VARIATIONS IN THE MORTALITY WITH RESPECT TO LUNAR PHASES

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Abstract. The overall mortality and cardiovascular mortality data from Romania within 1989–1995 were processed. They exhibit an increase by about 10% caused by the increase of inhabitants and by the increase of their average age. The percentage of cardiovascular mortality increases as well. Both data series display a pronounced annual wave supplemented by a smaller semiannual wave, resulting in a double maximum in January and April and a minimum in August. There is also a variation with the social week, given by a combination of the 7-day and 3.5-day wave, with a maximum on Thursday and Sunday and a distinct minimum on Friday. The mortality depends also on the lunar synodic cycle. This variation has a form of the semilunar wave with maxima two days before first and last quarter. The difference in the mortality between maxima and minima was tested and appeared to be significant. The semilunar wave is supplemented by some smaller waves with shorter periods but not by a lunar wave. This semilunar variation agrees surprisingly well with the same variation found in the sudden cardiovascular mortality data in Brno (400,000 inhabitants), Czech republic, within 1975–1983. This data set includes all cases of sudden death due to cardiovascular defeat at home, etc., not in hospital (i.e., earlier than medical assistance arrived). The maxima of the semilunar wave lay two days before the first and two days before the last quarters and their position depends on the solar cycle. Moreover, waves with periods between 3 and 4 days appear to be significant as well. All these periodicities in both data sets (from Romania and from Brno) are only connected with the lunar month and are not pronounced if these data are arranged with respect to some other effects (e.g., solar rotation).

The Computing and Health Statistics Centre in Bucharest collects mortality data from Romania. For each day the total amount of people who died in that day with an additional information about the cause of their death are being saved. We restricted ourselves only to the years 1989–1995 and on two data sets: the general mortality and the cardiovascular mortality. The average daily mortality is 708 people per day, from this 427 (60%) had a cardiovascular cause. This means that about 1.8 million people died within 1989–1995, of these about 1.1 million due to cardiovascular diseases.

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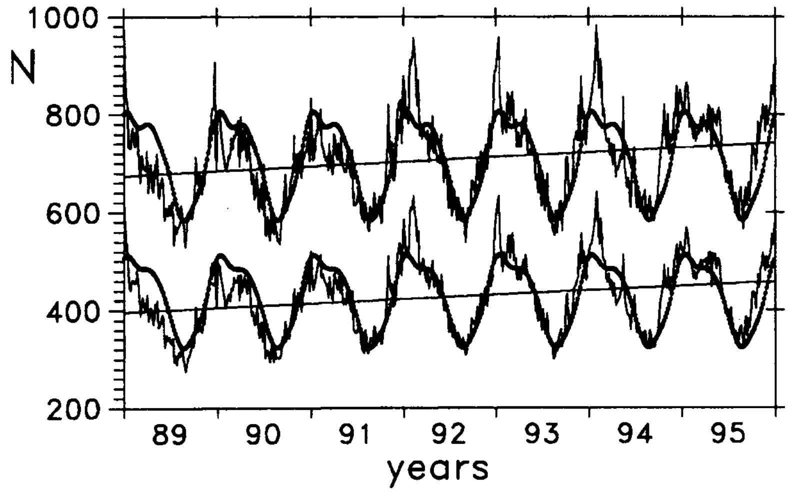

Figure 1. The course of the general mortality (upper graph) and of the cardiovascular mortality (lower graph) in Romania 1989–1995 with a linear regression line and a combination of annual and semiannual sine waves given by a thick line.

In Figure 1 the course of the general mortality during the selected years is presented. The annual wave is very strong and exceeds significantly the day-to-day fluctuation. Moreover, a permanent increase from 1989 to 1995 can be seen. The regression line expresses an increase from 674 on the beginning to 742 to the end of the investigated period (10.1%). This increase is done partly by the increase of the total inhabitants in the country and partly by the increase of the average age of the inhabitants as in all developed countries. The course of the cardiovascular mortality is nearly the same, with the same annual wave, but the increase is more rapid: from 396 to 458 during the same time interval (11.6%). This results in a percentage increase of cardiovascular mortality from 58.5% to 61.4%.

Figure 1 shows a pronounced annual variation, and the same is valid for cardiovascular mortality too. These waves have been subjected to Fourier harmonic analysis in order to determine harmonic components of them. There is a strong annual wave, supplemented by a smaller semiannual wave, other harmonics can be neglected. The maximum of the annual wave occurs in the second half of February and the minimum occurs near the second half of August for both general and cardiovascular mortality. The combination of the annual and semiannual waves keeps the same position of minima but it creates a double maximum in January and April for both data series. This combination is presented in Figure 1 without respect to the regression line – one can therefore compare the gradual increase of the mortality. The same analysis has been applied to the data in each year separately in order to determine if there is a change in the above described parameters. Some fluctuations in the amplitude and phase of the annual wave display no regular trend.

