INTRODUCTION

This publication presents complete life tables for 2000-2004 and 2001-2005. The tables present data by single years of age, for males and females separately. The data are presented for the entire population, for Jews and others, for Jews, and for Arabs. This publication also includes, for the first time, tables on confidence intervals for life expectancy, and confidence intervals for probabilities of death among all population groups.

The Central Bureau of Statistics produces two series of life tables - complete and abridged[1]. The abridged life tables (by five-year age groups) represent annual data (for five-year age groups) are produced on the basis of single years, and the complete life tables (for single years) are produced for periods of five calendar years (moving averages). Because different methods are used to calculate the two types of tables (see below), values of life expectancy in the complete life tables may differ from those in the abridged tables, especially in older age groups.

MAIN FINDINGS

Life expectancy at birth in 2001-2005 was 81.6 years for females and 77.5 years for males. Among Jews and others, life expectancy was 82.0 years for females and 77.9 years for males, similar to the life expectancy among Jews – 82.0 for females and 78.1 for males, and among Arabs – 78.4 for females and 74.7 for males.

Assuming that current mortality patterns remain unchanged, more than half of the females born between 2001 and 2005 can expect to live more than 84 years, and more than half of the males born in the same period can expect to live more than 80 years. Approximately 25% of the females and 16.5% of the males born between 2001 and 2005 can expect to live at least 90 years. Females aged 65 in this period can expect to live an additional 19.6 years on average, and those aged 80 can expect to live another 8.6 years on average. Males aged 65 can expect to live 17.4 more years on average, and those aged 80 can expect to live another 7.8 years on average.

An international comparison revealed that Israeli males ranked among the group of countries with the highest life expectancies. According to the World Health Report 2006[2], which presents data for the year 2004, the life expectancy of Israeli males is one year (rounded) less than that of Japan (79 years), the country that ranks first place. Males in Canada, Sweden, Switzerland, Italy and Australia have similar life expectancies to those of their counterparts in Israel. Israeli females rank lower, and their life expectancy is four years less than that of the leading country, Japan (86 years). Women in Greece, Austria, Finland, Germany, Norway, New Zealand, and Singapore have a life expectancy similar to that of Israeli women.

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1 See *Statistical Abstract of Israel,* Central Bureau of Statistics, Chapter 3.

2 World Health Organization, *The World Health Report 2006: Working Together for Health,* Geneva, 2006.

METHODS OF COMPUTATION

A. Types of Life Table

There are two types of life tables: "cohort" life tables, and "period " or "current" life tables. In cohort life tables, mortality patterns in a particular birth cohort are observed until all individuals in that cohort die. For example, the annual mortality probabilities of persons born in 1894 could be tracked until 1993, and their mortality pattern could be obtained at every age, from birth to age 100. With this data a life table can be compiled for the whole cohort, assuming that all of them had died by 1994.

To produce such a life table, mortality data have to be collected over a long period of time. This is practical only in "closed" populations (with no migration), which is far from the case in Israel. Moreover, the value of a generational table is mainly historical, because it reflects mortality patterns of individuals born long ago and who lived under different conditions from those prevailing at the time the table is constructed.

Period life tables are compiled because it is impractical to calculate cohort life tables, and because it is desirable to describe current mortality conditions. Unlike a cohort life table, a period life table reflects the mortality conditions of a hypothetical cohort born in a given year, on the assumption that among members of that generation, the mortality patterns existing in a given year will persist throughout their lives. For example, the life table for 1990 assumes that survivors of the generation born in 1990 will be exposed at every age from 0 to 100 to mortality rates that existed at those ages in 1990, i.e., mortality rates are assumed to be constant. The life tables presented here are complete period life tables for single years of age from birth (age 0) and to age 100.

B. Confidence Intervals

Mortality rates in Israel, as in all countries, are subject to stochastic variation (statistical error) and to a variety of non-statistical errors, such as those that arise from errors in reported year of birth or age at death. Due to both kinds of error, calculated mortality rates may differ from the "true" mortality rate, which would have been obtained if it were possible to overcome statistical and reporting errors. Statistical errors are more significant among smaller populations, as well as in cases of single years of age or short periods of time.

This publication presents, for the first time, confidence intervals for the probability of death and for life expectancy. These confidence intervals are symmetric, reflect only stochastic variation, and are based on the assumption that age-specific deaths follow a binomial distribution[1].

A confidence interval of 95% represents a range in which the true value of the parameter will be found in 95% of the cases. In cases where the confidence intervals of calculated and "true" morality rates overlap, the difference between the rates is not statistically significant.

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1 Chiang, C. L., "Statistical Inference Regarding Life Table Functions". In: C.L. Chiang, *The Life Table and its Applications*, Malabar, FL: Robert E. Krieger Publishers, pp. 153-167, 1984.

The confidence interval of the probability of death (q_x) is dependent on the number of deaths in the reference group. Accordingly, there are differences in the relative width of the confidence interval at different ages. At younger ages, in which there are fewer deaths, the confidence interval is wider, whereas at older ages, where there are more deaths, the confidence interval is narrower. Similarly, the relative width of the confidence interval differs between population groups. Because there are fewer deaths in the Arab population than in the Jewish population, the relative width of the confidence intervals is greater among the Arabs.

The confidence interval of life expectancy is dependent on the confidence interval of the probability of death, and therefore is narrower for the Jewish population than for the Arab population. For example, among Jewish females the confidence interval for life expectancy at birth is (±) 0.1 years, compared with (±) 0.25 years for Arab females.

