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AN APPROACH TO BUILDING A UNIVERSAL HEALTH CARE MODEL:
Morbidity Model of Degenerative Diseases

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Preface

Throughout the world, those responsible for developing national health care systems are becoming more and more aware of the need for using analytic tools to aid in performing a wide range of planning functions. The development of a health care system model as one of these analytic tools is the main task of the bio-medical team in IIASA's research area Human Settlements and Services.

This paper deals with one part of that task. The first part describes an approach to building a universal health care model and defines submodels as steps in building the model. The relations of this approach to other studies already undertaken are also discussed. The second part of the paper deals with the morbidity model of degenerative diseases, the first step toward realizing the national health care model. Descriptions of other submodels will be published in the future.

Abstract

There have been many different approaches to building health care models. Because of these differences, it is sometimes difficult to relate the developed models to each other.

We have therefore first defined the submodels of the health care system and clarified the relation of our approach to studies already undertaken. The submodels also show the steps in building the health care model.

The first step was to construct the morbidity model of degenerative diseases. The validity of the model was tested for various countries, using statistics from the World Health Organization. The fit of the model to empirical data was satisfactory. The model was applied to an international comparison and estimation of trends in degenerative diseases. The study showed the feasibility of this type of approach in health planning.

Contents

BUILDING A UNIVERSAL HEALTH CARE MODEL

Introduction

The importance of health planning is widely recognized. However, standard techniques of health planning have not been developed and there have been cries for better technologies in many places.

Many health statistics have been published. While some of them include detailed data, these data may be insufficient for health planning, and the health planner encounters great difficulties in how to use the statistics. Some of the reasons are the following.

Ordinary statistics do not give the data in the form required by health planners or decision makers. The decisions that health planners have to make may regard an increase in beds for the year, or the budget for some area of medical research. But statistics do not give the data in appropriate form.

Second, statistics show no interrelations among various data. At present they give the number of patients, and the death rate or prevalence rate of some diseases by region or country. These numbers are related, but no standard technology has been developed to analyze the data in their interrelationship.

Moreover, it usually takes many years to make plans work so that plans must be prepared in advance. But data for the future--which are essential for health planners--are not given in ordinary statistics.

These are some of the problems that health planners encounter. To overcome these difficulties, methods that can answer the above questions must be evolved. Analysis of the data by a simulation model is one of the approaches in this direction. The purpose of this study is to investigate the feasibility of health care modelling and to build a model using the statistics available at present.

Predictive or Optimization Model?

Models may be roughly classified into two groups. The first type is for predicting the future trends of various indices under given conditions; it may be called a predictive model. The second type is for calculating the optimized condition under a given objective function. This is sometimes called an optimization or prescriptive model; it is generally used for the best allocation of limited resources.

The predictive model gives the policy maker the data he requires. He may repeat calculations under different policies,

but it is his responsibility to decide which policy he should choose. Using the prescriptive model, the policy maker can get a unique solution for his problem if the model works successfully. But in using this type of model, he must give the objectives of the system in clear form, and the solution is applicable only for his objectives. If the objective is different, the solution can be entirely different.

In large-scale health care systems, it is not easy to define the objective function of the system. The objectives are usually very sensitive to the social or political conditions; those of a country may be different from those of a region. And the objectives of a region again differ from those of medical institutions.

In spite of the difficulty in defining objective functions, the health care system itself is at least in part independent of social or political factors. It includes biological processes such as morbidity, birth, death, or recovery from diseases. These processes are universal regardless of the social or political environment.

The insurance system or type of supply of medical care may be influenced strongly by social systems. But since the desire of people to recover from illnesses is universal, all health care systems must have some common ground in analytical methods.

These facts suggest that there is a possibility of defining the structure and function of the health care system and to build a universal model that covers at least its universal features. Such a model will be of the predictive type in the first step, with policies as external variables.

The approach used in this study was to first build a predictive model based on these considerations.

Concept of the Model

One reason why health statistics are difficult to interpret may be that they are the result of interactions of various factors. For instance, the number of patients is influenced by the population age-sex structure, incidence rate of diseases, attitudes of consumers toward seeking medical care, and so on. Accordingly, even if the number of patients increased in the previous year, it is very difficult to predict whether this increase will continue in the following year.

With this in mind, our analytic approach is to transform the statistical data into more essential factors that can be more easily interpreted, and to build a model using these factors [1]. "Essential" here means that the factors are directly related to the health care system and that secondary effects on these factors are identified.

In the dynamic process, there are two kinds of measures: *amount* and *rate*. These are used in ordinary health statistics. The number of population or patients is *amount*, and the birth rates or death rates are *rates*. In general, with these two measures, if the rates are determined the amounts are automatically determined. In this sense, rate may be regarded as more essential than amount. We have therefore tried to identify rates as essential factors in health care.

The essential factors we have identified in our model are population structure, morbidity rate (MR), recovery rate (RECOV), patient registration rate (RPR), awareness rate (AR) and death rate (DR).

Primary Components of the Health Care System

Population Structure: PN(i): As sick persons constitute a subset of the total population, it is necessary to know the size of the total population. Since diseases are dependent on age and sex, the population must be classified by age and sex.

The population structure is a function of birth rates and death rates; therefore, in the strict sense, the population structure may be regarded as a secondary factor to the birth and death rates. However, the models for estimating the population structure from these rates have been extensively studied by researchers of population phenomena [2,3]. In this health care model, the population structure is therefore regarded as a primary factor. In implementation of the model, the population model will be included and run at the same time.

Morbidity Rate: MR(i): As shown in the upper part of Figure 1, the population is divided into two groups--healthy (HP) and sick (TS). Sick defines persons with some disease, regardless of the treatment. The person himself may not know that he is ill; these people are included with the TS at this stage. There are also some people who consider themselves sick but, from the medical point of view, are actually not sick at all. They visit physicians, only to be examined and told that they are in fact healthy. But, since they are nonetheless consuming medical resources, they are classified with the "total sick" group.

Since this is a dynamic process, a rate can be assumed between these two amounts, namely, the number of persons transferred from the healthy stage to the sick stage in a unit time. This rate is defined as the morbidity rate (MR).

Since the number of total sick is not known, it is usually difficult to estimate the morbidity rate, except for some special circumstances. This will be discussed later.

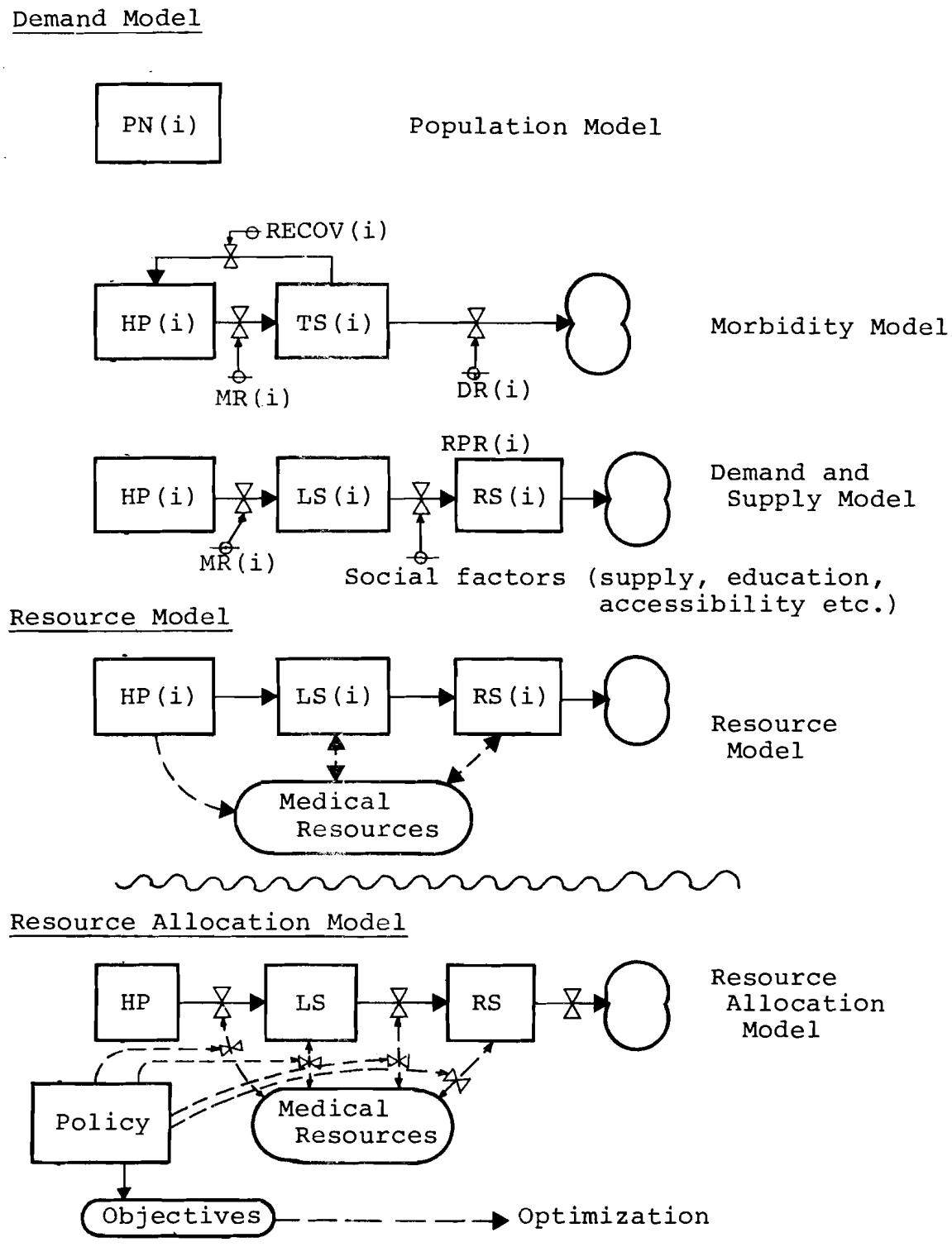

Figure 1. Submodels of health care.

Recovery Rate: RECOV(i): Persons who get illnesses may recover--in some cases after medical treatment and in others spontaneously. This summary rate may be defined as the recovery rate (RECOV).

Death Rate: DR(i): Persons who get illnesses may die even after medical treatment. This rate is defined as the death rate of patients (DR). Note that this rate is different from the ordinary death rate in health statistics (the number of persons who die per unit of time, divided by the total population): when there are more healthy persons, the ordinary death rate decreases. Accordingly, the ordinary death rate represents more the number of sick persons or the prevalence rate, whereas the death rate of patients reflects, in some part, the level of medical care. This will be discussed in the next sections.

Patient Registration Rate: RPR(i): As shown in Figure 1, the total sick can be divided into two groups--latent sick (LS) and actual registered patients (RS). Latent sick defines sick persons who have had no medical treatment. Those sick who treat themselves with some medicine without consulting a physician are also regarded as latent sick.

Awareness Rate: AR(i): The latent sick may be further divided into two groups--aware (AS) and unaware (UAS). Unaware sick are those who consider themselves healthy, although they actually have some illness. Aware sick are those who know they have some illness but, for some reason, are not under medical treatment.

This classification may be unnecessary in certain types of diseases (acute infections, surgical cases). However, in chronic diseases, such as diabetes mellitus or hypertension, it is well known that there are many latent sick who do not consider themselves sick. These people become aware of their illnesses only when they are medically educated. In some diseases this process is very important in estimating the number of patients. Therefore, in this model the rate between these two stages is defined as awareness rate (AR).

