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Seasonality of Mortality in Human Populations of Chile as Related to a Climatic Gradient

by

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ABSTRACT. – Mortality of human populations in Chile was studied from a latitudinal and seasonal perspective, and related to climate and main diseases. Approximately 3 mill. deaths were analyzed. Seasonality considered along a latitudinal and climatic gradient is almost absent in the northern portion of the country, in the central part peaks are evident in summer, at latitudes 40°S in winter and at 45°S in winter and spring. Seasonality along the years of analysis shows a different behaviour for the different zones of the country and no unique pattern is evident. A clear relationship between the air enthalpy and seasonality of mortality is detected. Circulatory diseases appear as the most important causes of deaths, exception made of latitude 40 where respiratory diseases are the significant causes of deaths. Age groups below one and above 65 years are mostly affected.

INTRODUCTION

The analysis of mortality in a given country is an important field of study from many points of view. Especially interesting are such studies in some countries, where different latitudinal patterns shape the landscape and show the evidence of different geographical features along a climatic gradient.

This is the case of Chile, extending over almost 40 degrees of latitude as a narrow north-south strip of land, on the west coast of South America. This gives as a result, the existence of at least 5 bioclimatic trends from north to south. (Hajek and di Castri, 1975; di Castri and Hajek, 1976). In such a diverse geographical setting the study of some vital statistics is an attractive challenge in a latitudinal, seasonal and climatic perspective.

It is a well known fact that seasonality of mortality exists in human populations, although different authors have reported that the time of peak as well as the intensity of it are not clearly resolved in regard to geographical zonalities and so it is possible to find in several articles also different seasons with the highest peak, different age groups affected by mortality and different climatic characteristics which are incidental to

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mortality rates (Cech et al., 1979a; Cech et al., 1979b; Goldsmith and Perkins, 1963; Momiyama and Katamaya, 1972; Momiyama, Katayama and Sato, 1978; States, 1977; Tromp, 1963; Tromp and Sargent, 1964).

No attempt will be made to discuss comparatively all the literature touching this subject.

The purpose of this paper is to reveal if seasonality of mortality exists in human populations of Chile, and if this is true, to determine its relation with latitude, and some of the causes of deaths and probable links with climate.

MATERIALS AND METHODS

For the study, monthly data of deaths for the old 25 administrative provinces of Chile were obtained for the period 1945 to 1975 from the records of the Instituto Nacional de Estadísticas (INE 1945-1974). A total of approximately 3 million deaths was analyzed. The monthly rate of deaths expressed as percentages from the total was related to the expected percentage of annual mean monthly death rate (that is 8.3%). The mortality was plotted as percentage deviation from the annual mean starting in January. An analysis of variance with a Scheffé test "a posteriori" was made for detecting possible differences between months for each of the provinces (Snedecor and Cochran, 1969). The value of F was used to define the intensity of seasonality. It was assumed that the higher the value of F, the higher was the seasonal course of mortality per province.

Also, the maximum positive deviation from the mean was used as a "seasonality index" (Io) to compare different provinces along a latitudinal gradient and to analyze the course of seasonality with time. Five year moving averages were used also for this purpose.

For the purpose of analyzing some causes of deaths and to relate these to seasonal changes and latitude, the mortality data were divided into a number of categories by codes given in the International Classification of Diseases, Injuries and Deaths (National Center for Health Statistics, 1967). These categories were:

001-009 and 020 to 136	Infectious and parasitic diseases
390-458	Circulatory diseases (cardiovascular)
460-519	Respiratory diseases
520-577	Digestive diseases.

It is necessary to point out here that some of the above mentioned information on causes of death per disease had to be obtained by indirect evidence, since the official statistics do not include simultaneously data of age structure, causes of deaths, monthly course and number of deaths per province, and so cross references were not possible.

In order to relate possible seasonality of mortality with climate, the air enthalpy was used according to the equation of Bradtke and Liese, modified by Mollier, and the values were classified according to the scale of thermal sensation of Brazol in 12 categories (Brazol, 1951).