Confidence intervals for life expectancy and for probabilities of death were calculated using the methods developed by Chiang[1] , where the significance level α=0.05 corresponds to a standardized normal distribution value of Z=1.96. The confidence interval was calculated for the estimated probability of death, which was obtained from the “smoothed” model.

$$S_{q_x}^2 = \frac{\hat{q}_x^2(1-\hat{q}_x)}{D_x} \qquad CI = 2*1.96*S_{q_x}$$

D_x – absolute number of deaths at age x.

C. “Smoothing” Techniques

Stochastic variation is not the only source of "error" in life table functions. Therefore, in order to overcome irregularities from all sources, it is customary to use a “smoothing” technique of some kind.

An “abridged” life table, which is based on wide age groups and not on single years of age, is less exposed to random variations and other errors. The problems are more serious when calculating a “complete” life table based on single years of age. Complete life tables in Israel for 1986 onwards were computed using the MORTPAK[2] software package, which was provided by the United Nations. The software allows for calculation of complete life tables by estimating a Heligman-Pollard (H-P) mortality model[3], by the least-squares method. In recent years, it was found that this program does not produce reasonable results for Israeli data. The fit between the model and the empirical data is not statistically significant, and it was found that the H-P model raises life expectancy at birth for all population groups (at least by 0.2 years) as compared to the abridged life table. Moreover, the curve of the model exceeds the boundaries of the confidence interval for empirical probabilities of death (q_x).

1 Chiang, C.L. 1984.

2 United Nations, *MORTPAK: The United Nations’ Software Package for Mortality Measurement*, 1988.

3 Heligman L. and Pollard J.H., “The Age Pattern of Mortality”, *Journal of the Institute of Actuaries*, Vol. 107, pp. 49-80, 1980.

Furthermore, although the parameters of the H-P model can be estimated, the statistical properties (standard deviation and significance) of the parameter estimates cannot be calculated, and thus the overall statistical significance of the model is not known. Finally, this smoothing procedure does not take into account the distinct features of the Israeli data: at certain ages, the smoothing procedure greatly reduces the probability of death (for example, the ages of compulsory military service) and at other ages (particularly at older ages), it increases the probability.

For these reasons a new method of smoothing was developed by means of a two-stage polynomial function[1], which is used as the basis for the complete life tables for the period from 1996-2000. The model is based on the Local Maximum Likelihood method[2], as well as on a technique for estimating change points[3].

This method has four advantages:

- The differences between life expectancies before and after smoothing are not statistically significant.
- Statistical parameters of the model can be estimated, such as variance, confidence intervals, and statistical significance.
- The model smoothes the age-specific probabilities of death (q_x) while taking account of the distinct features of the Israeli data.
- The method is easy and convenient to use.

In the new method life expectancy is calculated in four stages:

Stage A: calculation of the q_x values based on single year of age mortality rates (m_x) for each population group and each sex, on average for the five year period (2000-2004 or 2001-2005).

Stage B: Testing the hypothesis that there is a change point in the model. If the hypothesis is not rejected we move on to stage C.

Stage C: Smoothing the q_x values by estimating one or two models of the q_x function, depending on whether a change point was found, one for the younger ages (up to the change point) and one for the older ages (after the change point).

Stage D: Calculation of all the parameters of the life table based on the model q_x values.

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1 Vexler A., Flaks N. and Paltiel A., "*A Method for Smoothing Mortality Functions using a segmented regression model: an application to Israeli data*", Working paper series No. 15. Central Bureau of Statistics, 2005.(Hebrew only).

2 Fan J., Farmen M. and Gijbels I., "Local Maximum Likelihood Estimation and Inference", *J.R. Statist. Soc.*, B. Vol. 60, Issue 3, pp. 591-608, 1998.

3 Koul H.L., Qian L. and Surgailis D., "Asymptotics of M-estimators in Two-phase Linear Regression Models", *Stochastic Processes and Their Applications*, Vol. 103, No. 1, pp. 123-154, 2003.

Components of the Life Table

The life table is based on age and sex-specific mortality rates, and consists of the following functions:

m_x: average mortality rates at age x, i.e., the number of people who died at age x divided by the average population at age x. The m_x values for computing the life table for 2000-2004 are based on average mortality rates for 2000-2004.

q_x: the probability of dying between age x and age x+1. The column presents the proportion of people dying between age x and age x+1 of those who lived until age x. The q_x values for ages of one year or more are derived from m_x values as follows:

$$q_x = \frac{m_x}{1 + \frac{1}{2} m_x}$$

l_x: the number of survivors at exact age x out of 100,000 infants born (radix of the table = l_0 = 100,000). The l_x values are based on the q_x values, on which basis the number of survivors since age x-1 is calculated.

$$l_x = l_{x-1} (1 - q_{x-1})$$

L_X: the number of person-years lived by the cohort that reached exact age x, between age x and age x+1.

$$L_x = (l_x + l_{x+1})/2$$

The values of L_0 (the number of person-years lived by the cohort between birth and its first birthday) and L_{100+} (the number of person years lived by the cohort from age 100 until the last one has died) are calculated differently for two reasons:
L_0 is affected by the non-linear distribution of deaths in the first year of life.
L_{100+} requires an estimate of the number of years that will be lived until the last member of the cohort has died. Thus:

$$L_0 = 0.3\ l_0 + 0.7\ l_1$$

$$L_{100+} = 1000\ (l_{100} / m_{100+})$$

T_x: the total number of person-years lived by the survivors to age x after reaching age x; T_X is the sum of L_x for all ages after x.

$\overset{o}{e}_x$: the life expectancy at age x. This is the average number of years a person may expect to live after age x, assuming that he survived to age x, and assuming that mortality rates are unchanging.

$$\overset{\circ}{e}_x = \frac{T_x}{l_x}$$

The complete life tables presented here show the l_X, q_X and $\overset{o}{e}_x$ functions. The values are calculated up to age 100.