Secondary Factors that Influence the Primary Factors

The primary factors defined in the previous sections are susceptible to the effects of various secondary factors. Most of the latter are of a social or economic nature. One of the reasons for defining the primary factors is to clarify the relationship of secondary factors to health care. Through the concept of primary factors, these relations are more easily understood than by using ordinary health statistics. The factors influencing the primary factors are summarized in Table 1.

Table 1.

Factor	Related Secondary Factors
Population Structure	Birth rate; death rate; initial population structure; migration.
Morbidity Rate	Environment; preventive medicine; nutrition.
Recovery Rate	Level of clinical medicine; level of health care; progress of medical science.
Death Rate	Same as above.
Patient Registration Rate	Accessibility to physicians, medical supply; economic state.
Awareness Rate	Education in medicine; standard of living; health screening.

Population structure is influenced by birth, death, or migration rates. Birth rates are influenced by population policy as well as by the population structure itself. Death rates are influenced by health care. Therefore, it is easy to see that there are some feedback loops between population structure and other factors.

Morbidity rate is influenced by environmental factors and preventive medicine. Pollution or urbanization effects must be analyzed in relation to morbidity rates. In some types of diseases, this morbidity is inherent to human beings; most diseases related to the aging process belong in this category.

Recovery rate is dependent on the level of clinical medicine and health care. Although there is an inherent recovery rate in diseases, in some diseases this recovery rate is strongly affected by the level of clinical medicine. This is also related to the patient registration rate: if it is high, the recovery rate will also be high.

Death rate is a counterpart of recovery rate. Persons who do not recover will eventually die. Clearly, therefore, death rate is affected by the same factors as recovery rate.

Patient registration rate is a function of accessibility of physicians. There are two components of accessibility: physical and economic. Since patients cannot visit physicians when there are no medical facilities, or when medical facilities are too far away, it is obvious that the registration rate is related to the number of physicians and the number of hospitals--that is, to medical supply. Sick people cannot be registered as patients if they cannot pay for the medical care. Recent insurance schemes reflect these economic factors. The effect of different policies of medical insurance must be analyzed in relation to the patient registration rate.

Awareness is related to education or the standard of living. When a campaign against cancer is presented on a television program, more people become aware of the minor signs of early cancer and visit clinics. Screening of diseases also have an effect.

In some diseases in which the awareness factor* is regarded as 1.0, these effects must be analyzed in relation to the patient registration factor.

Submodels of Health Care

As shown in the above discussion, the health care system is a complicated system related to various social and economic

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*The awareness factor is defined in [1].

factors. The building of a model that includes all these factors may be too complicated; hence it is necessary to divide the health care system into several submodels (Figure 1). We therefore divided the health care model into five models. (These submodels are almost identical to those mentioned in [4], but for the sake of clarification of the following discussion, we define them here.)

Demand Model: The demand submodel comprises three models. The first, the *population model*, estimates the number of persons classified by age and sex in the projection of future years. This type of population model has been fully investigated by researchers of population phenomena. In this study, the model developed by Keyfitz and Flieger [3] was used for the estimation of the population.

The second, the *morbidity model*, analyzes the factors related to the incidence of diseases. Since these are not single, the factors must be analyzed and a model built according to different types of diseases. In the study, the diseases were classified into four groups [5] mentioned in many papers. This classification will be discussed in detail later.

In the *demand-supply model* (or resource utilization model), the process related to transferring latent sick to registered patients is analyzed. In some diseases, the factors related to awareness rate must be analyzed. Most of these factors are social or economic. Medical supply is another important factor related to this process.

Resource Model: Health care resources will be analyzed in relation to various other social or economic factors. The main variables are the number of health care personnel and hospital beds. The factors related to the distribution of the resources must be analyzed.

Resource Allocation Model: At this level of model development, the problem of HCS resource distribution will be analyzed according to population composition and geographic and perhaps other peculiarities, taking into account different objectives of health care management.

All these submodels are necessary as components of the health care system. As the first step toward building such models, we describe the modelling of the morbidity of degenerative diseases.

MORBIDITY MODEL OF DEGENERATIVE DISEASES

Classification of Diseases

There are various kinds of diseases whose origins have different characteristics. In the morbidity model, diseases must be classified according to the nature of their cause. This type of classification may be different from ordinary classifications such as the International Classification of Diseases (ICD). These are based on the pathology of the diseases and used for diagnostic purposes, while the classification in this study is required for health planning. However, the correlation between the two systems must be clearly defined. We used the classification of diseases proposed by one of the authors of this study, with some modifications [5].

Degenerative diseases are inherent to human beings, as they are due to the aging process. In these diseases, the morbidity rate usually increases with age. In this study, three groups of diseases are defined as degenerative:

- Cardiovascular diseases (ICD A80 - A88);
- Malignant neoplasms (ICD A45 - A60);
- Senile deaths and deaths from unknown causes (ICD A136 - A137).

We included senile deaths and deaths from unknown causes because in some countries, especially in developing countries, death in old age is classified as a senile death when the cause is unknown.

The second type of disease is *infectious disease*. They are of external origin, and can therefore be prevented by removing the cause. It is also possible to recover completely from such diseases. The morbidity and recovery rates are generally influenced by the level of preventive and therapeutic medicine. There are two types of infectious diseases--gastrointestinal and respiratory. In the model, these two will be treated separately.

The third type of disease is also of external origin, but the cause is *the progress of civilization*. Since technology cannot be compared to microorganisms, this type of disease must be differentiated from infectious disease. Diseases due to labor accidents, to pollutants, to urbanization are examples. These diseases will increase with the progress of civilization unless countermeasures are taken.

Malnutrition is the cause of the fourth type of disease, which is often related to infant deaths. Since infant mortality reflects different factors of adult diseases, this will be analyzed in this category in the study.

According to the classification mentioned above, four morbidity models that interact with each other will be developed. However, in this report, only the morbidity model of degenerative diseases will be discussed. Other models will be discussed in a separate report.

Assumptions in the Degenerative Disease Model

In the morbidity model of degenerative diseases, the following assumptions were introduced about the nature of degenerative diseases.

- The morbidity rate, MR(i), of the degenerative disease depends only upon the age (i).
- Sick people suffering from degenerative diseases never recover; this means that the recovery rate, RECOV (i), of degenerative diseases is equal to zero.
- Persons who became ill will die after a certain definite time. The mean of the time, defined as duration of illness (T), is dependent only on the type of disease.

We have no definite proofs for these three assumptions; however, for the following reasons we believe that they can safely be made.

The first assumption is naturally understood from the definition of degenerative disease. But the diseases classified as degenerative, namely cardiovascular and malignant, have to be shown to have this characteristic. It is not possible to measure the morbidity rate directly in any disease at present. Since the onset of the illness is not known, the morbidity rate can be estimated only from the death rate.

Figures 2a and 2b show the death rates from cardiovascular and malignant diseases in various countries, obtained from the statistics of the World Health Organization [7]. One of the characteristics these figures show is that, although the total death rates differ widely by country, the death rates of each age group coincide well. This is especially true in developed countries. The figures for age-dependent death rates in developing countries are somewhat lower than those for developed countries; but if the deaths from unknown causes are included, the figures approach those of developed countries. On the basis of this fact, and also in relation to the third assumption, we took the morbidity rate to be dependent only on age. The morbidity rates used in this model are presented in Figure 3. The method of estimating the rates will be discussed later.

The second assumption was based on medical considerations. It is believed that degenerative diseases are progressive diseases from which the patient never recovers. Some types of

malignant diseases can now be successfully treated by surgical procedures. However, in the total number of deaths from malignant disease, these cases are exceptional and in this study were treated as negligible. If in the future degenerative diseases can be successfully treated, this assumption may be removed.

Since the onset of illness is not known, the duration of sickness (T) also cannot be measured directly. However, the nature of degenerative diseases gave rise to the third assumption. If effective treatment of these diseases is introduced, the duration time (T) will also increase.

The duration times used in the calculation are 2 years for malignant diseases and 15 years for cardiovascular diseases. The basis of the estimates will be discussed later.

Structure of the Degenerative Disease Model

The structure of the morbidity model of degenerative diseases is illustrated in Figure 4. As is shown in the definition of the morbidity model, the population of each age group is divided into two groups: healthy persons, HP(i), and sick persons TS(i). The sick include latent patients. The transfer rate from the healthy to the sick stage is defined as the morbidity rate, MR(i), and that from the sick stage to death as the death rate, DR(i). The death rate per total population in the age group is referred to as DRPN(i). The recovery rate, RECOV(i), is 0 according to the assumption, and the morbidity rates are given in each age group. We also assumed that the persons who become ill will die after a certain time. With this structure, the only input required for the model is the number of population in each age group; if that is given, all other variables can be calculated from equations (1) to (3):

$$TS(i) = \sum_{j=i-T}^{j=i-1} HP(j) \cdot MR(j) \quad , \tag{1}$$

$$HP(i) = PN(i) - TS(i) \quad , \tag{2}$$

$$DRPN(i) = \frac{HP(i-T) \cdot MR(i-T)}{PN(i)} \quad . \tag{3}$$

In the first several age groups, since the morbidity rate is 0, HP(i) is given by equation (4):