Six regions were defined along Chile, forming groups with those provinces showing homogeneous trends, and for each of the groups one representative province was used as a sample due to their population number or climatic characteristics. For each of them the age structure was studied, as well as the causes of deaths and the percentages of analyzed causes.

RESULTS AND DISCUSSION

The analysis of the monthly averages of mortality for the 25 provinces shows the existence of certain months with a greater seasonality of deaths which alternate in a north-south sequence (Fig. 1).

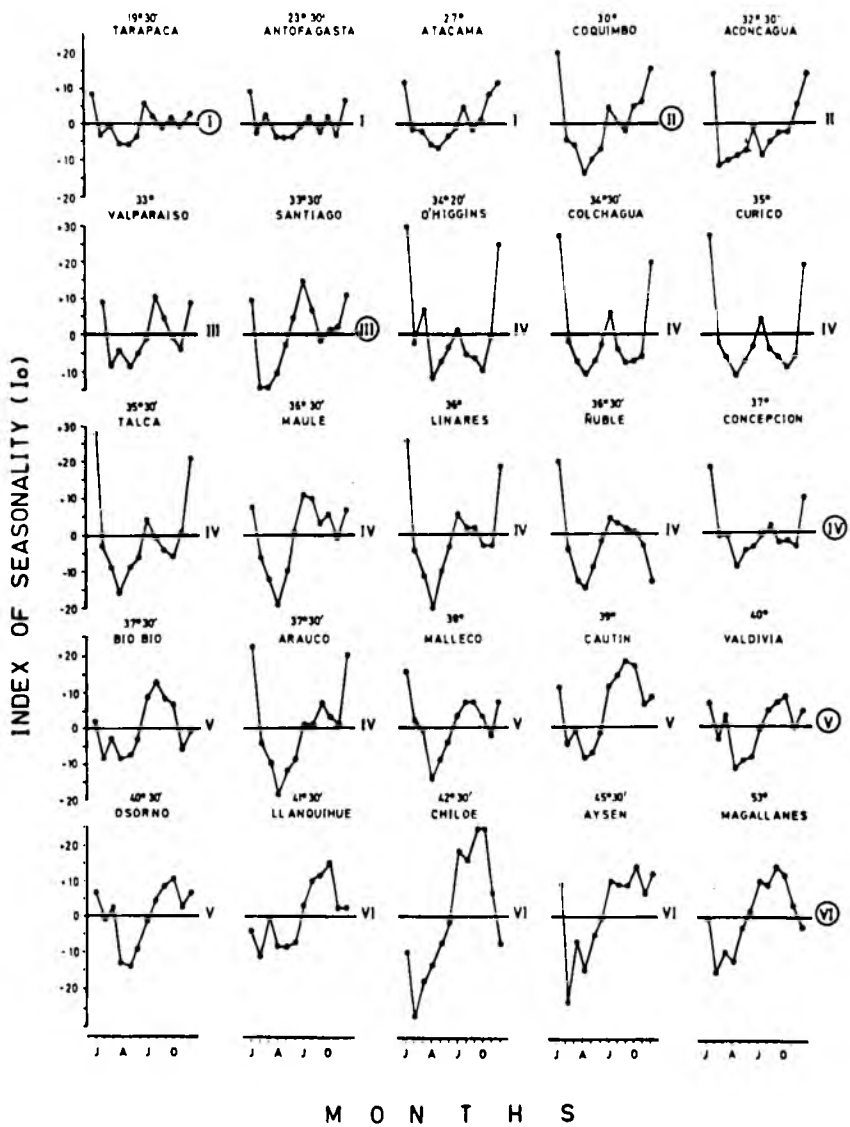

Fig. 1. Annual course of mortality in human populations for the old 25 provinces of Chile, expressed as an index of seasonality (Io). Roman numerals indicate the geographic regions with relatively homogeneous conditions of mortality. Numerals in circles indicate the province used to represent one whole region.

