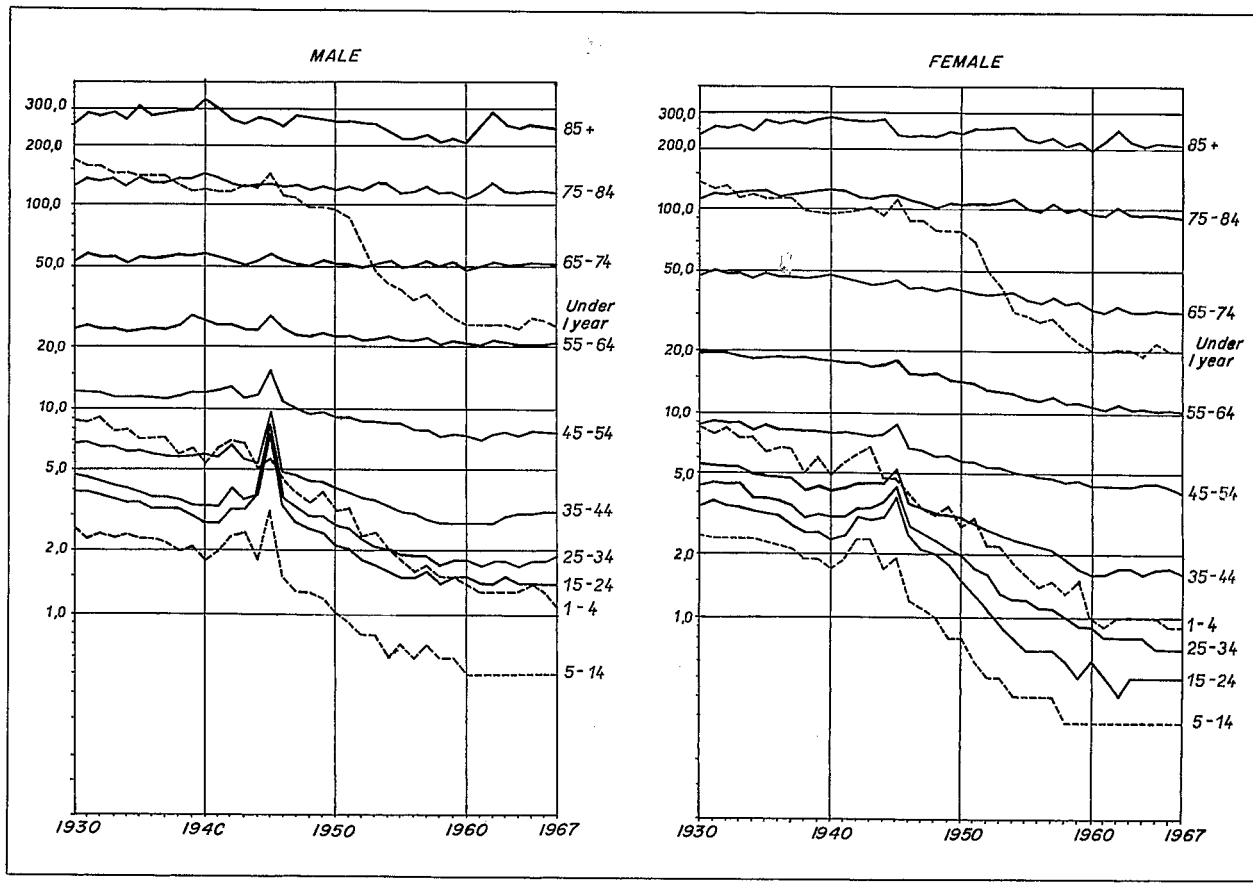


Figure 3. Death rate per 1,000 population, by sex and age: Czechoslovakia, 1930-67.

age. The decrease of death rate among *females*, subdivided in the analogous way, was as follows.

Decrease in death rate	Age group	Actual range of decrease (in percent)
Very pronounced--------	0-34	86-79
Pronounced-------------	35-44	66
Intermediate-----------	45-74	50-33
Minor------------------	75+	22-15

The curves in figure 3 display some conspicuous irregularities, especially a transient increase in the last years of World War II; other less marked peaks were caused by influenza epidemics. Influenza is the only epidemic disease which, at irregular intervals, influences mortality in this part of the world. The death rate increases significantly in the years with major influenza epidemics. In addition to the deaths from influenza, excess mortality occurs for a number of other conditions such as chronic bronchitis and ischemic heart disease during an influenza epidemic. Major influenza epidemics occurred in the years 1939, 1959, and 1962. In addition, there were several minor epidemics which affected general mortality to a lesser extent. The general features of the age- and sex-specific trends, ignoring the transitory changes, may be described as follows.

The death rate of children (both sexes) before the war showed only a moderate decline; after the war the decline was accelerated especially in the 1950's. Since 1960 a leveling-off has been observed.

The death rate for the age groups 15-24 and 25-34 years can be described in a similar

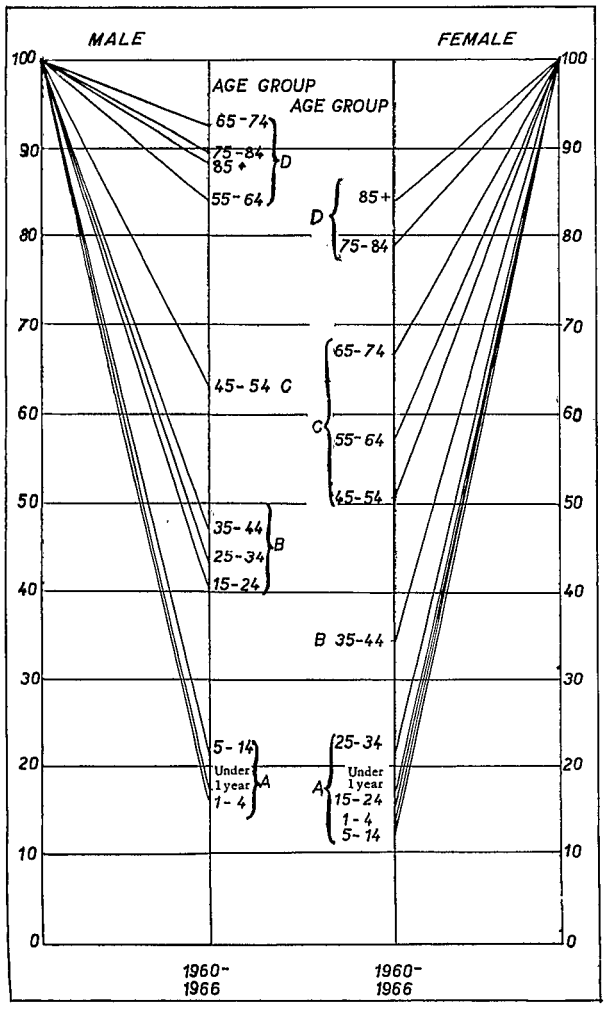


Figure 4. Decline in the death rate in Czechoslovakia from 1930-39 to 1960-66, by sex and age.

(1930-39 = 100)

way, except that the decline in mortality was much slower.

The prewar decline in mortality among males 35-44 years was insignificant; after the war it accelerated. In 1958, the death rate began to level off. Since 1963 there has been evidence of a minor increase.

Among males, aged 45-54 and 55-64 years, the death rate before the war was almost stable. A mild decline after the war came to a standstill around 1958; in the age group 45-54 years, a slight increase in mortality was observed. For the 65-74-year-old males, mortality was almost stable throughout the period under observation. It is worth noting that a slight decrease was recorded for this age group in the first years of World War II. In the ages above 75 years the picture was similar. Only a small relative decline in the rate was observed before 1960, followed by a slight increase.

Among females 45-64 years of age, there was a minor decline in mortality before the war. After the war the mortality continued to decline until 1960 when it leveled off. For females aged 65-74 years, the trend was almost flat, with a slight decline in the first years of World War II and again during 1954-61. Among females in the age group 75-84 years, the picture before 1945 was similar to that for females 65-74

Table 3. Ratio of death rates, by sex and age: Czechoslovakia, 1940-66

Sex and age	1940-1949[1]	1950-1959	1960-1966
Male	Ratio of death rates (1930-39=100)		
Under 1 year	78.6	35.7	18.5
1-4 years	67.5	28.1	17.5
5-14 years	76.9	31.9	21.8
15-24 years	86.3	47.9	40.7
25-34 years	86.6	52.1	44.0
35-44 years	84.7	53.3	47.3
45-54 years	95.7	70.6	63.3
55-64 years	97.3	87.5	83.3
65-74 years	96.6	93.5	92.8
75-84 years	97.0	91.6	89.8
85 years and over	97.8	83.3	88.5
Female			
Under 1 year	78.0	35.3	17.5
1-4 years	66.7	27.5	13.7
5-14 years	70.4	21.0	13.4
15-24 years	78.9	27.8	15.8
25-34 years	78.1	34.6	20.8
35-44 years	79.2	48.6	33.9
45-54 years	85.2	59.9	50.5
55-64 years	87.5	67.7	57.4
65-74 years	90.8	78.5	66.7
75-84 years	95.3	87.4	78.9
85 years and over	99.1	90.4	83.9

[1]Ratio for 1940-49 excludes 1945.