$$HP(i) = PN(i) \quad . \tag{4}$$

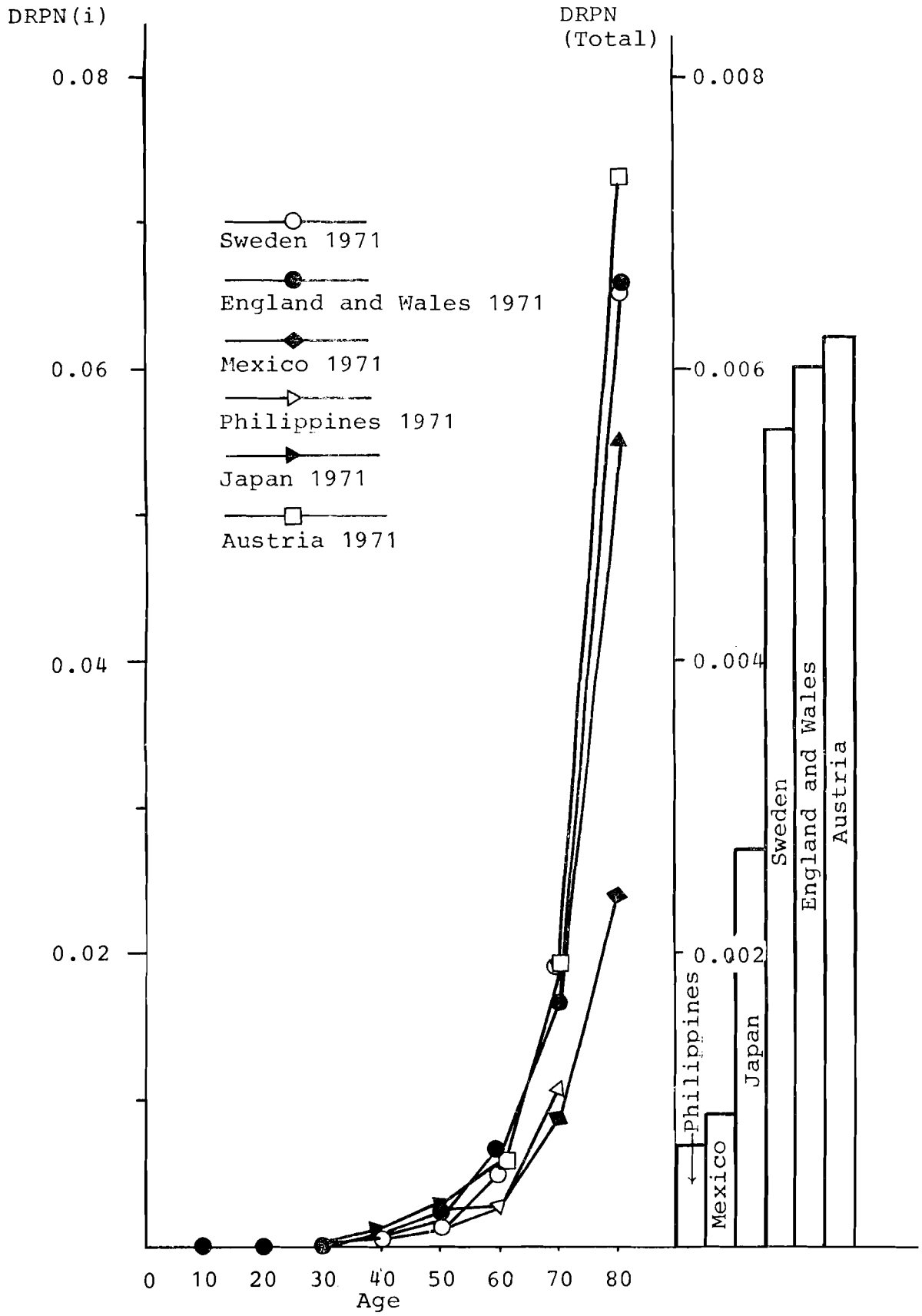

Figure 2a. The death rate, DRPN(i), of cardiovascular disease.

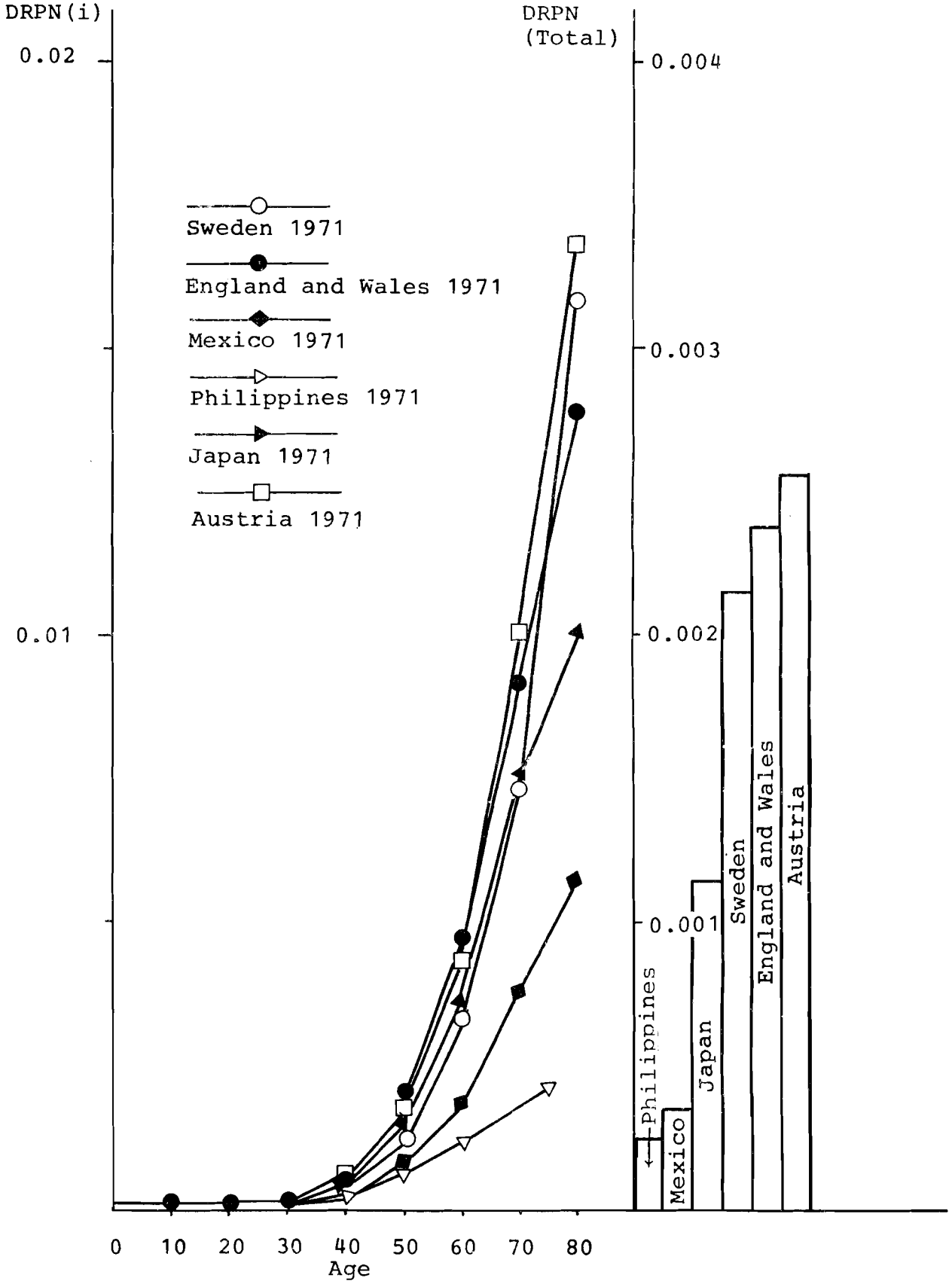

Figure 2b. The death rate, DRPN(i), of malignant neoplasms.

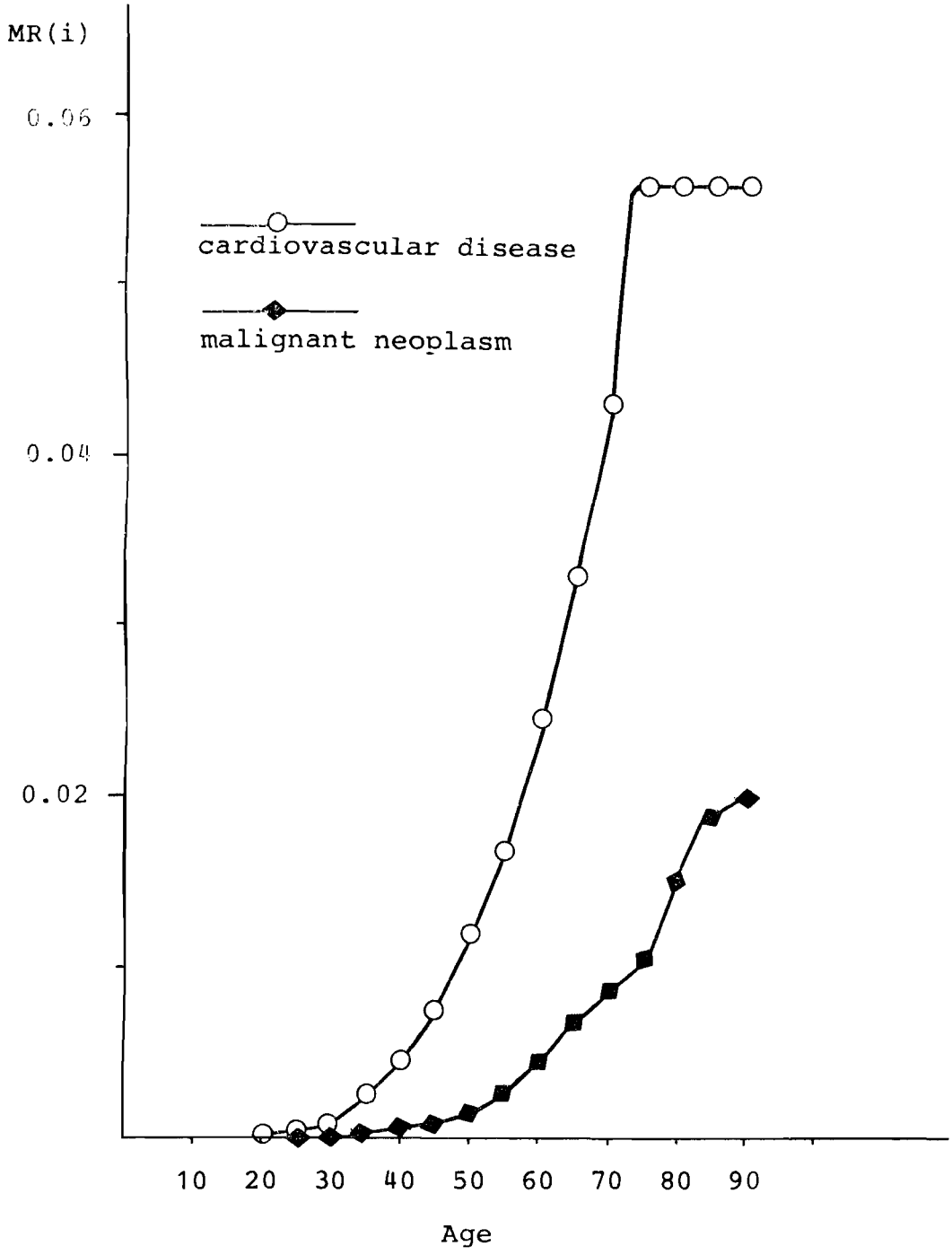

Figure 3. Morbidity rate specified for age and sex.