In the northern part of the country January is the month with the largest incidence of deaths, even when a clear trend of seasonality does not exist. From the latitude of 29 degrees onwards an increase of the seasonality in the summer months is observed, especially January and December and also a secondary peak corresponding to the month of July, at about 33 degree of latitude. This situation is even more marked up to the latitude of 39°, although the differences between both peaks are strongly marked.

At latitude 40 this situation is reversed and a slightly higher seasonality in the winter months becomes evident. Finally at latitude 45 the greatest seasonality is present in winter and spring and the minimum in summer.

The latitudinal analysis then shows that the greater seasonality is produced in the central provinces of the country (that is 33 to 40 degrees) with a progressive decrease toward the geographical extremes of the country.

Fig. 2 shows a grahical representation of the F value versus latitude. As was stated before, the higher the value of F, the more marked is the difference between months and therefore the seasonality.

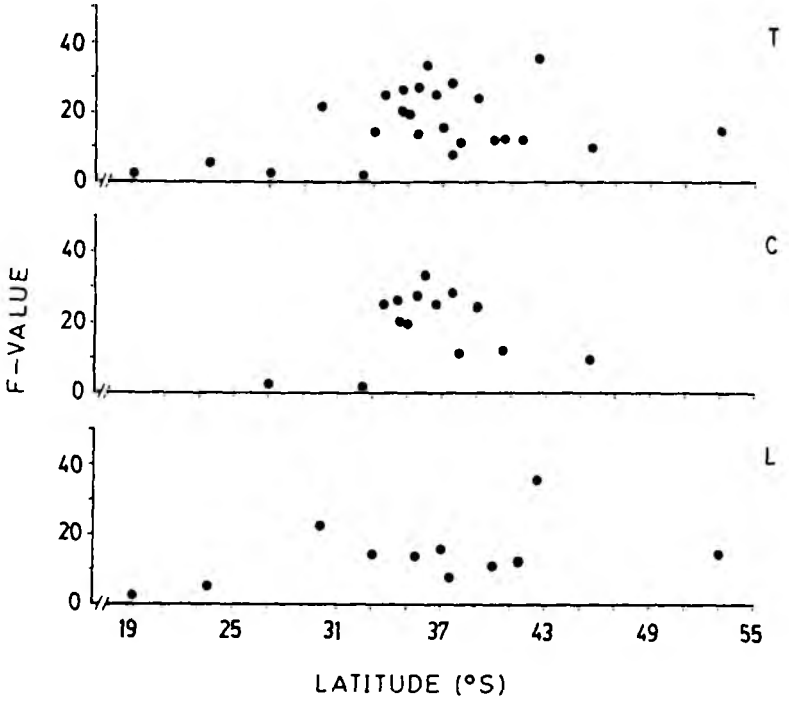

Fig. 2. Relation between the F value as a seasonality index and the latitude. T = Total of provinces, C = Continental provinces; L = Littoral provinces.

We can see that in the northern part of the country, the overall seasonality (upper part of the graph) is only slightly marked. (No month shows significant differences). The highest seasonality is found in the central provinces as was discussed before.

Fig. 2 also shows that the provinces with a maritime influence, (middle part of the

graph) tend to show lower seasonality values, in contrast to those of the continental provinces (lower part of the graph) in which a greater dispersal of points is observed.

So, we could suggest that the environmental conditions related to the amplitude of temperature oscillations which are more marked in the central and continental provinces, are evidenced by a more marked seasonality and therefore a higher F value. In contrast to the latter, we find the extreme southern and northern provinces, climatically more stable and with a low (not significant) F value.

The analysis of the latitudinal behaviour of the indices of maximum and minimum seasonality (Io) shows again that in the central part of Chile we have a clearly evident seasonality of mortality (Fig. 3).