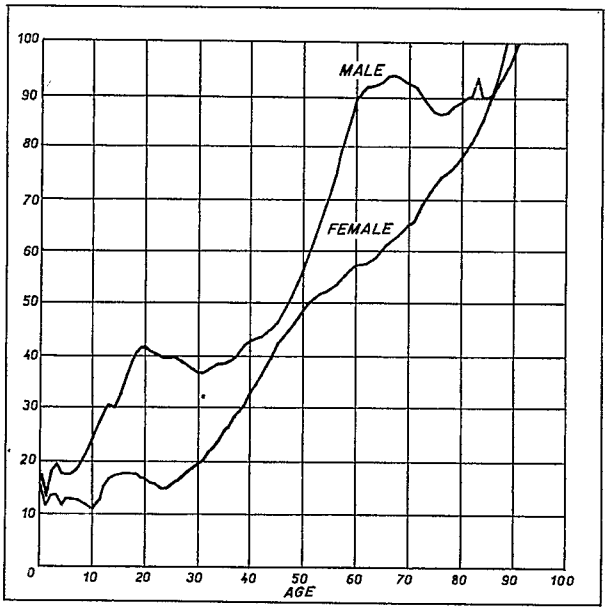


Figure 5. Ratio of life table death rate in 1960-61 to life table death rate in 1929-32: Czech lands.

(1929-32 = 100)

years, but a slight decrease occurred after World War II. The trend of the death rate for females above 85 years was also similar; a minor increase before the war might be mentioned.

The general features of the development are shown in table 3. In comparing death rates by sex, it may be seen that the females were already lower than those for males in the 1930's. The difference increased in the course of the following 25 years. The sex differences in the rate of decline may be shown using the probabilities of death from the life tables. In figure 5 a curve has been drawn giving the course of the death rate for the period 1929-32. The decline in female mortality is shown by a fairly regular curve, but striking irregularities are seen in the curve for males. The first peak around 20 years of age in the curve for males corresponds probably to an increase of fatal transport accidents which partly compensated for the mortality decline from infective diseases (among others tuberculosis). The second peak—between 60 and 70 years—resulted, beyond doubt, from the rising trend of myocardial infarction and of bronchogenic carcinoma. These causes of death are highly prevalent among males in this age group.

Current National Data

In addition to the study of time series, cross-sectional analyses can be useful for the purpose of this study. If the age- and sex-specific death rates of two (or more) different regions are compared during a certain comparatively short period, the resulting inter-regional variations will be determined by the same factors which are responsible for the changes of mortality in time.

Two contrasting regions were chosen for such a comparison: the region of Northern Bohemia, a highly industrialized area for many decades, and the region of Eastern Slovakia, which is mainly agricultural (fig. 6).

Mortality among infants and children of ages 1-9 years was higher in the agricultural region. In the age groups from 10 through 34 years among males and from 10 through 49 years among females the rates were nearly equal (with minor deviations in both directions), while above the age of 35 years in males and above 55 years in females the mortality in the agricultural region was considerably lower (table 4).

These results are in keeping with the results of the analysis of trends in time series. The infant and child mortality in Czechoslovakia (as well as in many other countries) rapidly declined in the course of industrialization, while

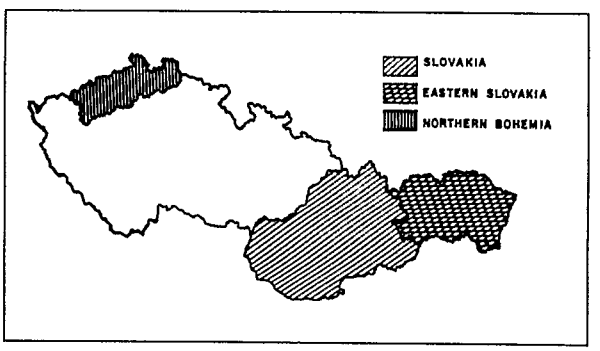


Figure 6. Territory of Czechoslovakia.

Table 4. Death rates, by age and sex: Northern Bohemia and Eastern Slovakia, 1963

Age	Male		Female	
	Northern Bohemia	Eastern Slovakia	Northern Bohemia	Eastern Slovakia
	Rate per 1,000 population in specified group			
Under 1 year	29.05	36.20	23.59	27.21
1-4 years	1.44	2.08	0.84	1.71
5-9 years	0.74	0.86	0.36	0.40
10-14 years	0.64	0.45	0.29	0.22
15-19 years	1.36	1.02	0.75	0.45
20-24 years	1.88	2.26	0.54	0.66
25-29 years	2.18	1.66	0.78	0.71
30-34 years	2.54	1.88	0.86	1.13
35-39 years	3.27	2.45	1.50	1.14
40-44 years	4.06	3.69	2.49	2.25
45-49 years	6.75	5.57	3.18	2.74
50-54 years	12.05	7.53	5.46	5.17
55-59 years	17.68	12.71	8.61	7.46
60-64 years	32.38	20.41	15.05	11.78
65-69 years	51.83	29.74	26.57	23.59
70-74 years	69.26	54.67	45.92	40.72
75-79 years	118.50	85.88	83.48	71.53
80-84 years	164.25	128.50	137.42	134.57
85 years and over	263.38	202.71	248.66	202.10

the decline of mortality among young adults was much slower and the decline (if any) among older males and females was only slight.

It certainly cannot be assumed that the older people have not profited by the progress of medical science and the improvement of preventive and therapeutic medical care; these benefits, however, were fully outweighed by the effect of factors, highly prevalent in any industrial society, which unfavorably influenced the population's health.

While the positive aspects of technical development make themselves felt fully and rapidly in the infant and child mortality, the cumulative effects of negative factors associated with industrial development are strongest among the elderly and fully compensate for the effect of positive factors.

As regards the cross-sectional analysis, no such compensation was possible in the previously agricultural region, and the result was a lower level of mortality among the elderly.

By similar arguments not only the parallel development of mortality in all highly industrialized countries but also the different onset of this development can be explained.

Limitation of Data by Cause of Death

The rapid decline in the general death rate during the past several decades is a consequence of a decline in the incidence of certain diseases or even eradication of some diseases, and of a reduction of the fatality rate in others. This decline was partly compensated for by the increase in the rate for other causes of death. The dynamism of the mortality trends cannot be grasped without a thorough analysis of the cause-specific mortality trends within homogeneous groups of nosological units.

Such an analysis is impeded by all factors which impair the validity and comparability of statistical data on causes of death extending over long periods. Of particular importance are changes in medical nomenclature and in the contents of nosological categories. More precise diagnostic criteria and their dissemination in

medical practice often resulted in shifting certain pathological conditions between categories of the International Classification of Diseases (ICD). For example, in 1955 only 17.7 percent of all deceased persons in Czechoslovakia had a postmortem examination; in 1965 not less than 31.6 percent of the deaths were autopsied. This improved the cause-of-death statistics considerably, especially as regards sudden and unexpected deaths where the postmortem examination is obligatory. The increased portion of people who die in hospitals, and case-finding programs involving several chronic diseases, also contributed to the improvement of cause-of-death diagnostics. It also turned out that even minor changes in the regulation and practice of certification of death, or of the application of cause-of-death selection rules often resulted in significant shifts among categories in cause-of-death statistics.

When conspicuous changes in the disease trends are observed, the question should be asked how far they result from changes in the incidence or fatality of the respective disease or nosological group and how far they can be explained by artifacts originating in one of the phases of the diagnostic process or selection of the underlying cause. Some of the factors influencing the mortality trends by cause of death are of a systematic character and can cause a considerable bias.

Cause-of-death statistics, e.g., from the year 1967, are without doubt more valid than those from the 1950's. Even improvements in diagnostics, certification, and coding, however, necessarily cause artificial trends. The statistical analysis alone cannot detect these artifacts; only detailed knowledge of the whole process (from the diagnosis to the selection of the underlying cause) can help to assess the validity of mortality data. The results of special epidemiological investigations, are often not subject to the limitations of routine statistics and are therefore useful in the detection of bias in demographic statistics.

For example, in the short period of 1959-61 the death rate for chronic bronchitis more than doubled. This was, most likely, the result of the new Czech and Slovak editions of the ICD Manual containing more detailed subdivisions. Before 1959, in more than half of these deaths "Cor pulmonale" was entered on the death certificate as cause of death without any indication of the underlying cause and was therefore classified among "Other heart diseases" (ICD No. 434).

So-called "multiple causes of death" were not a major problem. According to Czechoslovakian experience, it would seem that the cases where it was not possible to determine the underlying cause of death from "train of morbid events leading directly to death" were rare exceptions. Experience with the revision of completed death certificates has shown that the entering of several diagnoses not belonging to the main "train of morbid events leading to death" was only exceptionally the result of hard thinking and deliberate choice of a "multiple cause." In most cases, several diagnoses were entered without proper consideration as to which of them belonged to the main sequence and which to "other significant conditions contributing to death," and which diagnoses should not be entered at all. There can be no doubt that careless completion of death certificates could bias the results.

All of the above-mentioned factors limit the validity of the trends in cause-specific mortality. For example, the mortality trends for pneumonia and chronic bronchitis in the period 1949-67 are at least partly caused by artifacts. The number of deaths from pneumonia was clearly overreported in the 1950's because some cases of terminal pneumonia were erroneously reported as underlying causes of death. At the same time, the number of deaths from chronic bronchitis was underreported since many deaths were attributed simply to "Cor pulmonale" and coded in the category ICD No. 434. In both instances the statistical data from 1967 on are more reliable, but the actual trend cannot be detected since the improvement of the cause-of-death diagnostics itself has created spurious trends. It is therefore necessary to regroup the causes of death into broader classes within which errors in diagnosis may have compensated for each other.