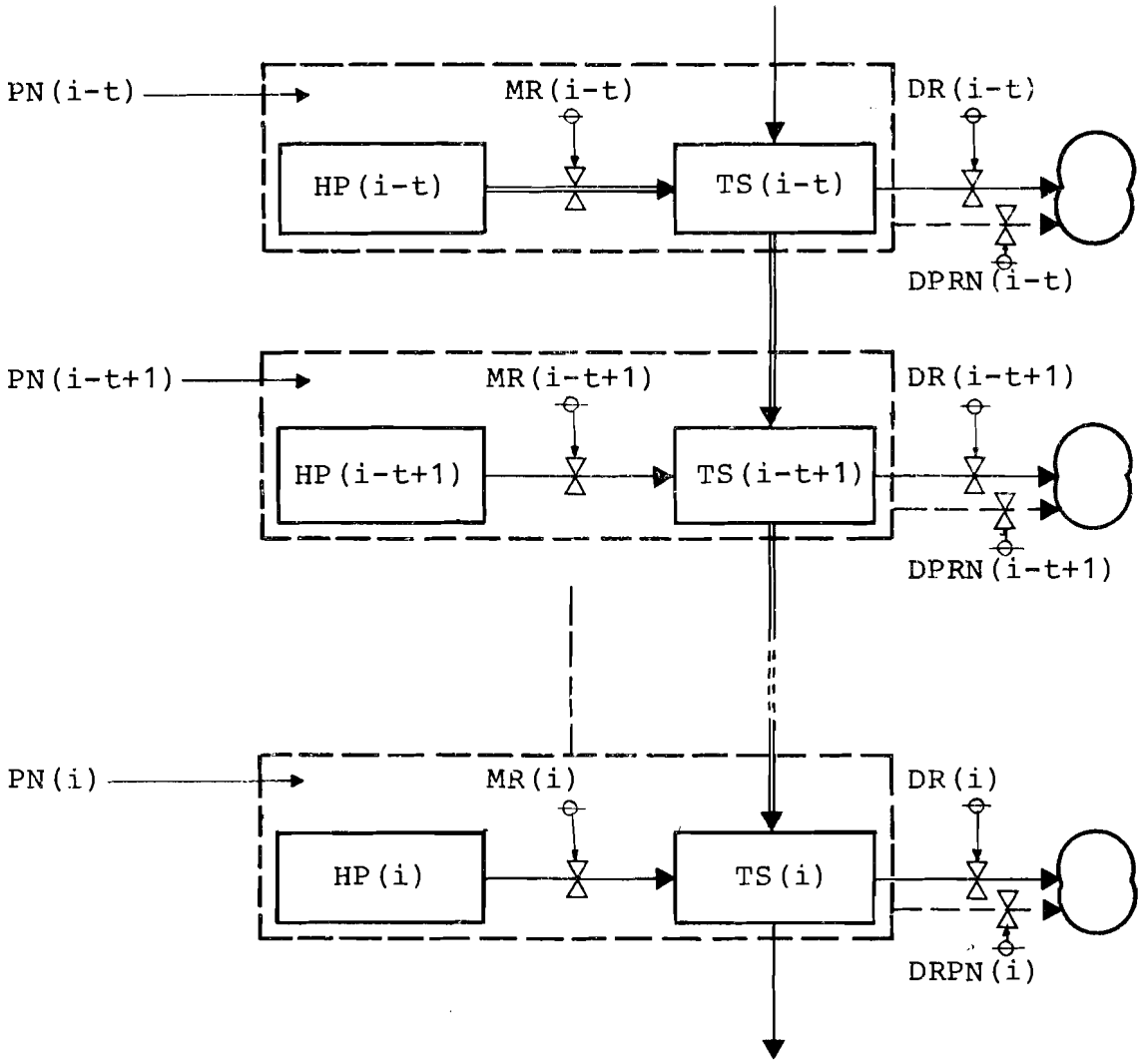

Figure 4. Structure of the degenerative disease model.

Accordingly, equations (1) to (3) can be calculated successively from the younger to the older age groups only if the population structures are given.

In these equations, it was assumed that the population structure is stable for the duration of sickness (T), and that the duration of the sickness is the same for each person. These assumptions are not necessary if more sophisticated calculations are used (cf. [6]).

Estimation of Morbidity Rate and Duration of Sickness

So far, we have assumed that the morbidity rates and duration of sickness are given. In this section, the method we used to estimate the figures is discussed.

If death rates per population DRPN(i) are given, the morbidity rates can be obtained from equation (5) by procedures similar to those described in the previous section:

$$MR(i) = \frac{DRPN(i+T) \cdot PN(i+T)}{HP(i)} \quad . \tag{5}$$

Here it is necessary to assume that the population structure is stable for the duration of the sickness. In developed countries, fairly reliable statistics of death rates, DRPN(i), can be obtained. Accordingly, if the duration of sickness (T) is determined, these morbidity rates can be calculated.

In this study, the duration of sickness was determined as follows. We first considered the number of sick persons, TS(i), calculated if a certain duration of sickness is given. It is difficult to know the real number of sick persons, because it must include the latent patients. However, from the data of some health screenings, we assumed a number of sick persons 1.5 to 2 times the number of reported cases in developed countries. In some countries, the number of cases of degenerative diseases in each age group are reported; these were compared with the results of calculations to estimate the duration of sickness. We also considered the experience in clinical medicine, where 2 years for malignant diseases and 15 years for cardiovascular diseases are taken as reasonable.

The morbidity rates and duration of sickness used in this model are based mainly on the data of Austria. We chose Austria because the population structure is stable and the number of senile deaths or deaths of unknown causes is very small. Thus the statistics were considered reliable.

Results of Calculations

To test the validity of the model, we applied it to various countries, using the data of the Philippines, Mexico, Japan, England and Sweden. In the calculation, a population structure of five-year intervals was used as initial data. It was then further divided into one-year intervals, and the variables for outputs were calculated separately for cardiovasular and malignant diseases. The results for the two diseases were then combined to obtain an estimation of prevalence for the degenerative diseases. The death rates thus obtained were compared with the figures from WHO statistics [7]. Figure 5a gives a comparison of total death rates in the countries tested, and Figure 5b shows the death rates in each age group. We think that the agreement is in a reasonable range.

Some of the results drawn by the CALCOMP 565 terminal are shown in Figures 6 to 13. Three countries with characteristic population structures were taken as examples (Figures 6 - 8).

Application of the Morbidity Model of Degenerative Diseases

The model described in this study is the morbidity model of the degenerative diseases only. Although it covers only a small part of the diseases, some interesting results can already be obtained.

The first application area will be an international or regional comparison of the death rates for, or number of patients with, degenerative diseases. In addition to the death rates estimated the model also gives the total number of sick persons with degenerative diseases. If statistics for patients with degenerative diseases are available, it is of interest to compare them with the results obtained from the model. A difference between the two figures would imply the presence of latent patients who have the possibility of seeking medical care. Analysis of the factors causing this difference will be important; and this will be the subject of the next study, namely, the resource utilization model.

The second application of the model is the projection to the future of trends in the degenerative diseases. Various methods have been developed to estimate the future population structure (population model). If the population and morbidity models are combined, the future trends in degenerative diseases are easily calculated, since the morbidity model is dependent only on the age structure of the population.

Figures 14a-c and 15a-c are examples of the calculations. Here the computer programs described by Keyfitz et al. [3] are used for calculating the future population structure.

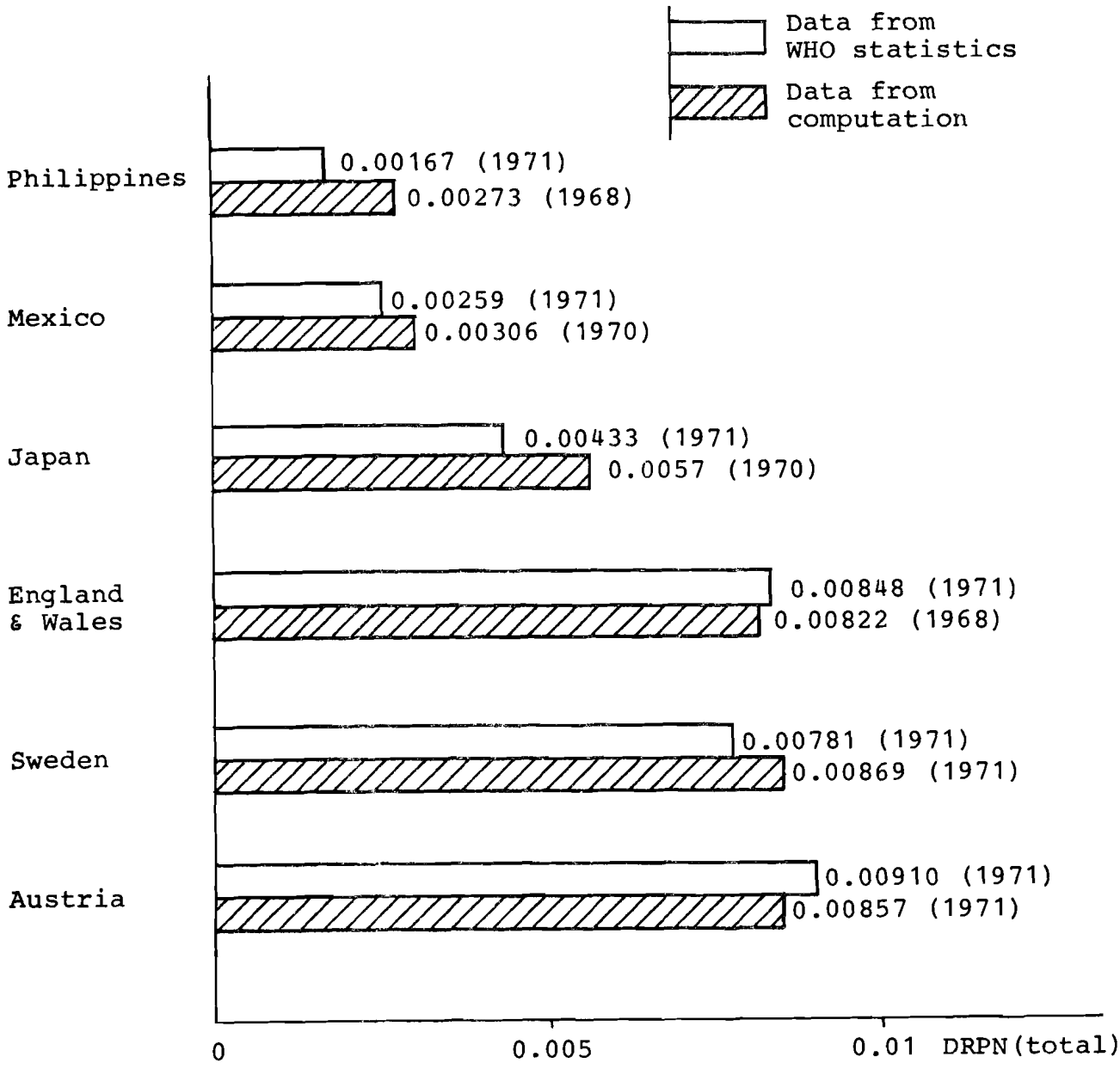

Figure 5a. Comparison of death rates, DRPN(total), from WHO statistics and from computations.