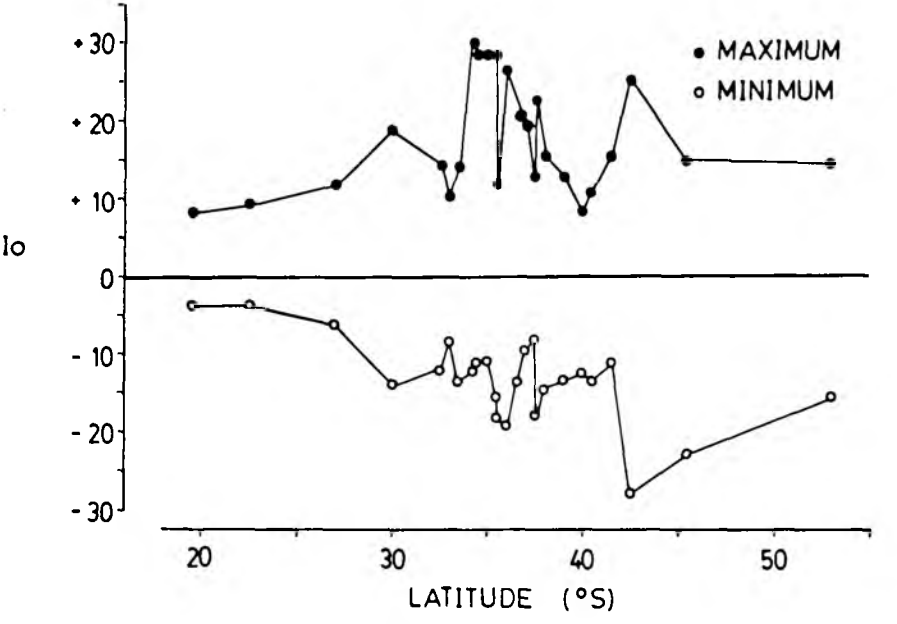

Fig. 3. Index of seasonality (Io) for the months with the maximum and minimum seasonality of mortality.

In those provinces with a more marked climatic seasonality there is a coincidence with the higher values of the index of seasonality of deaths. For example, in the northern zone (Province of Tarapacá) climatic conditions are relatively uniform throughout the year and large fluctuations of the indices of seasonality do not exist. In the central provinces (33° to 39° of latitude) the climatic seasons of the year are clearly defined, as well as the index of seasonality of deaths. In the austral zone of the country, in spite of the existence of warmer microclimatic conditions, within the buildings, due to constant heating along the whole year, we can see also a clear seasonality, but shifted in regard to the month of the maxima. This might be associated to those months with a change of external climatic conditions and the great differences which are produced with respect to controlled environments.

Considering the similarity in the behaviour of some of the analyzed provinces, we have established a division in 6 regions, each of them with relatively homogeneous

characteristics. For this we have considered both the number of peaks as well as the season in which they occurr (Fig. 1).

The first region comprises the provinces of Tarapacá, Antofagasta and Atacama, located between 18 and 29 degrees of latitude. This region shows no marked seasonal trend, the values slightly oscillating around the mean. The second region is formed by the provinces of Aconcagua and Coquimbo, 29 to 33 degrees, with a marked seasonal trend evident in the summer months December and January and a lower secondary peak in winter. The third region corresponds to the province of Valparaíso and Santiago, 33 to 34 degrees, which have two marked peaks, in winter and summer, being the former higher than the latter. The fourth region is the most extended one, between 34 and 39 degrees of latitude. The provinces show the summer months with a relatively high value of the index and a less significant peak in winter. The fifth region comprises the provinces of Arauco to Osorno, 39 to 42 degrees and here we can observe for the first time along the gradient, that the spring months appear with the highest seasonality values. The secondary peak of summer is less marked. The last region is extended from 43 to 52 degrees of latitude. This region groups those provinces which have a marked seasonality in the winter-spring months. The values for the summer are negative, that is below the mean.

On the other hand, the analysis of the moving averages of the index of maximum yearly seasonality along the series studied (Fig. 4), shows an increasing trend of the value of the seasonality index, suggesting an increase in the overall yearly seasonality.