National Trends by Cause of Death

Data on causes of death are available only for 1937, and then annually for the period 1949 to date. Figure 7 presents in graphic form the trends for 10 classes with the highest death rates.

A picture is presented of the dramatic development which in less than 20 years has completely changed the mortality pattern in Czechoslovakia. A continual increase was observed in the groups of neoplasms, cardiovascular diseases, diseases of the nervous system (above all, cerebrovascular), as well as of accidents, poisonings, and violence. A continual decline has been recorded in the classes of infective and parasitic diseases and senility, symptoms, and unknown causes. Other classes were less numerous and—especially as causes of death—less important; the general tendency was: first decrease, later stabilization, and, in the 1960's, a minor increase. This third group includes diseases of the respiratory system, the digestive tract, and the genitourinary system. The increase in infant mortality from certain diseases of early infancy resulted from the fact that in 1965 the World Health Organization (WHO) definition of a liveborn child was adopted by Czechoslovakia.

Remarkable are the major fluctuations in the cardiovascular and cerebrovascular diseases. They coincide with outbreaks of major influenza epidemics and therefore can be explained as their direct consequence. The causes of the reversal of the declining trend in a few classes will be discussed later. It would be emphasized that the leveling-off or reversal of the previous downward trend cannot be fully explained by changes in the age and sex structure of the population.

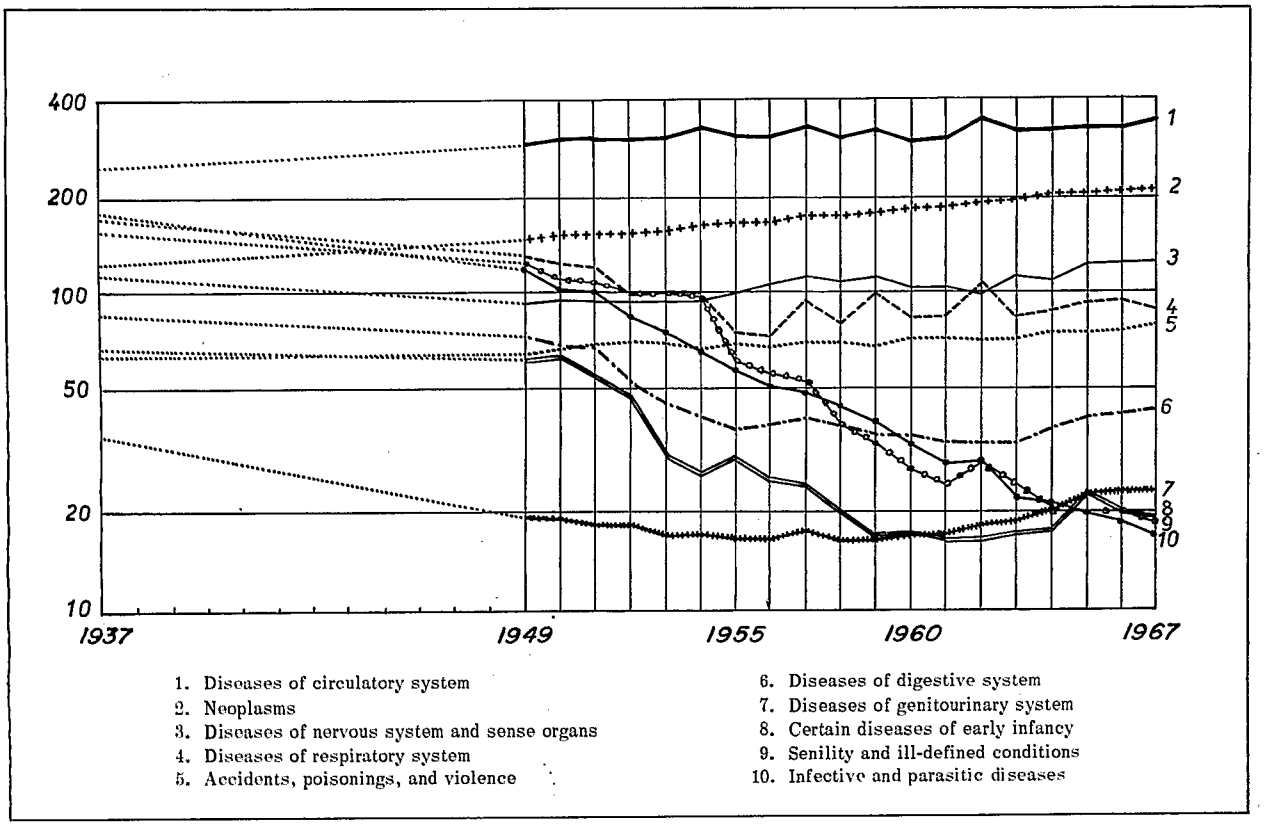


Figure 7. Death rate per 100,000 population for the 10 most frequent groups of causes of death: Czechoslovakia, 1937 and 1949-67.

The mortality pattern has changed significantly in the course of the past 30 years. The percentages which the 10 most frequent classes were of all causes of death has changed between 1937 and 1966 as follows:

Class of the International Classification of Diseases (7th Revision)		1937	1966
I.	Infective and parasitic diseases	19.7	1.8
II.	Neoplasms	10.3	21.1
VI.	Diseases of the nervous system and sense organs	8.9	12.5
VII.	Diseases of the circulatory system	18.9	33.1
VIII.	Diseases of the respiratory system	13.0	9.1
IX.	Diseases of the digestive system	6.5	4.2
X.	Diseases of the genitourinary system	2.7	2.3
XV.	Certain diseases of early infancy	5.1	2.0
XVI.	Symptoms, senility, and ill-defined conditions	12.0	2.0
XVII.	Accidents, poisonings, and violence	4.9	7.6

The trends of the crude mortality rates in 17 classes of the ICD allow the following preliminary conclusions.

1. Apart from the classes which had only a minor share among causes of death, the development of mortality in Czechoslovakia between 1937 and 1966 can be characterized as follows. Infective, respiratory, and digestive diseases, diseases of early infancy, senility, and unknown causes of death declined from 659.8 to 191.3 per 100,000 population, or from 50.4 percent to 19.2 percent of all deaths. Neoplasms, circulatory diseases, and accidents increased from 446.4 to 617.4 per 100,000 population, or from 34.1 percent to 61.9 percent of all deaths.

2. Diseases with a marked declining trend were highly prevalent among children and young adults; the only exception was, of course, the category "Senility and ill-defined conditions." On the other hand, diseases showing an upward trend were characteristic of old age.

3. The general trend of the crude death rate—regularly declining and, in the 1960's slowing down—was a consequence of relatively rapid and partly antagonistic trends in the various causes of death.

4. The results of our observation during the past 10 years (1958-67) may be summarized as follows:

Among *infective and parasitic diseases* (class I of the ICD), the decline continued at an almost constant rate, but the death rates for these diseases have reached such a low level that a further decline could have only a minor influence on the total death rate.

The increase in *neoplasms* (class II) continued very regularly.

In *diseases of the nervous system and sense organs* (class VI) there has been a slight increase after a temporary decline (most likely an artifact). Some 90 percent of the deaths in this group were of cerebrovascular origin.

An inconsiderable increase in *cardiovascular diseases* could be explained as a result of the aging of the population. The development of the death rate in this group will be discussed later in more detail. In each year with a major influenza epidemic a conspicuous but only temporary increase was observed.

Diseases of the respiratory system (class VIII) were steadily declining after the introduction of antibiotics in general medical practice. They reached their minimum in 1955-56; after that a slight increase followed. It will be shown later that this increase resulted from improvements in certification of death.

Certain diseases of early infancy (class XV) were declining for a number of years, above all as a consequence of improved preventive and therapeutic care for mother and child, but partly also as a consequence of the declining

birth rate. The slight increase in the 1960's was caused by the adoption of the WHO definition of a liveborn child.

Symptoms, senility, and ill-defined conditions (class XVI) continued to decline and in 1967 reached its lowest rate of 18.3 per 100,000 population.

The rapid decline of mortality lasted until 1959. The subsequent leveling-off can be explained as follows. The declining death rate in classes I, VIII–XII, and XV of the ICD reached such a low level in the 1950's that even a continuing decline could contribute very little to the general trend of mortality; on the other hand, the persisting increase of cardiovascular diseases and malignant neoplasms changed the mortality pattern in such a way that since about 1960 these two groups of diseases have played a decisive part in the development of the general death rate.

The mechanism of interaction of antagonistic trends will be analyzed in "Trends for a Heterogeneous Population."

Western Czechoslovakian Trends by Cause of Death

The development of mortality after World War II (from 1949 to 1967) had a very different character from the period ending in 1948 (fig. 3). Immediately after the war, a rapid decline of mortality began, above all among children and young adults. Besides other factors, it was the result of large advances in medical science and of better health care following the unification of the health services in 1951.

The general structure of the eastern part of the state was different. In the period under study in this paper, Slovakia was less industrialized. Until recently, Slovakia had higher death rates and a different pattern of cause-specific mortality (table 5). Slovakia has been going through stages of development similar to those of the western part of the Republic, with a somewhat delayed onset, but at a higher speed.

It was therefore expedient to separate the two parts of Czechoslovakia, since the trends in the cause-specific mortality were the main object of study. Only the analysis for the western part of Czechoslovakia (Czech regions) will be given here. It contains a more detailed survey of mortality by causes of death for the period from 1949 through 1967. The most important results can be seen from figure 8.