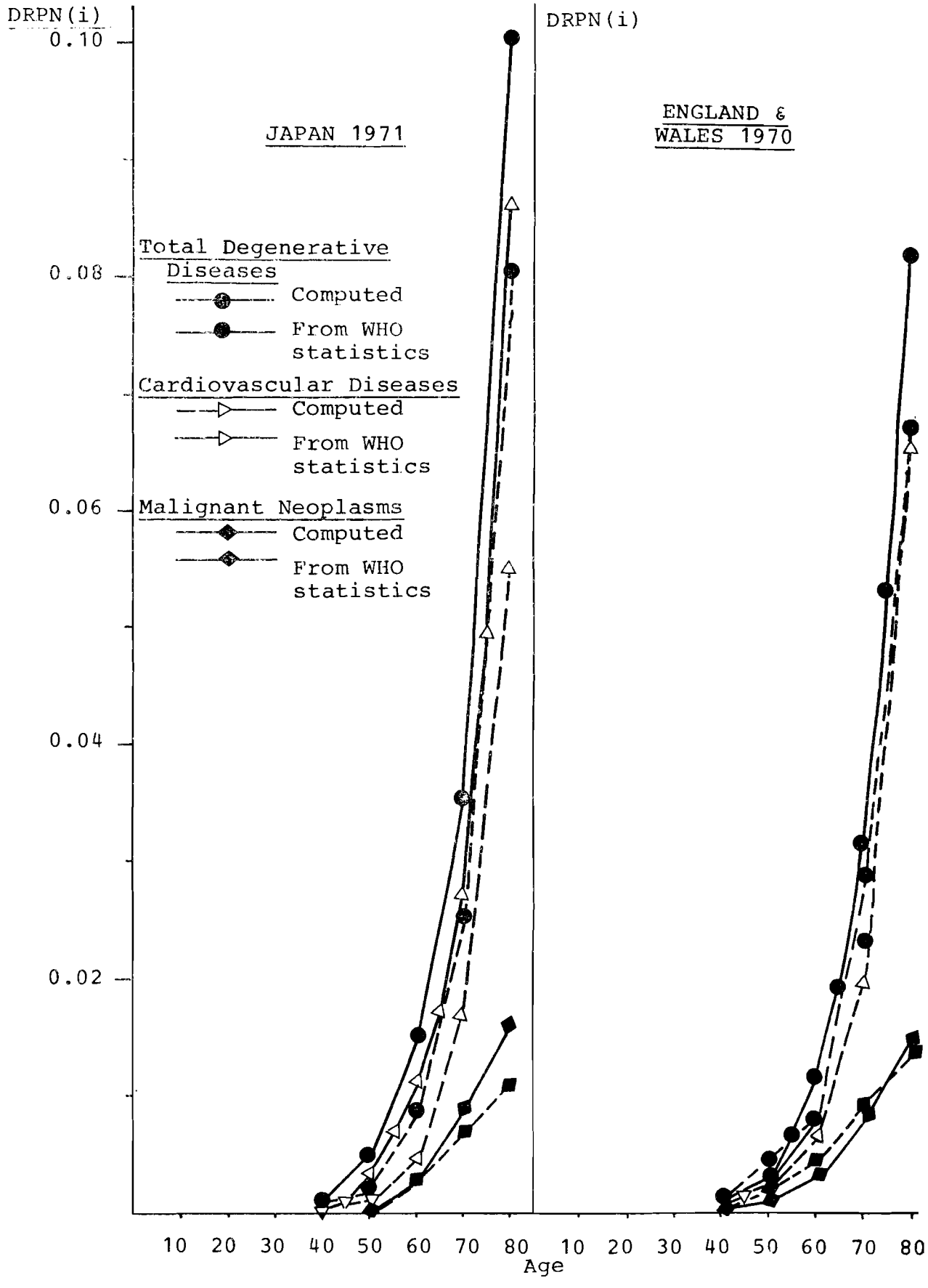

Figure 5b. Comparison of WHO statistics and results of computations.

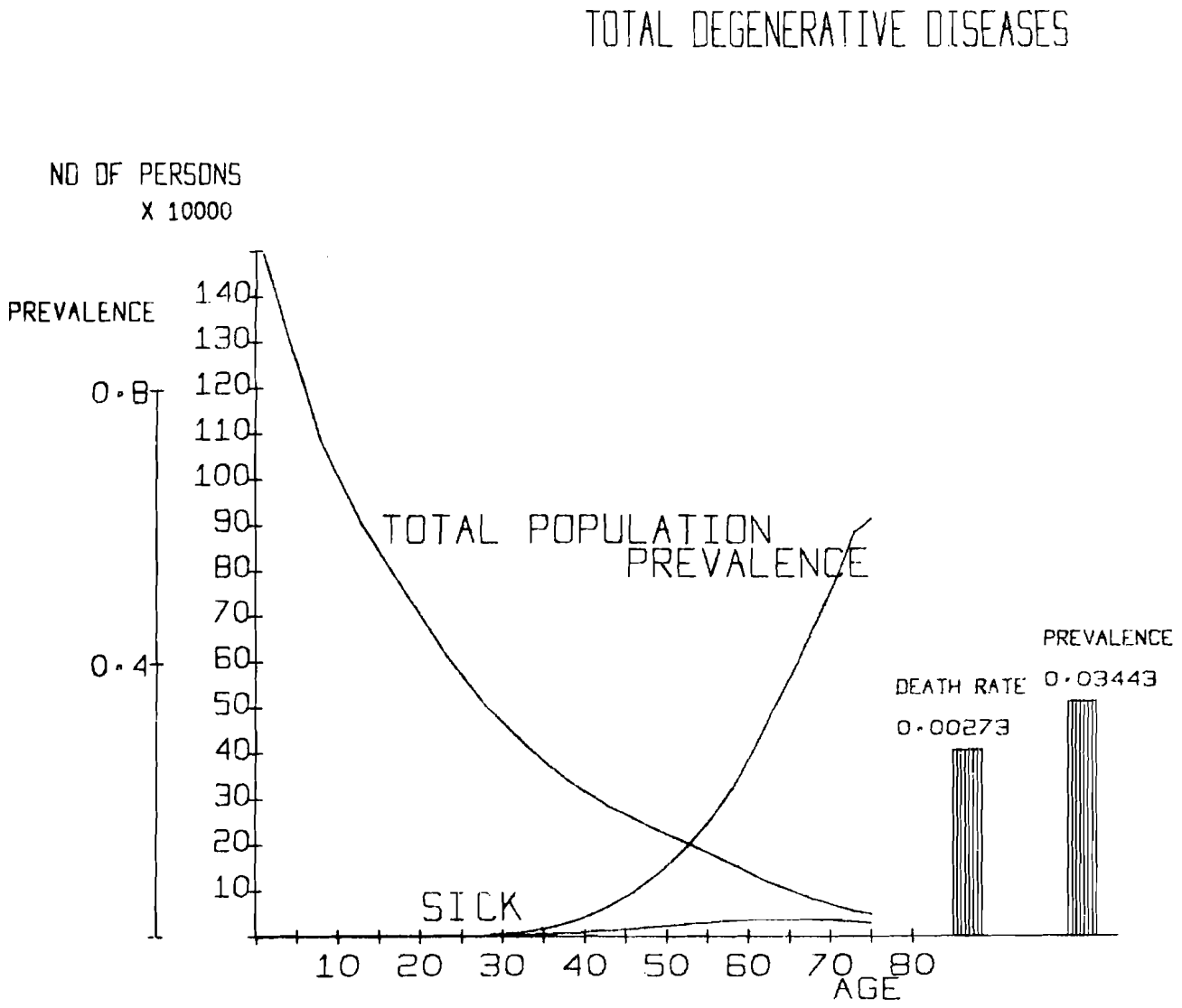

Figure 6a. Number of sick, prevalence and death rates of degenerative diseases (Philippines, 1968): result of Calculation 1.

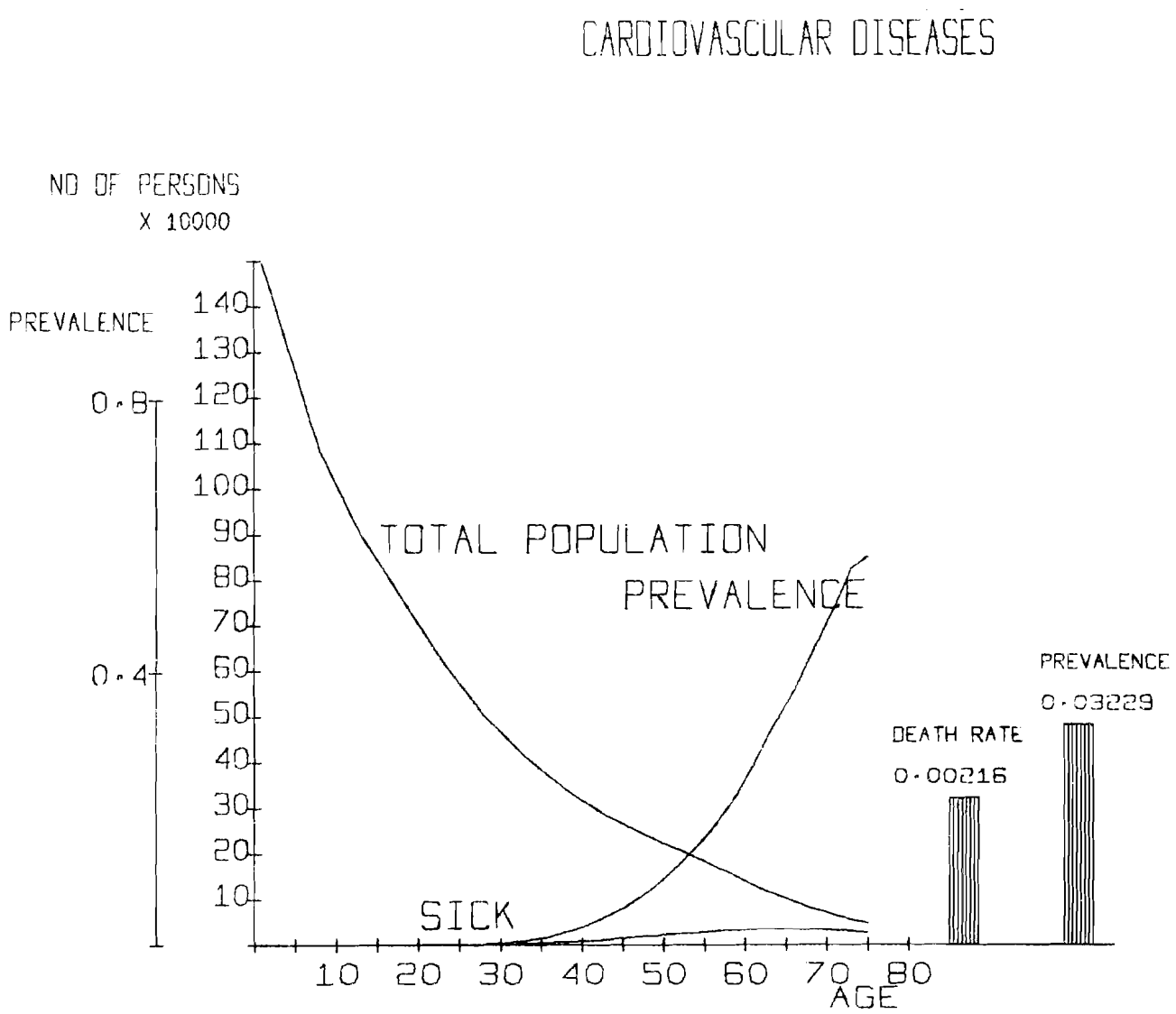

Figure 6b. Number of sick, prevalence and death rates of degenerative diseases (Philippines, 1968): result of Calculation 1.