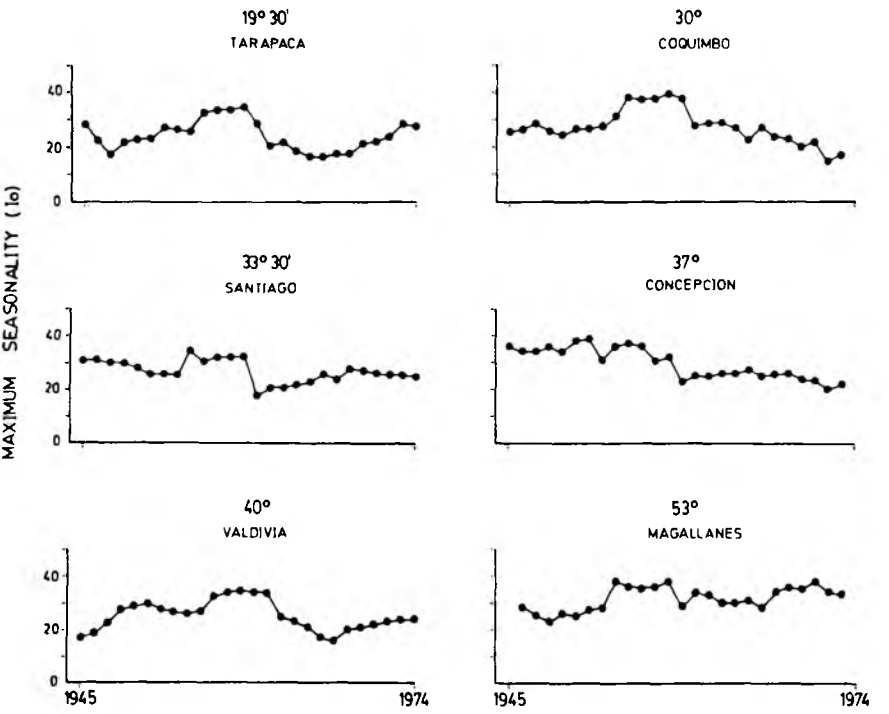

Fig. 4. 5-year moving averages of the index of maximum yearly mortality for the period 1945 to 1975 for some selected provinces of Chile.

In the central provinces, the decrease of the maximum seasonality might be due to the decrease of infant mortality mainly in the summer months.

In the case of Magallanes, the reason might be related to the fact that historically there has been a similar proportion of mortality in the extreme ages (that is below 1 and above 65 years) and that the decrease of infant mortality makes more seasonal the deaths in winter and spring which affect the groups over 65 years of age.

We think that the air enthalpy (which considers at the same time the hygric and thermal conditions) might be a good index which synthetizes fairly well the bioclimatic conditions in a human perspective and might be applicable in a country extended over so many degrees of latitude as Chile does.

Fig. 5 shows the values of the air enthalpy for January and July in a latitudinal gradient in Chile. In general it may be said that the enthalpy decreases at a rate of approximately 8.4 kJ per kilogram per degree of latitude (Hajek, 1979). In this graph we may also see that the values of January and July are closer at the southern points of the regression line.

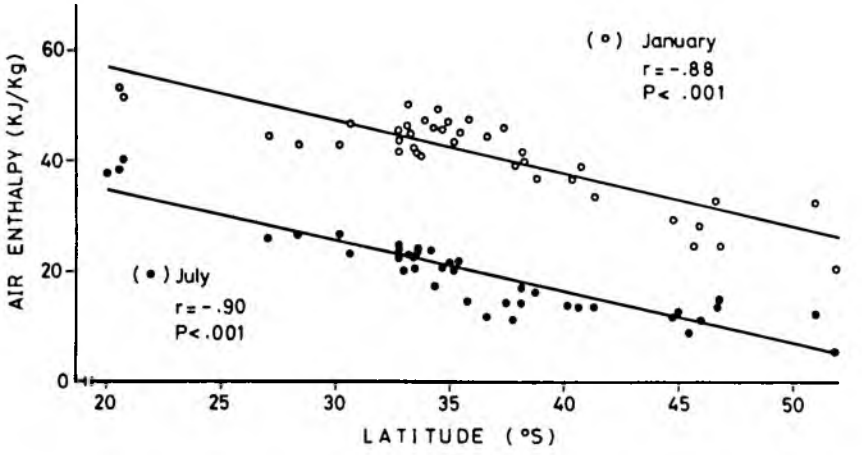

Fig. 5. Relation between latitude and the air enthalpy in Chile for January and July. (Hajek, 1979, modified).