A very significant decline of mortality from infective and parasitic diseases (ICD Nos. 001-138) resulted from the rapid decline of the incidence and fatality of pulmonary and extrapulmonary tuberculosis. The most favorable results were achieved among children and younger adults. Because the screening programs, diagnostics, and evidence of tuberculosis were on a fairly high level, the established trend can be accepted as reliable.

A considerable decline was recorded in the death rate for syphillis and its sequelae; almost no deaths from diphtheria, whooping cough, and poliomyelitis were recorded in 1966-67.

The death rate for malignant neoplasms (140-205) has been increasing continuously and regularly throughout the period 1949-67. A minor part of this upward trend can be explained by the changing age structure of the population. For example, the death rate for males increased by 67.0 percent in the period 1949 to 1966. Only 17.5 percent of this can be attributed to changes in the age structure of the population; the remaining 51.4 percent were partly due to better diagnostics (see the decline of "unspecified neoplasms"), and a substantial part was a real increase, mainly of the deaths from malignant neoplasms of the respiratory system (160-164). Other groups with a considerable increase were genitourinary cancer (180-181) and leukemia and other hemoblastoses (200-205). By far, most important was the increase in lung cancer. These three categories will be denoted as subgroup A; all other sites will be included in the subgroup B. The increase of mortality was as follows:

	Rate per 100,000 males
Subgroup A	
1949	39.5
1960	99.1
1967	137.1
Subgroup B	
1949	127.1
1960	130.9
1967	148.2

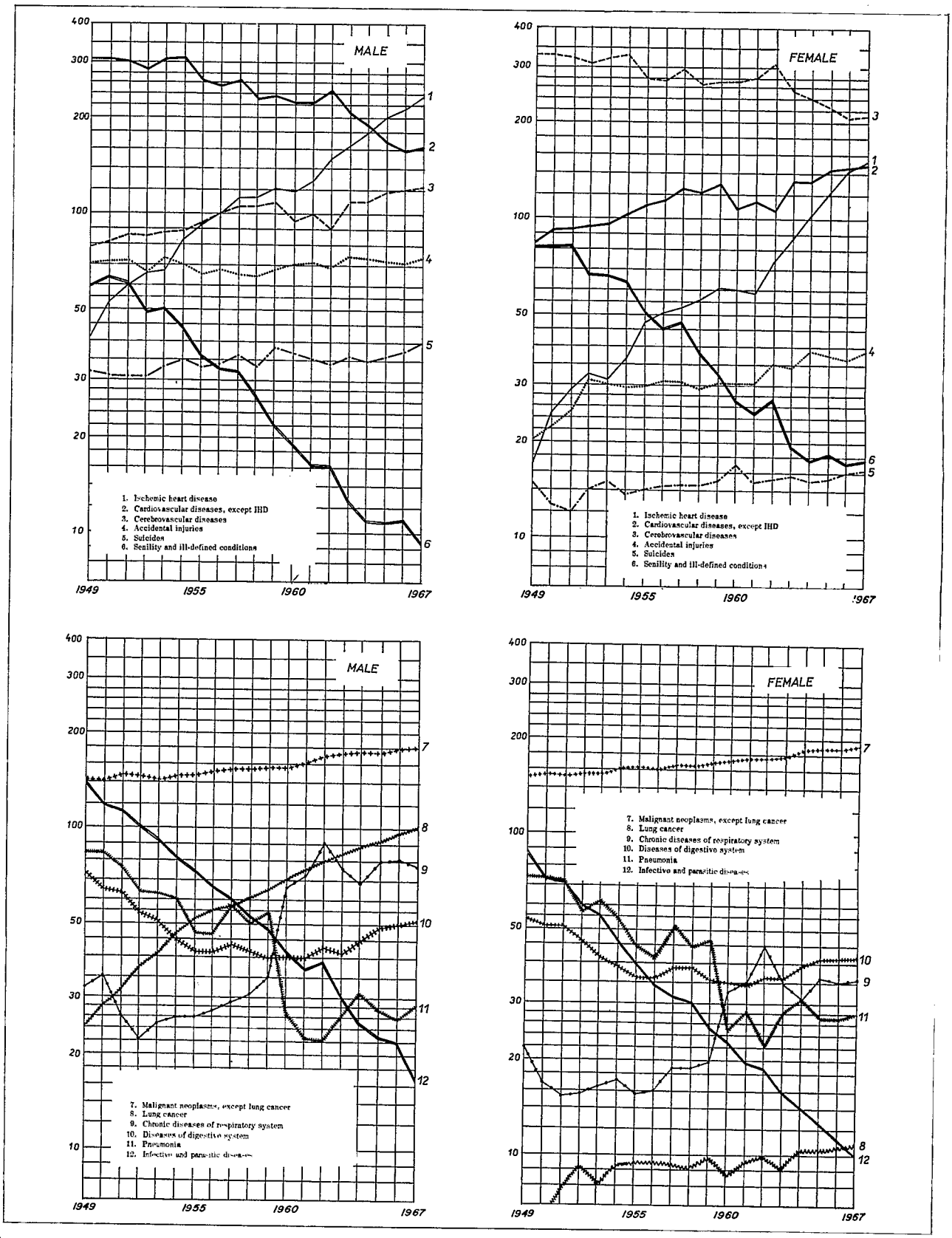


Figure 8. Death rate per 100,000 population for 12 selected causes of death, by sex: Czech regions, 1949-67.

Table 5. Death rates for selected causes of death, by sex: Czech regions and Slovakia, 1949 and 1966

Cause of death	Czech regions		Slovakia	
	1966	1949	1966	1949
	Rate per 100,000 population			
Male				
All causes	1,176.6	1,267.0	892.3	1,265.1
Selected causes	1,095.1	1,159.2	813.1	1,132.7
Infective and parasitic diseases	20.0	139.4	34.2	158.4
Malignant neoplasms	278.3	166.6	162.7	85.2
Cerebrovascular and cardiovascular diseases	497.0	433.9	321.1	181.4
Diseases of the respiratory system[1]	107.0	117.6	101.6	157.8
Diseases of the digestive system	50.1	73.6	35.9	91.7
Certain diseases of early infancy	23.0	66.5	28.0	137.1
Senility and ill-defined conditions	11.2	59.2	27.7	234.8
Accidents, poisonings, and violence	108.5	102.4	101.9	86.3
Female				
All causes	982.3	1,091.3	756.5	1,159.1
Selected causes	892.4	994.8	686.4	1,054.4
Infective and parasitic diseases	11.0	89.5	16.7	127.1
Malignant neoplasms	198.4	159.0	126.8	86.8
Cerebrovascular and cardiovascular diseases	495.0	436.1	349.8	211.7
Diseases of the respiratory system[1]	62.3	96.3	73.1	133.7
Diseases of the digestive system	41.7	54.5	29.2	70.0
Certain diseases of early infancy	14.5	43.4	18.3	103.5
Senility and ill-defined conditions	17.4	81.1	40.0	298.2
Accidents, poisonings, and violence	52.1	34.9	32.5	23.4

[1]Except upper respiratory infections and influenza.

The upward trend in subgroup A was very marked, while the increase in subgroup B can be explained as a consequence of the aging of the population, and partly also as a result of improved diagnoses, especially in the oldest population groups. More details are given in table 6.

In almost all of the age groups, there was a marked increase in the male death rate for subgroup A. On the other hand, the death rate for subgroup B declined in all age groups above 34 years.

It follows from table 7 that there was a decline in the age-specific female mortality from cancer in all age groups between 25 and 74 years, and only above 85 years was a significant increase recorded, no doubt as a consequence of improved diagnostics in this age group.

In the subgroup of benign neoplasms (210-229), only a minor decline was observed, but the deaths from neoplasms of unspecified nature (230-239) have shown a considerable decline which was, beyond doubt, produced by better diagnostics.

Diseases of the heterogeneous class of allergic, endocrine system, metabolic, and nutritional diseases (240-289) were infrequent as causes of death. Worth notice are diabetes mellitus with an upward trend and allergic asthma with

Table 6. Death rates among males for malignant neoplasms, by age: Czech regions, 1949 and 1960

Age	Subgroup A[1]		Subgroup B[2]	
	1960	1949	1960	1949
	Rate per 100,000 males in specified group			
Under 1 year	4.6	4.4	4.6	1.1
1-4 years	6.9	11.6	3.3	0.6
5-14 years	4.4	3.2	2.2	1.3
15-24 years	6.9	6.0	4.3	4.5
25-34 years	10.2	8.1	10.8	9.6
35-44 years	22.0	16.8	28.5	29.7
45-54 years	93.5	63.6	100.9	116.6
55-64 years	365.9	156.9	326.2	346.3
65-74 years	646.0	295.1	692.0	787.5
75-84 years	611.3	304.3	1,000.0	1,133.3
85 years and over	275.5	223.3	706.0	960.6

[1]Subgroup A includes malignant neoplasms of respiratory system (160-164), malignant neoplasms of genitourinary organs (180,181), and neoplasms of lymphatic and hematopoietic tissues (200-205).

[2]Subgroup B includes all other malignant neoplasms.

a decreasing trend. Rickets as a cause of death has completely disappeared.

Diseases of the blood and blood-forming organs (290-299), although infrequent as causes of death, declined in all age groups.