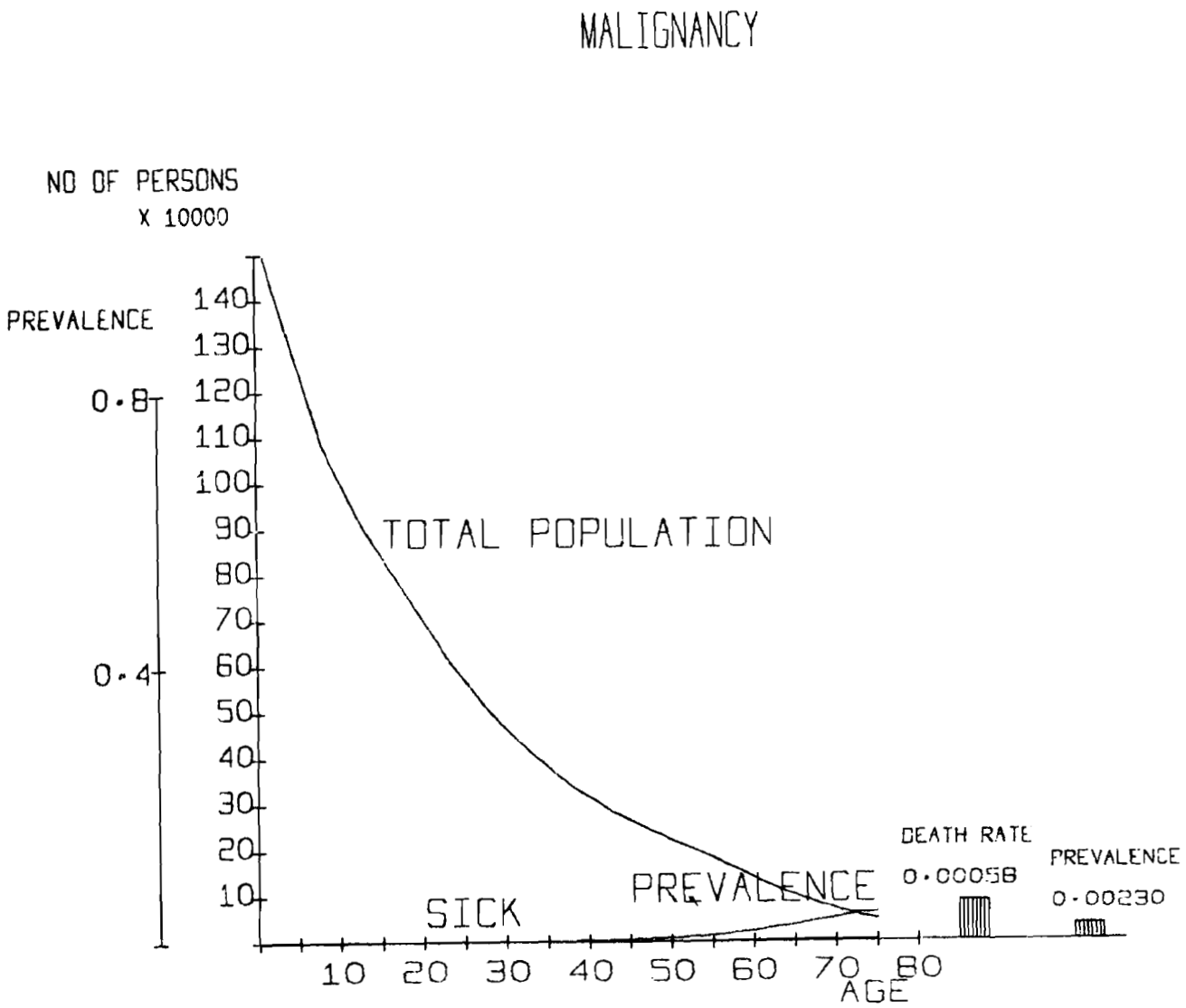

Figure 6c. Number of sick, prevalence and death rates of degenerative diseases (Philippines, 1968): result of Calculation 1.

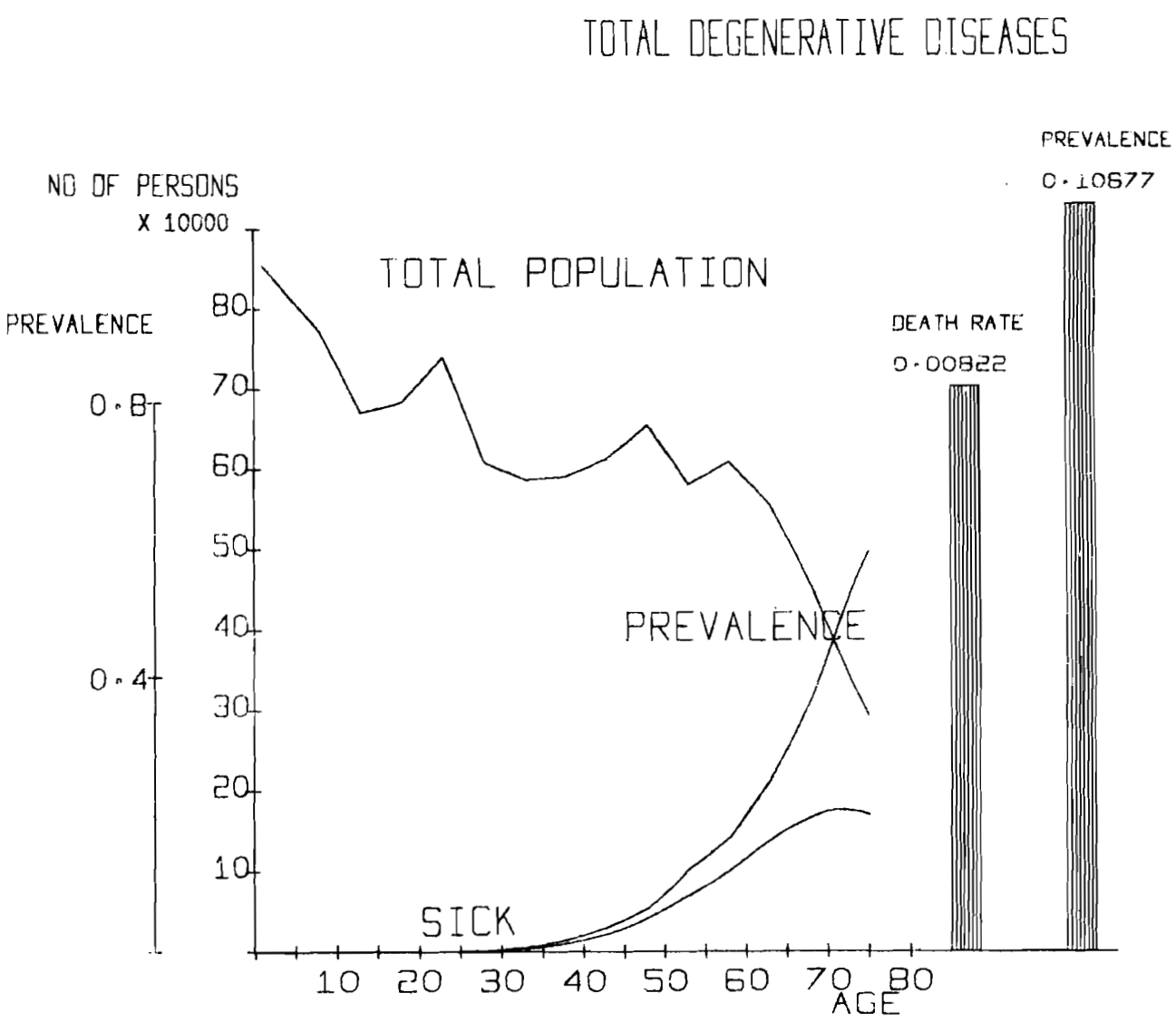

Figure 7a. Number of sick, prevalence and death rates of degenerative diseases (England and Wales, 1968): result of Calculation 2.

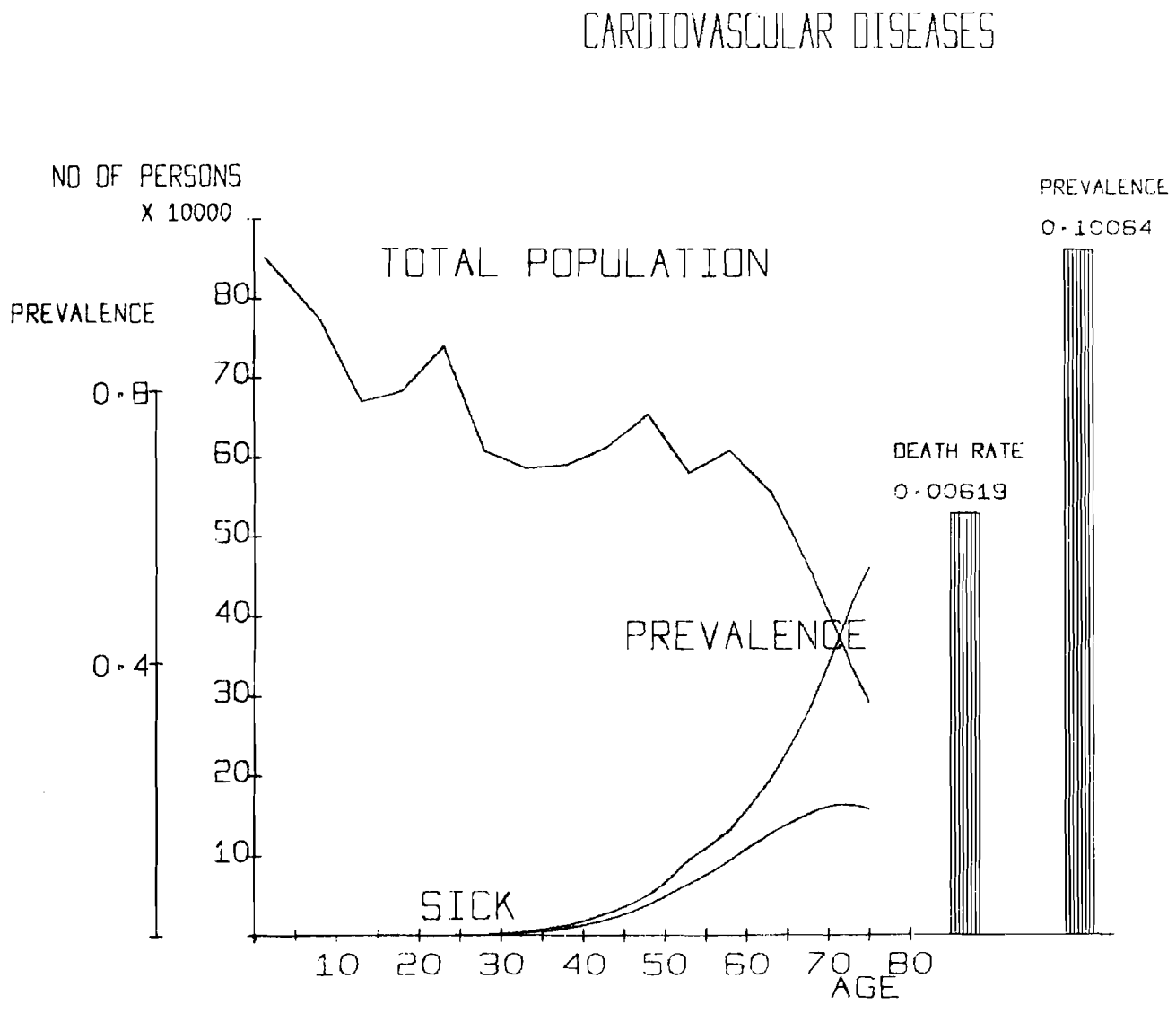

Figure 7b. Number of sick, prevalence and death rates of degenerative diseases (England and Wales, 1968): result of Calculation 2.