In Fig. 6, we have included on the left-hand side the values of mortality by seasons for the different regions and on the right side, the values of the air enthalpy in categories. Lower numbers mean colder categories; 6 is optimum with about 38.5 KJ/Kg. When we analyze the latitudinal gradient comparing the air enthalpy with the seasonal trends of mortality, we find that at higher latitudes and cooler climatic conditions the mortality occurs mainly in spring and winter. In the northern provinces, with warmer climate, the higher seasonality of mortality is concentrated in summer. This could be due to the fact that at latitude 40 approximately, the more favorable conditions of thermal sensation are replaced by colder ones (lower categories of the scale) which show increments both in a temporal and spatial perspective as we advance with increasing latitude.

Fig. 7 is divided into two parts. The upper part shows the percental distribution of 4 groups of diseases and the total of those diseases. This total is further divided according to age groups in the lower part of the graph.

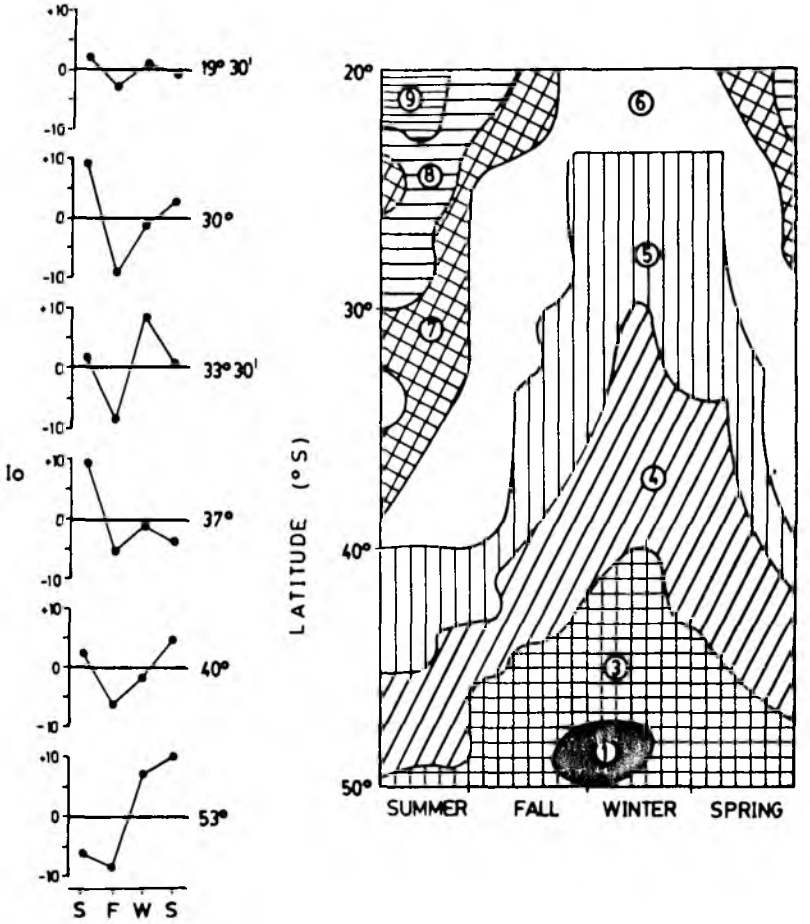

Fig. 6. Latitudinal gradient of the air enthalpy as compared with the seasonal trends of mortality of human populations in Chile. Categories of the air enthalps are: 9, uncomfortable; 8, very warm; 7, comfortable, in summer acceptably warm; 6, comfortable, in autumn, most comfortable; 5, comfortable, in winter, acceptably cool; 4, cool; 3, moderately cold; 1, cold.