Table 7. Death rates among females for malignant neoplasms, by age: Czech regions, 1949 and 1960

Age	1960	1949
	Rate per 100,000 females in specified group	
Under 1 year	-	4.6
1-4 years	8.0	8.5
5-14 years	7.1	4.7
15-24 years	8.5	5.9
25-34 years	19.7	22.1
35-44 years	54.4	71.5
45-54 years	185.5	187.6
55-64 years	374.7	391.5
65-74 years	729.4	730.0
75-84 years	1,148.8	1,126.4
85 years and over	1,171.1	1,010.8

Mental disorders (300-326) (above all, psychoses) can, beyond doubt, appear as underlying causes of death; it is, however, not clear under what circumstances this is justifiable. The practice in the period 1949-67 was obviously variable and the downward trend is probably spurious.

Cerebrovascular diseases (330-334), as a cause of death, constitute one of the most important nosological groups. Among males, the death rate for this group has increased by 55.6 percent in the period 1949-67. Less than half of this increase can be attributed to the aging of the population. The age-specific male death rates for cerebrovascular diseases in 1949 and 1960 are shown in table 8. Up to the age of 64, there was a considerable decline. The rate for the age group 65-74 showed only an insignificant change, but a marked increase was observed for the age group over 75 years. Since the quality of clinical diagnoses improved and the number of postmortem examinations increased considerably, it can be assumed that the real trend was declining in all age groups but that the improvement of diagnostics produced a spurious upward trend, especially among the elderly.

Table 8. Death rates among males 25 years of age and over for cerebrovascular disease, by age: Czech regions, 1949 and 1960

Age	1960	1949
	Rate per 100,000 males in specified group	
25-34 years	2.4	2.5
35-44 years	6.4	11.4
45-54 years	30.5	46.6
55-64 years	139.3	192.7
65-74 years	555.3	543.1
75-84 years	1,566.4	1,146.4
85 years and over	2,359.2	1,820.6

Other diseases of the nervous system (340-369) caused not more than 8 percent (males) and 6 percent (females) of all deaths among diseases of the nervous system and sense organs (330-398) and had a decreasing tendency over the period 1949-66 (decrease by some 50 percent).

The death rate for the combined group of cerebrovascular and cardiovascular diseases (330-334 and 400-468) increased among males between 1949 and 1966 from 433.9 in 1949 to 497.0 per 100,000 population, that is, by 14.5 percent. But the age-adjusted death rate (probabilities from 1949, age structure 1966) for 1949 was 515.8 per 100,000. This group, as a cause of death, increased therefore by a smaller percentage than would result from the change of the population structure by age. (In 1967 the expected and observed frequencies were almost equal.)

Among females, the influence of changing age structure was even more significant. The death rate for cerebrovascular and cardiovascular diseases between 1949 and 1966 increased from 436.1 to 495.0 per 100,000, or 13.5 percent. As the expected increase was 38.6 percent, the actual increase was considerably lower.

The change in the death rate for the group of circulatory diseases can be explained, for the time being, only tentatively. There has been a very rapid decline in the death rate for myocardial degeneration (422), namely, a decrease of 86 percent among males and 80 percent among females in the period 1949 to 1966. The most probable explanation is the overreporting of myocardial degeneration in the 1950's. It is well known that this diagnosis was often reported as the cause of death, instead of undesirable terms such as "unknown cause" or "senility."

A more realistic picture of the real trend can be obtained from the period 1960-67. If the exceptional year 1962 is left out (major influenza epidemic), the prevailing trend can be found by the least-squares method. The average rate of yearly increase found in this way was 0.9 percent for males and 0.8 percent for females. Since some 0.3 percent can be explained as the result of changes in the age structure, the net yearly increase of the age-adjusted death rate from cerebrovascular and cardiovascular diseases can be estimated at about 0.5 percent. This seems to be a more reliable evaluation of the recent trend of this nosological group than the hypothesis of a decline inferred from the period 1949-66.

The most important single cause of death is coronary heart disease (420) which shows a remarkable upward trend among both males and females. The male-female ratio in 1966-67 was 1.5:1. The upward trend for both sexes, however, seems to be somewhat overestimated because the diagnosis of coronary heart disease has improved greatly during the period 1949-67. But a major part of the observed increase was, no doubt, real; this conclusion has been corroborated by results of special epidemiological studies.

There was a major increase in hypertensive (heart) disease (440-447) around 1960, and since that time the death rate has remained on this higher level. Very rapid changes in the death rate for any cause of death (except for epidemic diseases) necessarily arouses suspicion that it is artificial. Here again, the improved reporting of the underlying cause of death is most likely responsible for the increase.

Chronic rheumatic heart disease (410-416) as a cause of death has shown, so far, no improvement, in spite of the declining incidence of rheumatic fever in the population.

Diseases of arteries (450-456) and diseases of veins (460-468) have also displayed a major increase, with considerable fluctuations in both directions.

All this seems to corroborate the above hypothesis that the decrease in the age-adjusted death rate from diseases of circulatory system, observed in the 1950's, was only spurious and was

caused by better diagnostics. On the other hand, the slight increase found in the 1960's is probably a true picture of the present development.

Acute upper respiratory infections can only exceptionally be underlying causes of death. Influenza in the years of major epidemics was an important cause of death. In other years, the deaths from "influenza" should probably have been attributed to pneumonia; the resulting error is, however, insignificant.

Other respiratory diseases (490-527) can be divided into two subgroups with widely differing trends. Deaths from pneumonia (490-493), formerly very frequent, declined after the introduction of antibiotics and became stable at a new level in the 1960's but showed major fluctuations in the years of influenza epidemics. The death rate for chronic bronchitis and other respiratory diseases was rather irregular. In the 1950's the death rate for this cause was low; it increased suddenly in 1960 and since that time has remained, with some fluctuations, on this comparatively high level. The low level of mortality from this cause in the 1950's was due to incorrect reporting of deaths because the direct cause—cor pulmonale—was often entered as a single cause of death and the underlying cause (in Czechoslovakia, most often chronic bronchitis) was not mentioned on the death certificate. The observed fluctuations can be attributed partly to the effect of influenza, partly, however, to changing diagnostic and coding practices. In view of the increasing exposition of the population to dust and increasing air pollution, and with regard to the results of special epidemiological studies, the conjecture can be ventured that the true picture of the trend in the period 1949-67 was a continual increase starting in 1949 at a much higher level and ending in 1967 at a still somewhat higher level (by some 25 percent) than reported. If this conjecture were correct, the death rate for chronic bronchitis in the Czech part of the country would be the second highest in Europe, following the United Kingdom.

After a sharp decline around 1955, the death rate for diseases of the digestive system maintained a constant level for several years followed by a slight increase beginning in 1962. This indicates the possible existence of heterogeneous subgroups with antagonistic trends. Actually, an increase was observed in several categories, especially in diseases of liver, gallbladder, and pancreas (580-587). On the other hand, a decline was recorded in ulcer of stomach (540), appendicitis (550-553), gastroenteritis and colitis, and peritonitis (576).

Diseases of the genitourinary system (class X), as causes of death, were almost constant for a number of years and began to increase after 1961. This was particulary true of infections of kidney (600). Their role among causes of death was, however, insignificant.

Diseases from classes XI-XIII (complications of pregnancy, childbirth, and the puerperium, diseases of the skin, and diseases of the bones and organs of movement) were only rarely causes of death.

Congenital malformations (class XIV) had a stable trend. In relation to the number of births (which was declining) the rate was, however, increasing, probably as a result of improved diagnoses and reporting. Recent data are fairly reliable.

Certain diseases of early infancy (class XV) showed an increase for similar reasons to those given above. Significant was the increase of the death rate from postnatal asphyxia and atelectasis (762), pneumonia of newborn (763), and diarrhea of newborn (764).

Class XVI, "Symptoms, senility, and ill-defined conditions," reflected in its development the improvement of diagnostics and reporting of causes of death. In 1949, for example, it included 4.7 percent of all male deaths and 7.4 percent of female deaths, while in 1967, not more than 0.8 and 1.8 percent. This could not have any major effect on the cause-specific mortality in other classes.

Accidents, poisonings, and violence (class XVII) constitute a group with a not very significant upward trend. The age-adjusted death rate for accidents increased by 5 percent from 1949 to 1966 among males and somewhat more among females. On the other hand, the age-adjusted rate was almost constant between 1960 and 1966 but increased again in 1967.

The ratio of the male to the female death rates was 3:1 in 1949 and nearly 2:1 in 1966-67. Several factors are responsible for the higher mortality of males: first, a greater proportion of men in high-risk occupations; second, their

larger participation in motoring and high-risk sports activities; and third a higher number of suicides.

The modest increase of the death rate for accidents resulted from antagonistic tendencies. During the period under observation the death rate for motor vehicle accidents was increasing proportionately to the density of traffic on the roads. Accidental falls, as causes of death, are characteristic of old age and increased, therefore, because the proportion of the elderly in the population increased. Some of the new technological processes in industry tend to reduce the incidence of casualties at work. On the other hand, fatal accidents in agriculture increased greatly.

It has been shown that the general trend of mortality is a result of summing up individual, partly antagonistic trends. This applies to the overall as well as to the age- and sex-specific mortality trends. These "elementary trends" often have a simple course, depending on the changes of certain factors which influence the incidence or fatality rate of diseases which are frequent causes of death.

The heterogeneity of individual trends was very marked. Besides causes of death with a stable trend, a number of causes of death were found with a strong tendency to long-term increase which was neutralized by the equally strong declining tendencies among other causes of death.

It has been shown that it is always difficult and sometimes impossible to establish, free from bias, all individual trends of mortality. It will be expedient to study, in the first place, only broad groups of causes of death where errors in estimate of trends can—to a certain degree—counterbalance each other.