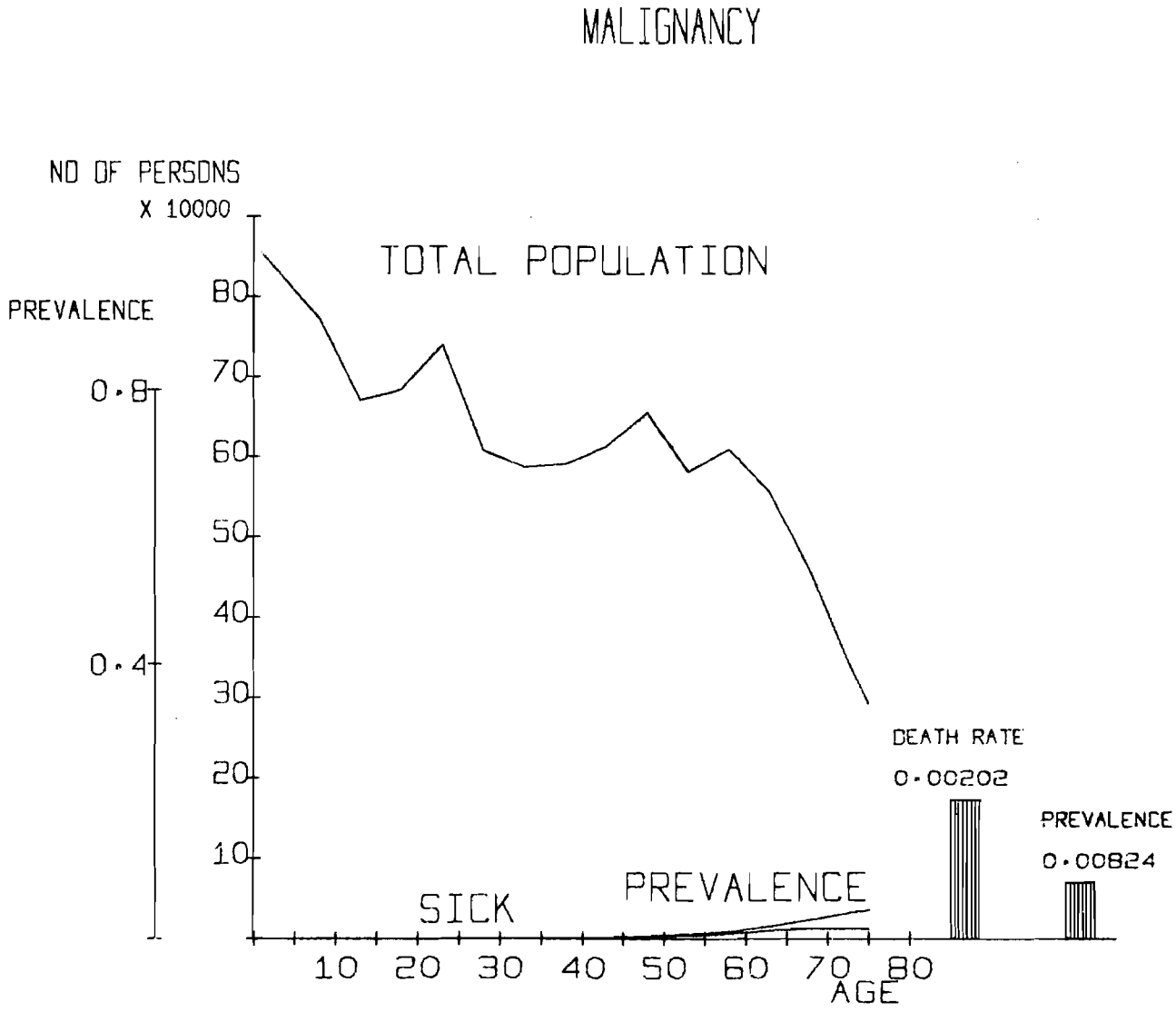

Figure 7c. Number of sick, prevalence and death rates of degenerative diseases (England and Wales, 1968): result of Calculation 2.

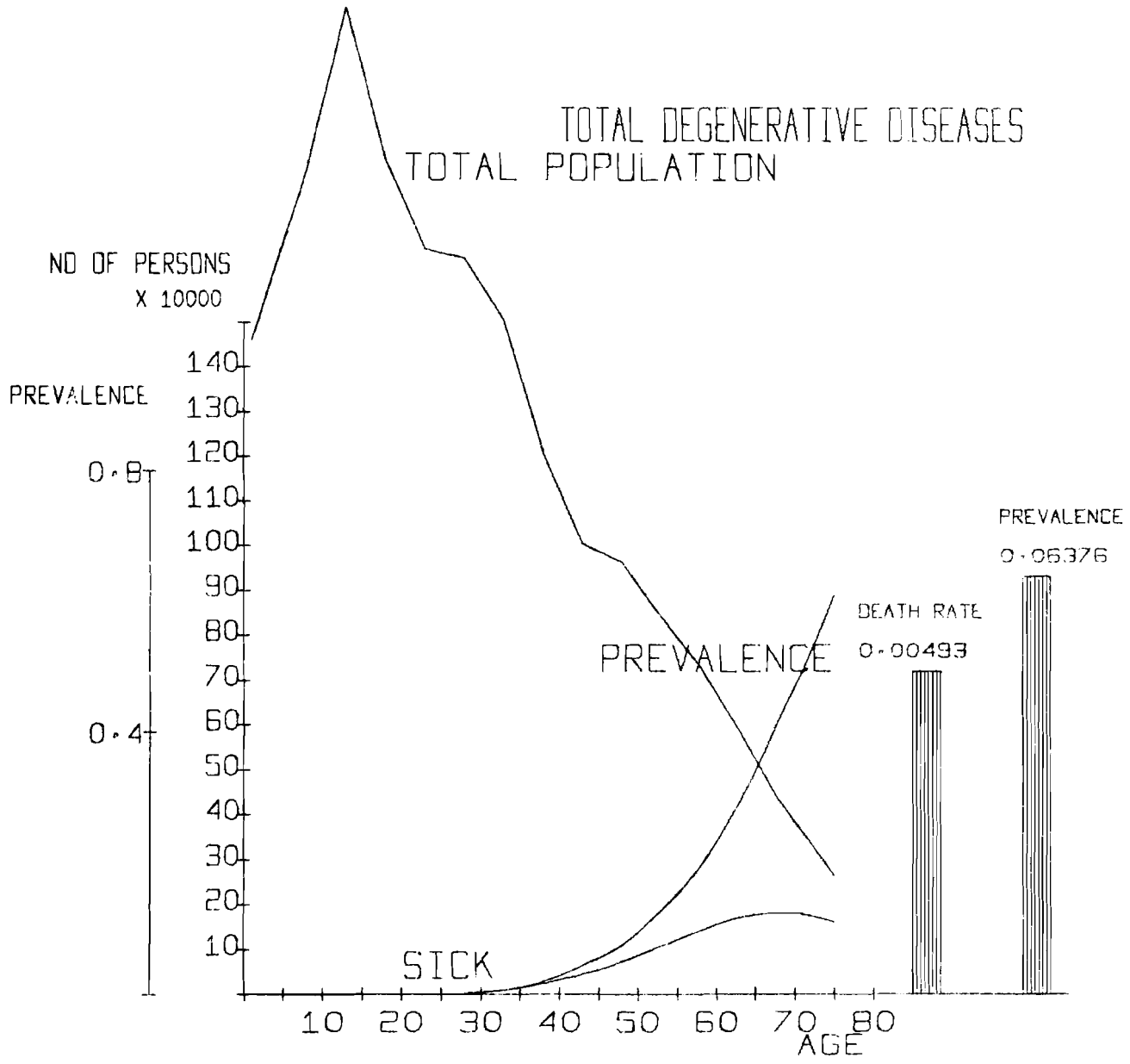

Figure 8a. Number of sick, prevalence and death rates of degenerative diseases (Japan, 1960): result of Calculation 3.

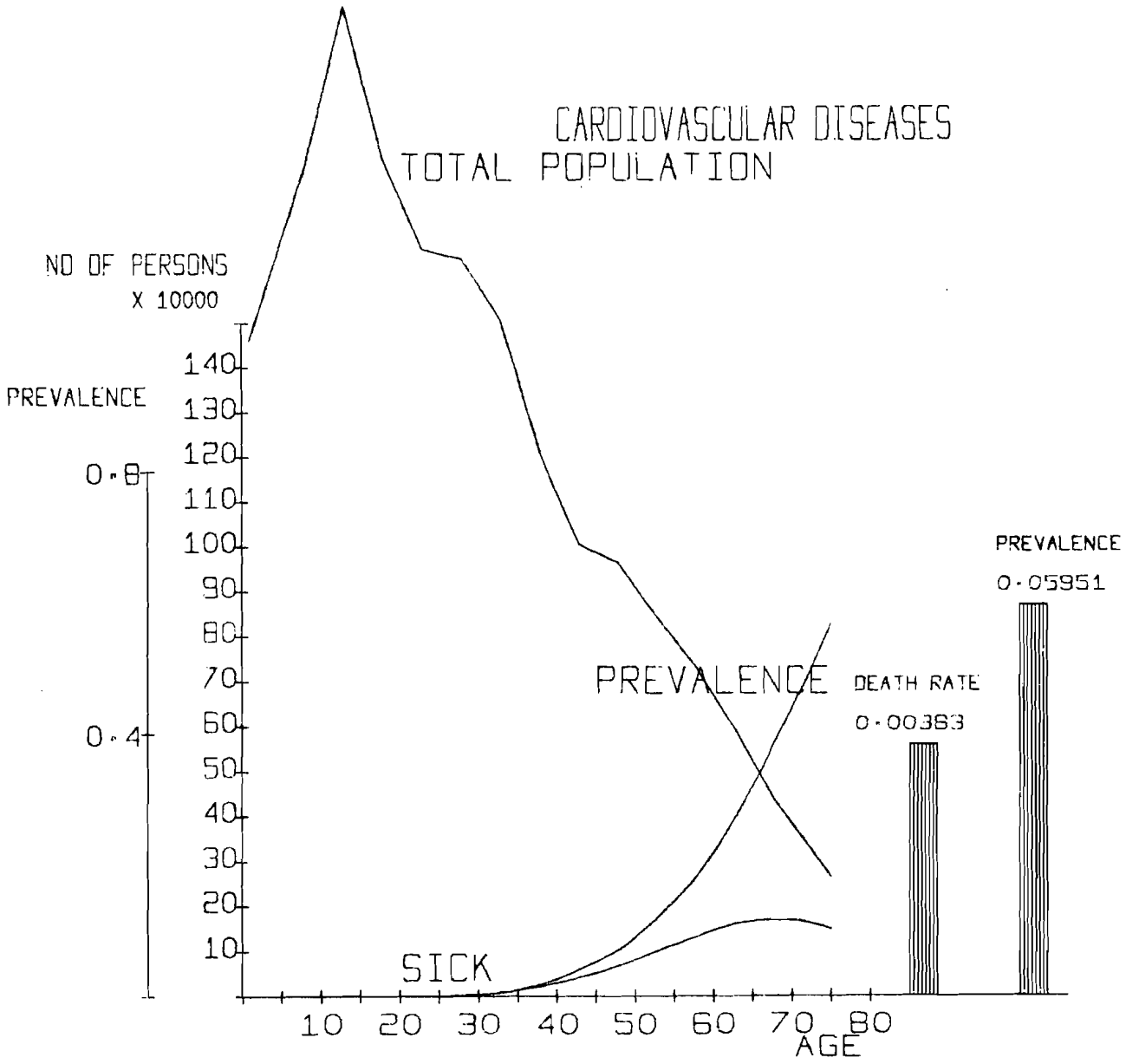

Figure 8b. Number of sick, prevalence and death rates of degenerative diseases (Japan, 1960): result of Calculation 3.