The analysis of the six provinces which are used as an example of larger regions reveals that along the whole country, the population mostly affected by deaths is that of the age groups below one and above 65 years. In all of the cases, the summation of both values gives over a 60 percent of the total of deaths grouped by age structure.

The different diseases selected for our study represent themselves over a 50% of the total causes of deaths per province. In the majority of the affected provinces the circulatory diseases appear as the most important ones, with the exception of Valdivia, at about 40 degrees of latitude, where respiratory diseases are the main cause of deaths.

It is important to point out that in those provinces which are representing the fourth region, here shown by Concepción, there is an increase of the causes of deaths due to

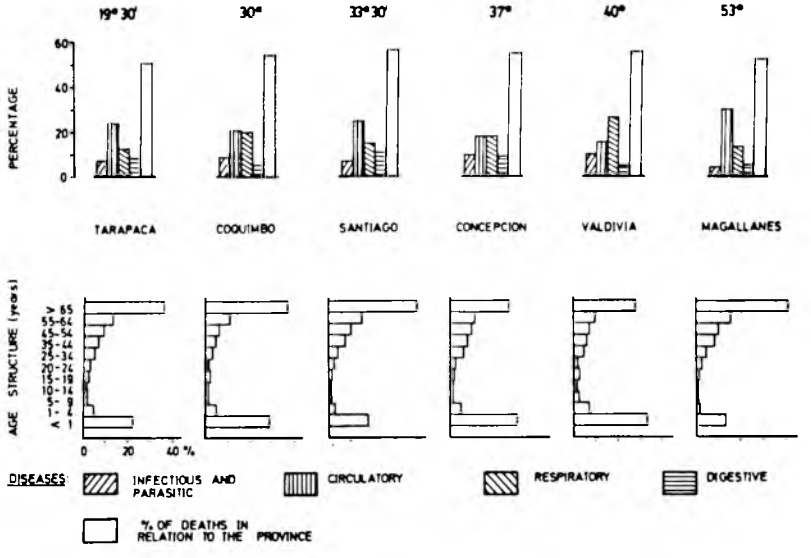

Fig. 7. Distribution of diseases as causes of deaths for some selected provinces of Chile. Upper part of the figure represents the percentage of the main causes of deaths for four groups of diseases. Unshaded columns correspond to the total percentage of the listed diseases in relation to the total of the province. The lower portion of the figure shows the total of deaths per province, according to age structure.

parasitic and infectious diseases, concomitantly with the increase of mortality of children below one year.

A more detailed analysis of the figures reveals that infectious and parasitic diseases have an effect on children of under 5 years of age (in a percentage always greater that 75%). The diseases related to the circulatory system in a percentage over 75 affect people above 55 years of age for all the analyzed causes. Respiratory diseases are related mainly to those people under one year of age and in a lesser degree people over 65. The province of Magallanes is an exception to this and here the respiratory diseases affect fundamentally people over 65 years. Finally, digestive diseases occur in a percentage higher than 76% in persons over 35 years of age.

We may conclude by saying that for Chile we have shown the existence of seasonality of mortality. This seasonality could be attributed to climatic factors, considering the general patterns detected in the country. The air enthalpy could be used to identify this aspect, and further research is necessary.

The analysis of the latitudinal gradient shows that in those geographically extreme provinces of the country, where climatic conditions are rather stable along the year, there is no marked seasonality of mortality. On the other hand, in those provinces of the central zone of Chile, with a highly fluctuating climate along the year, a notorious seasonality of deaths is observed, which can alternate in the summer or winter months. Coincidentally, the fall season does not show a marked seasonality for any of the analyzed provinces. From this situation we may conclude that those more clearly defined seasonalities are associated with high or low temperatures and to clear daily oscillations, associated with a higher air humidity.

The aspect related to the diseases needs further analysis, especially in view of the fact that official statistics can only be handled using indirect evidence, as already stated.

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