TRENDS FOR A HETEROGENEOUS POPULATION

Suppose that the general death rate can be divided into mutually exclusive components, for example, death rates by cause of death:

$$q(t) = q_1(t) + q_2(t) + \ldots + q_n(t) \qquad (1)$$

where t denotes time. The rates $q_i(t)$ can be considered as continuous functions of t, having the first and second differentials. If simple mathematical models of the observed data (death rates) are found, the function (1) can be analyzed by mathematical methods.

As shown above, the time series of cause-specific death rates representing homogeneous components of the general mortality are often monotonous and have an approximately constant rate of increase or decrease:

$$log \; q_i(t) = a_i + t.b_i \qquad (2)$$

$$q_i(t) = e^{a_i + tb_i}$$

$$q(t) = \sum_i q_i(t) = \sum_i e^{a_i + tb_i} \qquad (3)$$

The shape of $q(t)$ can be found as follows:

$$\frac{dq(t)}{dt} = \sum_i b_i \; e^{a_i + tb_i} \qquad (4)$$

$$\frac{d^2q(t)}{dt^2} = \sum_i b_i^2 \; e^{a_i + td_i} \geqslant 0 \qquad (5)$$

The function $q(t)$ is therefore convex if

$$b_i \neq 0$$

for at least one value, b_i. If

$$b_i \geqslant 0 \text{ for all } \underline{i}$$

$$b_i > 0 \text{ for at least one } \underline{i}$$

then (4) is positive and $q(t)$ has an upward trend.

If all b_i are nonpositive and at least one b_i is negative, then (4) is negative and $q(t)$ has a downward trend.

If at least one b_i is positive and at least one negative, then

$$\lim_{t=-\infty} q(t) = \lim_{t=+\infty} q(t) = +\infty$$

and since the function $q(t)$ is convex and continuous, it will exhibit a change of the downward into an upward trend (part a of fig. 9).

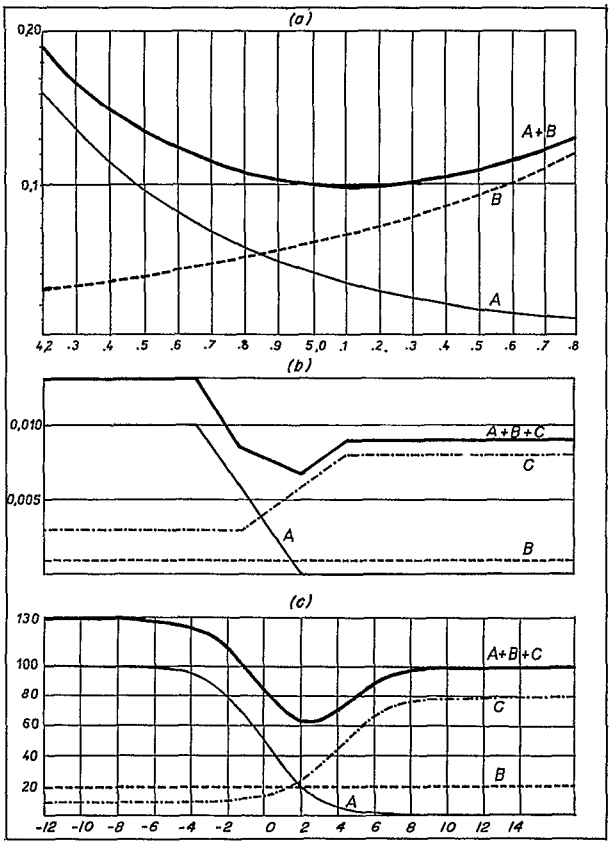


Figure 9. Mathematical models of trends in heterogeneous populations I.

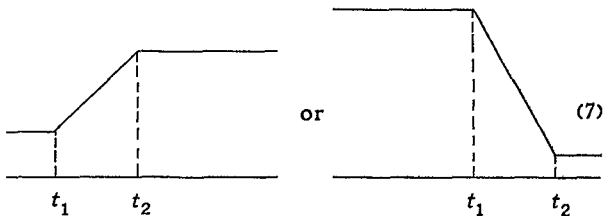
For our purpose only the segment of the curve (3) has a real meaning where

$$0 \leqslant q(t) \leqslant 1 \qquad (6)$$

It is assumed that the condition (6) is always fulfilled.

It follows from (6) that (3) can be a satisfactory approximation of the actual trend only within a limited time period. Sooner or later the upward phase must level off and, under constant conditions, it will tend to become stabilized at a certain new level. Any permanent change of the main determinants of death will probably result in an equally permanent change of the mortality level.

For example, a mortality decline in the time interval from t_1 to t_2 followed by a stabilization at a lower level can be represented by a polygonal line



If two elementary antagonistic trends of the type (7) are confounded, the general trend may have the form (part b of fig. 9) exhibiting again a passage from one level to another—this time, however, connected by a convex polygonal line with a minimum. A passage between the two flat levels can be also monotonous or concave with a relative maximum.

Another representation of the passage between two flat levels provides the "logistic curve" (8).

The function

$$q_i(t) = \frac{a_i - b_i}{1 + k_i e^{c_i t}} + b_i, \quad c_i > 0, \; k_i > 0 \qquad (8)$$

tends to b_i if t increases and tends to a_i if t decreases:

$$\lim_{t=-\infty} q_i(t) = a_i \qquad \lim_{t=+\infty} q_i(t) = b_i$$

For example, the equation

$$q_1(t) = \frac{a-b}{2^t+1} + b, \quad 1 > a > b > o, \quad b < \tfrac{1}{2}$$

represents the decrease from the level a to b.

The equation

$$q_2(t) = \frac{b-a}{2^t+1} + a$$

represents the increase from b to a.

The sum

$$q_1(t) + q_2(t) = a + b$$

is a constant; this is the expression of a stable level of mortality.

The resulting equation

$$y = a + b$$

represents a straight line parallel to the x-axis.

A shift in time of one of the two components can be expressed by the substitution, for example,

$$t = t' + 5 \quad \text{or} \quad t = t' - 4,$$

so that

$$q_3(t) = \frac{b-a}{2^{t+5}+1} + a$$

or

$$q_4(t) = \frac{b-a}{2^{t-4}+1} + a$$

The results

$$y = q_1(t) + q_2(t)$$
$$y = q_1(t) + q_3(t)$$
$$y = q_1(t) + q_4(t)$$

are charted by figure 10.

This schematic example shows that even a minor change, namely a somewhat earlier (or delayed) onset of the accelerated increase of one of the two components, for example, $q_2(t)$, can produce unexpected and bizarre swellings or depressions which would certainly be suspect of being caused by artifacts, should they be seen in any statistical material based on observation. A search for some special factor or factors responsible for this "swelling" or "depression" would be in this case futile since no such factors exist.

In a similar way the curve "C" in figure 9 is connecting two different levels. And again, a shift of one component along the x-axis has created an irregular course with a transitory "depression."

It has been shown that under certain assumptions as regards elementary trends the superimposition of these trends leads to a convex curve. It can be either J-shaped, and then it represents a monotonous (steadily increasing or declining) course, or U-shaped, reflecting a change from declining to increasing phase.

These models resemble the actual situations which existed in Czechoslovakia after World War II. Groups of causes of death have been found with marked antagonistic trends. Increasing trends were observed, among others, in lung cancer, ischemic heart disease, chronic bronchitis, and road casualties. On the other hand, communicable diseases (above all tuberculosis), pneumonia, diseases of early infancy, and degeneration of the myocardium were declining throughout the period under observation. Only a minor part of causes of death remained approximately constant.

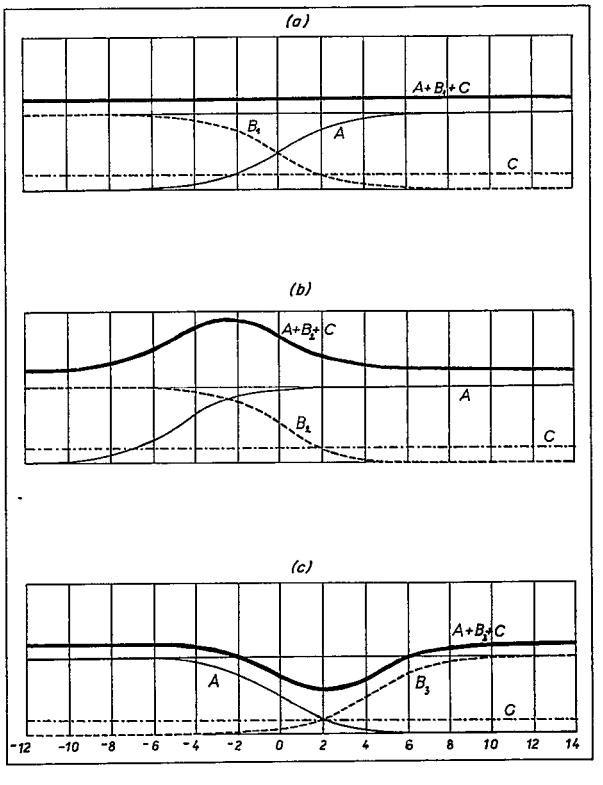


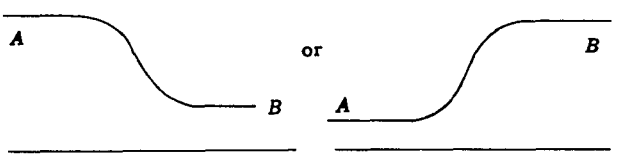
Figure 10. Mathematical models of trends in heterogeneous populations II.