The mortality data exhibit an interesting dependence on the social week. Both the general and cardiovascular mortality display a distinct minimum in Friday and a maximum in Sunday, with a subsidiary maximum in Thursday. This variation can be described as a combination of two waves with periods of 7 day and 3.5 day. The amplitude of both waves is relatively high. The same pattern repeats every year. The explanation of this variation is not easy. A maximum in Saturday and Sunday could be expected because in these days medical assistance may be less accessible but the presented results do not show this effect. The 7-day and 3.5-day periodicity has been reported in a review paper by Cornélissen et al. (1992). These significant periodicities have been found in 47 data series from the entire world (see references in their paper).

The series of mortality data display a slight dependence on the lunar synodic cycle. This variation can be obtained using superposition of epochs. Using a sufficiently long time series (a large number of superimposed epochs) variations not dependent on the lunar cycle are averaged out. Nevertheless, in the case of lunar variations, some difficulties may arise because time distances between any lunar quarters are not given by an integer number of days. Therefore this method has been applied to each lunar quarter separately, using the interval from −3rd to +3rd day only (see also Sitar, 1991). These four seven-day series were then connected into one cycle. The lunar cycle is thus described by 28 numbers, the 29th point being equal to the first one. The first day corresponds to the new moon, the eighth day to the first quarter, the 15th day to the full moon, and the 22nd day to the last quarter. Lunar variation in our data set calculated by the described method is shown in Figure 2 for the general mortality. Very similar dependence was obtained for the cardiovascular mortality. Despite the high noise level, increased mortality can be observed shortly before the first and the last quarter. Fourier harmonic analysis applied on the lunar variation curve discovered the semilunar wave to be the strongest, being supplemented by a group of waves with shorter periods and lower amplitudes. No lunar wave has been observed. This semilunar wave is shown in Figure 2. It reaches its maxima two days before the first and the last lunar quarters and its minima two days before the new moon and the full moon. The amplitude of semilunar wave is much smaller than that for annual variation. For the cardiovascular mortality the appropriate maxima and minima appear in the same position. This regularity agrees surprisingly well with the variations of the sudden cardiovascular mortality in Brno, Czech Republic, in 1975–1983 described in Střeštík and Sitar (1996), though the sudden cardiovascular mortality is a different category of mortality.

The significance of the semilunar wave has been tested by the Student's t-test of significance. The whole data set has been subdivided into two parts: the first containing days between −5th and +1st day after the first and the last lunar quarter, in the second, the days between −5th and +1st day after the full and new moon were included. The difference between the average mortality in both groups exceeds the limit of 99% significance (t = 2.04). Any shift of the limits between these two

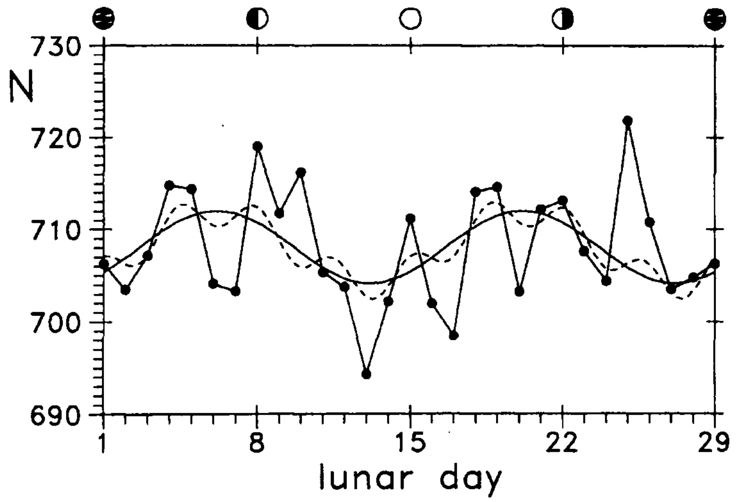

Figure 2. Lunar variation of general mortality in Romania 1989–1995 (solid with black circles) with a semilunar wave (solid) and a combination of semilunar wave with the 3.7-day wave (dashed).

groups (e.g., a selection between −4th and +2nd day, etc.) reduces rapidly the values of the t-parameter. Very low and insignificant differences have been found for any subdivision with respect to the lunar wave (e.g., from −7th to +6th day after the full/new moon).