Some of the elementary trends had a regular and monotonous trend. Exceptionally, the *U*-shaped form was found, but in each case it could be shown that the group was heterogeneous and consisted of at least two homogeneous subgroups with antagonistic trends. For example, "Other respiratory diseases" with a *U*-shaped trend were broken down into pneumonias which were declining during the period under observation and chronic respiratory conditions, with an upward trend.

The trend of any cause of death—or of any homogeneous group of causes of death—is brought about by changes in the main causative factors. When negative factors prevail an upward trend will result, and vice versa.

In Czechoslovakia the known conditioning factors have gone through considerable and rapid changes within the past several decades, causing equally rapid and profound changes in the pattern of cause-specific mortality. It took only a few years to eradicate poliomyelitis and to reduce substantially the death rate from tuberculosis, pneumonia, and diseases of early infancy. On the other hand, a considerable change occurred, within relatively short periods, in smoking habits, in general patterns of behavior, etc. It may be accepted that some of the changes in mortality were the direct consequence of the changing environment, habits, and social relations. In some instances, such a relationship could be revealed by special epidemiological studies. Many of the factors, however, are still unknown. Even in these cases, however, it is rational to presume that the rapid changes among diseases of unknown etiology—so far as they are not artificial—can be explained in a similar way.

It stands to reason that a stable level of causative factors will eventually result in a constant level of the death rate for a specific cause of death. After a rapid change of the main factor (or factors) a passage from one level to another will follow:



If, on the other hand, the changes of the most important conditioning factors are of longstanding character, a long-term trend of the corresponding cause of death can be expected. All three types of elementary trends have been observed since World War II.

COMPONENT PARTS OF DEATH RATES WITH DIVERGENT TRENDS

Some of the important causes of death after World War II showed a regular trend so that one of the curves mentioned in the preceding section could be fitted with observational data. This applies, among others, to infections, malignant neoplasms, ischemic heart disease, and accidents. Many other causes of death, however, showed in their development irregularities which could only be interpreted as artificial. It was therefore not feasible to carry out the breakdown into elementary trends.

Instead, an attempt will be made to regroup the causes of death into three main sections with upward, downward, and stationary trends. It is assumed that the above-mentioned irregularities and diagnostic errors will compensate for each other within these broader groups.

Group A with an upward trend includes the following causes of death: malignant neoplasms (ICD Nos. 140-205), diabetes (260), vascular lesions of the central nervous system (330-334), heart diseases *except* myocardial degeneration (400-434, *except* 422), vascular diseases and hypertension (440-468), chronic respiratory diseases (500-527), and diseases of liver, gallbladder, and pancreas (580-587).

Group B with a downward trend among males contains infective and parasitic diseases (001-138), benign and unspecified neoplasms (210-239), mental disorders (300-326), diseases of the nervous system *except* cerebrovascular (340-369), degeneration of myocardium (422), pneumonia (490-493), ulcer (540-542), infections of kidney (590-594), diseases of prostate (610-612), diseases of the skin and organs of movement (690-749), certain diseases of early infancy (760-776), and senility and ill-defined conditions (780-795).

Among females, group B includes the same diseases, *except* infections of kidney and diseases

of prostate, but *includes also* asthma (241), diseases of blood and blood-forming organs (290-299), diseases of the digestive organs (*except* diseases of liver, gallbladder, and pancreas, 530-578), and complications of pregnancy, childbirth, and the puerperium (640-689).

Group C includes all remaining causes of death, among others, influenza.

The same letters A, B, and C will denote the death rates from the corresponding group of causes of death.

A', B', and C' will be used for the observed data; A, B, and C will denote the values of the interpolated curves.

The polygons $A'(t)$, $B'(t)$ have a regular, generally convex course, so that $\log A'(t)$, $\log B'(t)$ are approximately linear. An attempt can therefore be made to fit straight lines

$$y = \log A(t), \qquad y = \log B(t)$$

by the least-squares method.

The polygons $\log A'$ and $\log B'$ as well as $\log A(t)$, $\log B(t)$ in the western part of Czechoslovakia (Bohemia and Moravia) in the period 1949-66 are charted by figure 11.

The interpolation $A(t)$, $B(t)$ is satisfactory. The goodness of fit was tested by the χ^2-method, and it was found that the differences are well within the limits of random variations.

$C(t)$ is equal to the arithmetic mean of $C'(t)$, $t = 1949, \ldots, 1966$.

The values A and B computed from the interpolated values $\log A$ and $\log B$, the horizontal straight line C and the sum $A + B + C$ are charted by figure 12. To facilitate comparison both the observed and interpolated values of the curves A, B, C and $A + B + C$ are shown in figure 12.

Major deviations $(A+B+C)$ $(A'+B'+C')$ are seen, in the first place, in the years of major influenza epidemics.

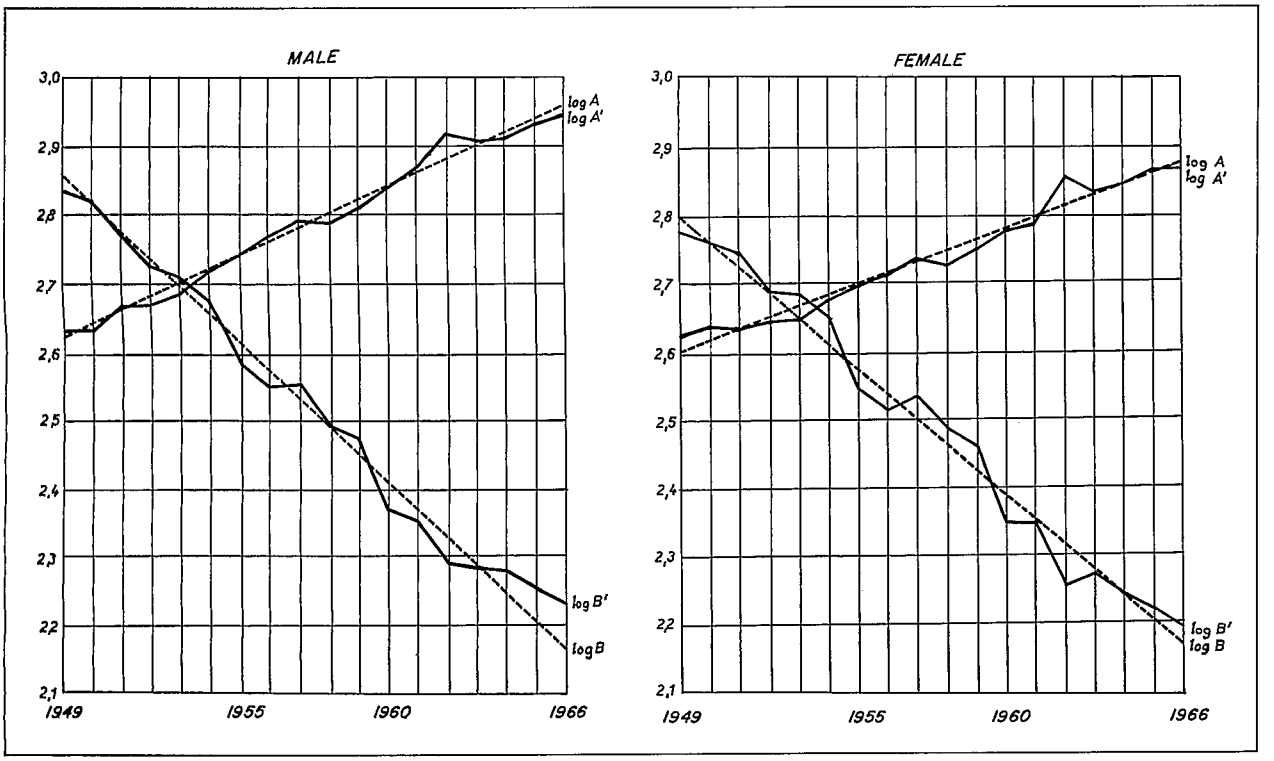


Figure 11. Linear interpolation of the logarithms of the components A,B of the death rate for males and for females: Czech regions, 1949-66.

(A - with upward trend; B - with downward trend)

The results can be summarized as follows:

Both variable components had, for all practical purposes, a constant rate of change (decrease or increase). The third component, C, had no influence on the shape of the overall trend $A + B + C$; it only moved the curve upwards.

At first, the interpolated curve $A + B + C$ was declining; later it flattened out, reached the minimum value around 1959-60, and has been increasing since then.

The change in the overall trend set in despite the fact that the trends of the elementary groups A, B, and C showed no variations in the rate of change. This can be explained as follows. At first, the declining trend prevailed; later, by the changes of both A and B curves, the absolute increase and decrease were balanced, still later the increasing trend prevailed.

FUTURE DEVELOPMENT OF MORTALITY

It might seem useful to extrapolate the curve reflecting the trend of the sum $A + B + C$ (fig. 12) and to use it as a basis for prediction of the future mortality trend. A closer scrutiny will show, however, that such a prediction has only a limited value. As stated earlier, the elementary trends corresponding to the development of individual causes of death (for example, lung cancer) are likely to have the form of logistic curves reflecting the change from one stable level to another. This process can, of course, be repeated if new factors emerge influencing mortality, or if some factors significantly change their intensity. So far, we have seen only the initial phase of the curve "A" (fig. 12) characterized by the

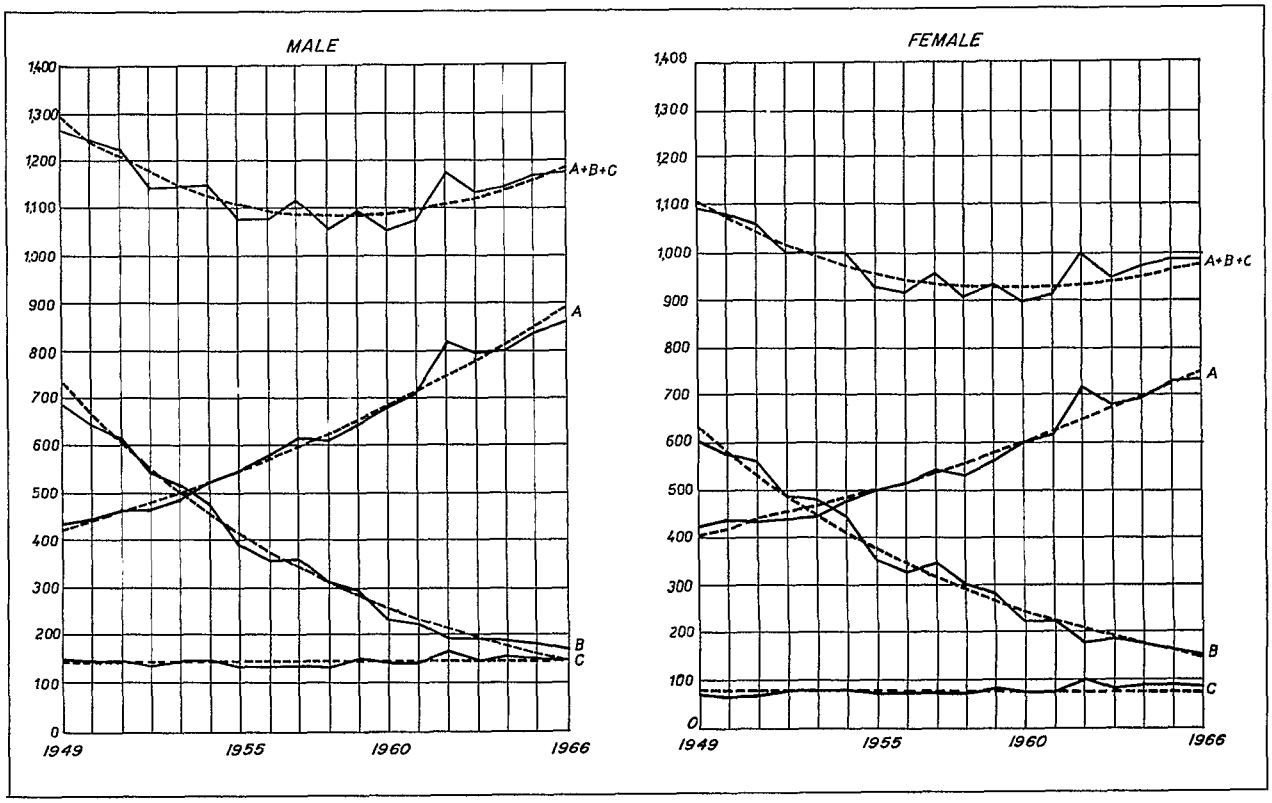


Figure 12. Breakdown of the crude death rate for males and for females into three components: Czech regions, 1949-66.

(Causes of death with: A - upward trend; B - downward trend; C - stable trend)

approximately constant rate of growth. After that, however, a second phase will necessarily follow with a diminishing rate of growth, eventually leveling off. Any reliable estimate of the time when the change in elementary trends will take place seems impossible on the basis of observational data which are now available.

A further increase in the crude death rate in the next several decades is almost certain. The crude death rate is near to 10 per 1,000 population. The average life span is about 70 years and probably will reach 72 years in the foreseeable future. The net reproduction rate has been near 1 for a number of years. If these demographic levels are maintained, the crude death rate will tend to the value

$$\frac{1{,}000}{\overset{\circ}{e}_0} \doteq \frac{1{,}000}{72} \doteq 14 \text{ per } 1{,}000$$

Only a substantial and permanent increase in the net reproduction rate or a revolutionary discovery in medical science, especially in prevention or treatment of one of the major killers among the common diseases, could alter this outlook.

As regards the age-specific mortality of males, a continuing decline in infant mortality is very likely. On the other hand, the possibility of a further increase in mortality of adults (25-44 years) as a result of frequent road casualties cannot be excluded. A further increase in the death rate for the age group 55-74 years seems also probable because of ischemic heart disease and lung cancer trends.

A continuation of the declining trend in the female age-specific mortality can be expected in age groups above 45 years. Later, it will probably be followed by a temporary stabilization at a somewhat lower level.

The above predictions are based only on analysis of demographic data. A few remarks which follow will deal with the problem, whether the underlying causes of mortality themselves cannot be changed.

The cross-sectional analysis, limited in this paper to a comparison of two regions (see "Current National Data"), has shown that major differences in mortality still exist among regions and districts which cannot be fully explained by differences in the age structure of the population or by any other objective reasons. This conveys a hope that improvement, especially in preventive medical care, which would bring the whole country to the level of the most advanced areas could help to overcome—at least temporarily—the present stagnation.

Special epidemiological studies of morbidity in relation to the level of health services have shown that a sizable proportion of patients suffering from cardiovascular and other chronic conditions who could greatly profit from systematic medical treatment for some reasons do not get it. Similarly, in a significantly high proportion of apparently healthy people pathological symptoms or signs have been found characterizing the examinees as "vulnerable" who could profit from individual preventive medical care.

Even without a major breakthrough in medical science, the application of contemporary knowledge could considerably influence some of the conditioning factors of mortality. The present balance of positive and negative factors leading to stagnation of mortality, in the first place of the male mortality, is by no means unalterable. However, it would not be realistic to expect too much. Many of the unfavorable factors are very difficult to change (e.g., air pollution, smoking, obesity, stress, etc.); on the contrary, an increased effect of some of them, or occurrence of new health hazards, cannot be excluded.

SUMMARY

The development of mortality on the present territory of Czechoslovakia during the past 100 years is characterized by a steady decline (ending in 1960) of the crude death rate. At first the decline was slow, later accelerated, still later slowed down again, and reached the minimum in 1960-61. Since that time it has been slightly increasing.

A greater part of the increase in the 1960's was due to changes in the age structure of the population. The age-adjusted death rate showed only a minor increase in male mortality and slight decline in female mortality. Age-specific mortality showed a slight tendency to increase among adult males, especially in the age groups 55-74 years. A slight decline was observed among females over 45 years.

The female death rate was already lower than that for males in 1930 and the gap widened from 1930 to 1967. In this period of time, all age-specific death rates declined; the gradient of decline was largest in the infant and child mortality and diminished with increasing age. At all ages, death rates for females had a larger gradient of decline than those for males.

Dramatic changes were recorded in the pattern of death rates by cause.

In the course of time, many changes were made in nomenclature and classification of diseases and in diagnostic methods and fashions as well as in the regulations and practice of the rules for selection of underlying cause of death. Consequences and limitations arising from this have been discussed in detail.

A cross-sectional analysis in different areas of the state, international comparisons, and results of special epidemiological studies have been used as subsidiary methods in the analysis of demographic data.

Main features of the cause-specific mortality development were: *increase*—neoplasms, cerebrovascular and cardiovascular diseases, chronic bronchitis, and road casualties; *decline* (or stable state)—all other causes, above all, the infective diseases.

A small number of nosological units highly frequent as causes of death and showing a large rate of change (increase or decline) were mainly responsible for the general trend of the death rate. Tuberculosis and pneumonia were most important among diseases with a declining trend; lung cancer, ischemic heart disease, cerebrovascular conditions, and chronic bronchitis were the leading conditions among causes of death with an upward trend.

It is worth noting that almost all of the above mentioned causes of death with an upward trend are more frequent among males and among older people.

Another important characteristic of the conditions with an upward trend is that so far no efficient methods exist that could substantially reduce their incidence or fatality.

For the analysis of the general trend, the causes of death were divided into three large groups:

A' - causes of death with an upward trend

B' - causes of death with a declining trend

C' - causes of death with stable frequencies

It has been shown that in the period of 1949-67 the functions

$$y = \log A', \qquad y = \log B' \tag{1}$$

were approximately linear. The straight lines

$$y = \log A, \qquad y = \log B \tag{2}$$

were fitted to the polygons (1) by the least-squares method. It was found that

$$y = A + B + C \tag{3}$$

is a convex line with a minimum reflecting the change from the declining to the increasing phase of the observed mortality trend.

From the analysis of trends the following important inference can be made: The convex form of the general trend in heterogeneous populations can result from superposition of antagonistic trends with constant rates of change. No new intervening factors need be sought to account for the leveling-off or reversal in the mortality trend.

At first, in 1949, the causes of death with a declining trend were very frequent as causes of death and the declining trend therefore prevailed. Later, both trends began to balance and the curve of mortality flattened out and reached the minimum in 1960. Afterwards, the conditions with an upward trend outweighed the other conditions and the mortality curve began to rise.

In the future, the crude death rate will further increase. The age-specific death rates of males will tend to be almost stable, except for the age group 55-74 showing a small increase. The possibility of an increase in other age groups, however, cannot be excluded. The infant mortality will probably continue to decline.

The age-specific death rates of females will probably further decline in the age groups above 45 years. The diminishing rate of decline allows the prediction that before very long the female death rates will also become stabilized at a somewhat lower level.

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