In Figure 2, strong fluctuations with shorter periods are clearly seen. Also in the Fourier harmonic analysis coefficients with higher amplitudes appear for some higher harmonics. The highest amplitude, even a little higher than for the semilunar wave, appears for the wave with the period of 3.7 day, i.e., 1/8 of the lunar day. This wave is supplemented by waves with periods of 4.9 and 3.3 day, i.e., 1/6 and 1/9 of the lunar day. The combination of the semilunar wave and the 3.7-day wave is given in Figure 2 together with the semilunar variation. The phase of the short-periodical wave is nearly identical in both cases of mortality. Though the interpretation of these short-periodical waves (including the two weaker waves) is not clear, it is obvious that they are connected with the lunar cycle. None of their periods corresponds, e.g., to the half of the social week (3.5 days).

Data on sudden cardiovascular mortality were collected from the city of Brno, the second biggest city in the Czech Republic (about 400,000 inhabitants) during the period 1975–1983. This data set includes all cases of sudden death, when people died at home, in the factory or office, on the street, etc., but not in a hospital (i.e., they died before any medical assistance could arrive) due to cardiovascular disease. The cardiovascular cause of their death was in all cases confirmed by autopsy. The total number of sudden deaths used in this paper is 1437.

The lunar variation in our data set prepared in the above described method of the superposition of epochs is shown in Figure 3. The conspicuous semilunar wave and

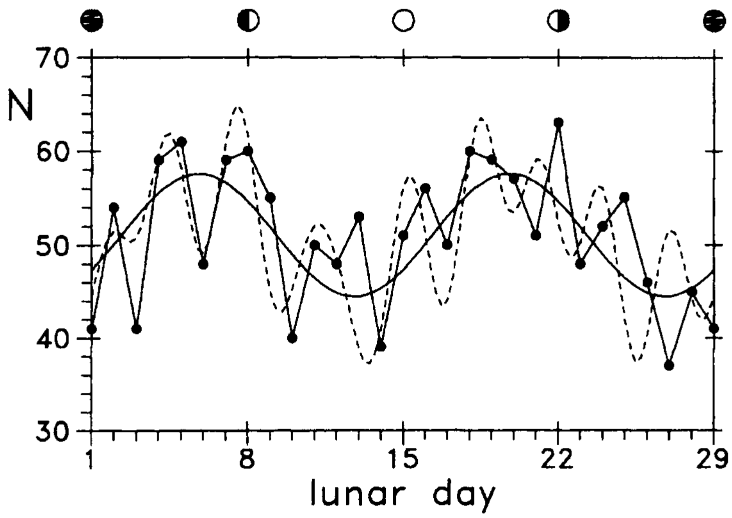

Figure 3. Lunar variation of sudden cardiovascular mortality in Brno 1975–1983 (solid with black circles) with a semilunar wave (solid) and a combination of semilunar wave with waves with periods of 4.23, 3.70, 3.29 and 2.96 days (dashed).

other possible waves can be more precisely determined using the Fourier harmonic analysis. Among the sinusoidal waves obtained by the Fourier harmonic analysis, the semilunar wave prevails. Its maxima lay two days before the first and last lunar quarters. A less pronounced lunar wave appears in the Fourier analysis with its maximum on the day of full moon and amplitude a little higher than one third of that of the semilunar wave. Due to this wave, the minimum near the new moon is a little deeper than the one near the full moon.

To investigate the dependence of the semilunar wave on the solar cycle we selected years near the solar maximum (1979–1982) and solar minimum (1975–1977) and performed the same analysis as for the whole interval. In years of solar minimum the maxima of the semilunar wave appear four days before the first and the last quarters, whereas in years of solar maximum these maxima are shifted to one day before the respective lunar quarters. In the years of solar maximum the lunar wave is more pronounced than in the years of solar minimum.

The significance of the semilunar wave has been tested by the Student's t-test of significance similarly as for Romanian data. The difference between the average mortality in both groups is significant (t = 3.16). Any shift of the limits between these two groups (e.g., selection from −4th to +2nd day, etc.) reduces the value of the t-parameter, but with a shift of one day in both directions, the t-value is still above the 99% significance level. No significant difference has been found for the lunar wave.

Figure 3 shows strong fluctuations with shorter periods. Also the Fourier harmonic analysis discovered coefficients with higher amplitudes for some higher harmonics. They are presented also in Figure 3 as the combination of four waves with periods of 4.23, 3.70, 3.29 and 2.96 days, i.e., 1/7, 1/8, 1/9 and 1/10 of the lunar month..

The pronounced semilunar waves, firmly connected with lunar phases and independent of the social week, suggest possible connections between the described mortality variations and Earth tides, with some time lag. A smaller semilunar wave has been reported in some geophysical and meteorological data as well (Bigg, 1963). Although the proper mechanism of the supposed influence of tides on the biosphere is not known, our results lead to the conclusion that the lunar factor should be taken into account in any investigation of external influences on biological processes.

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