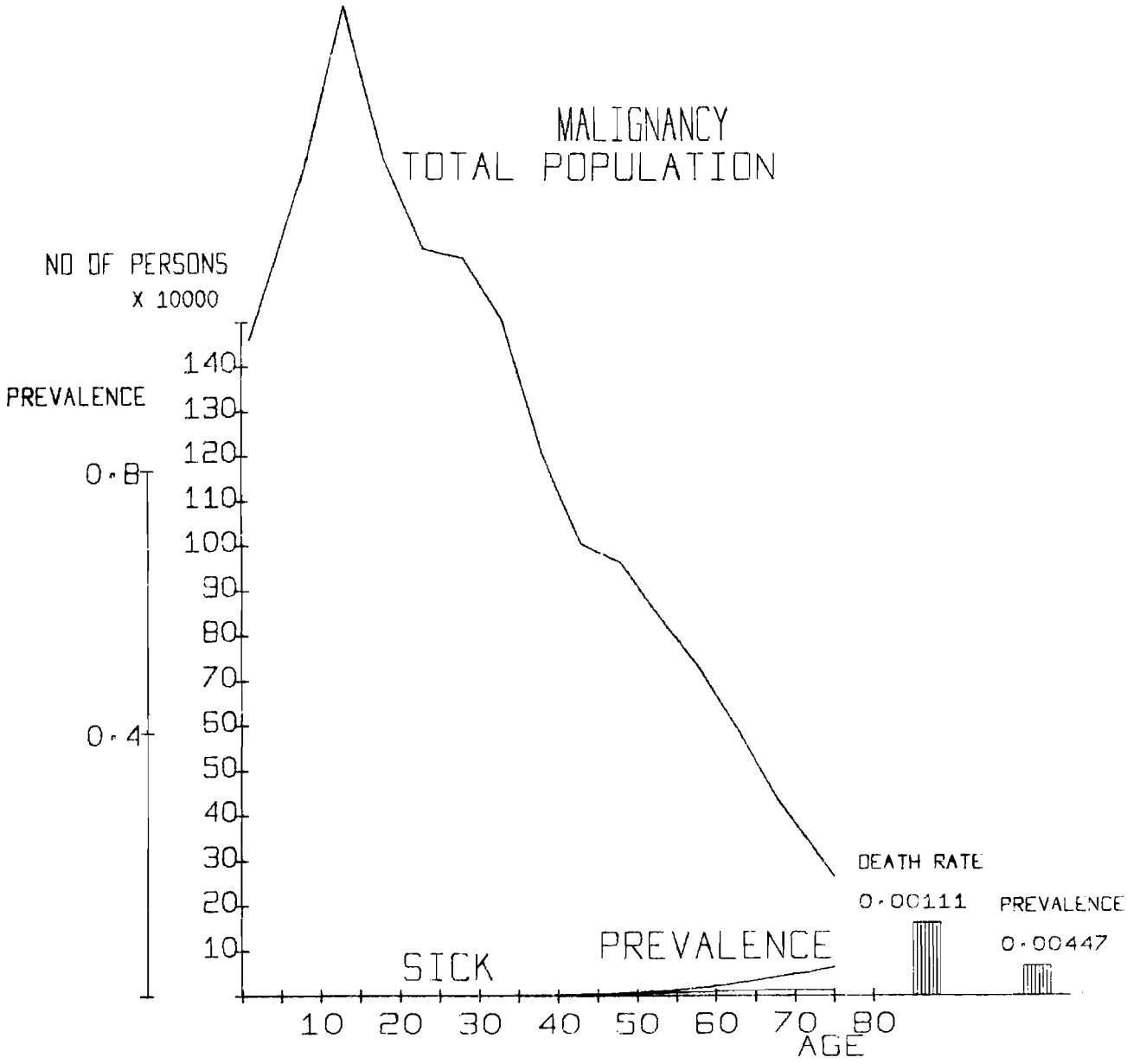

Figure 8c. Number of sick, prevalence and death rates of degenerative diseases (Japan, 1960): result of Calculation 3.

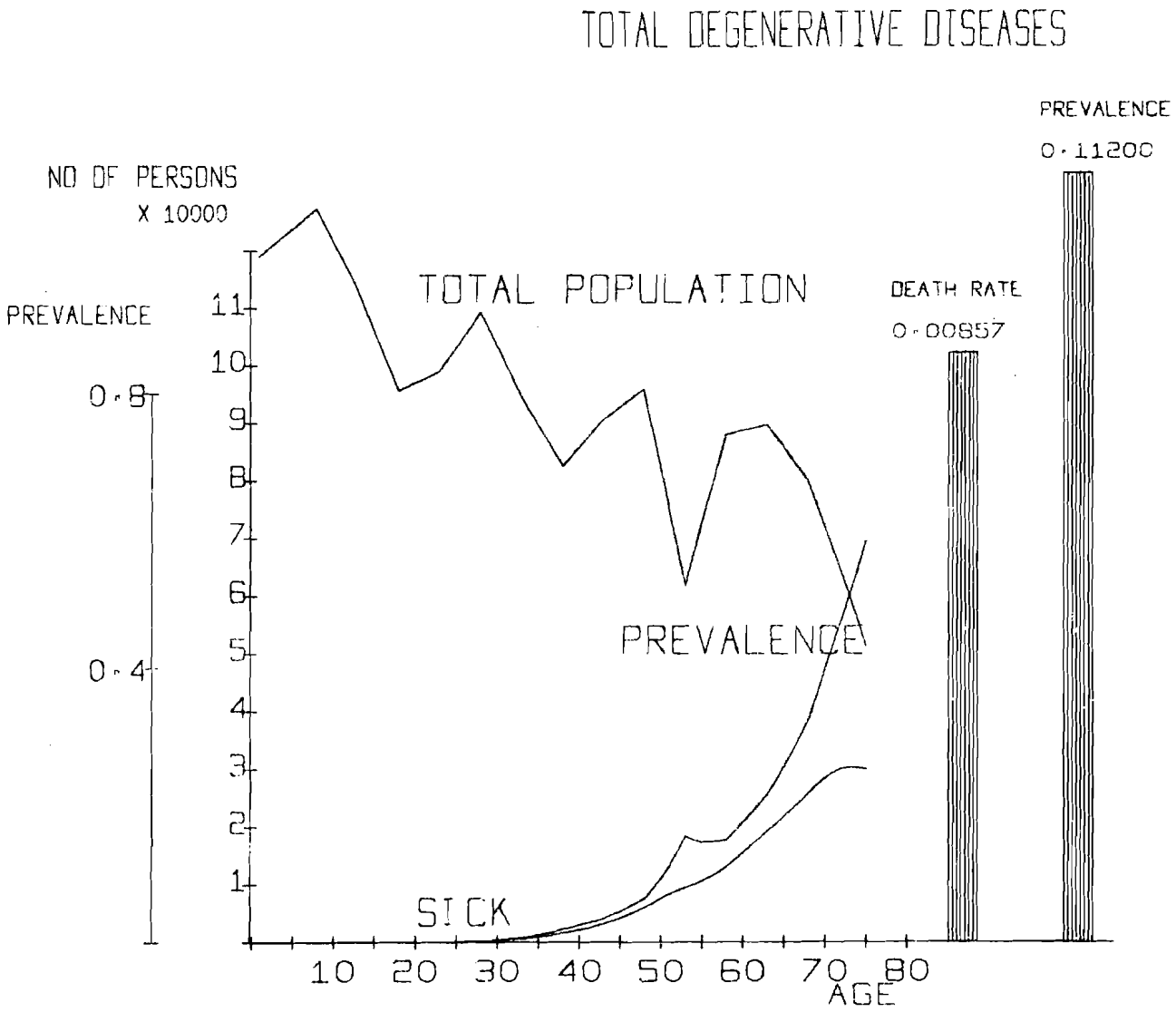

Figure 9. Total degenerative diseases: Austria, 1971.

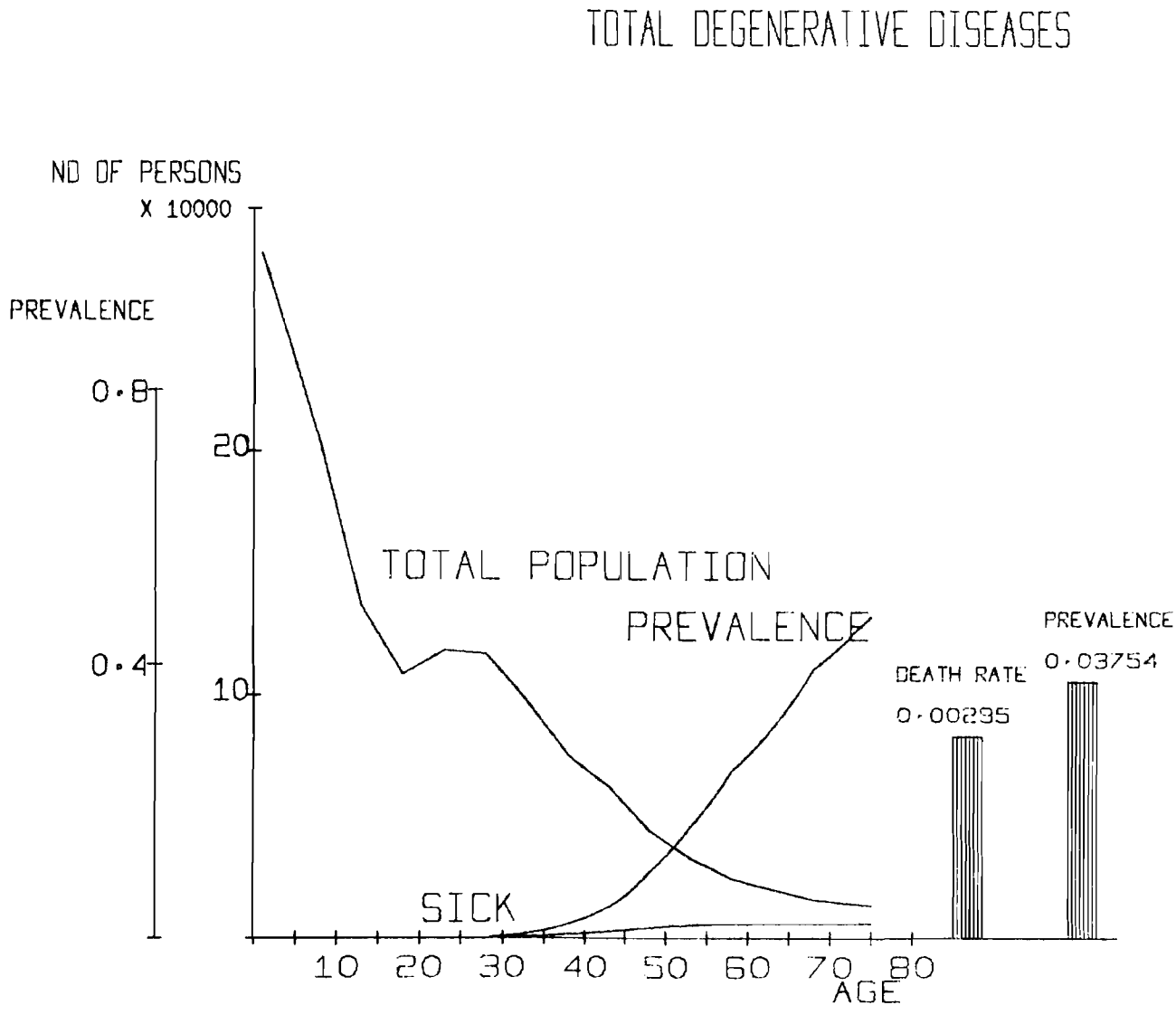

Figure 10. Total degenerative diseases: Ghana, 1960.

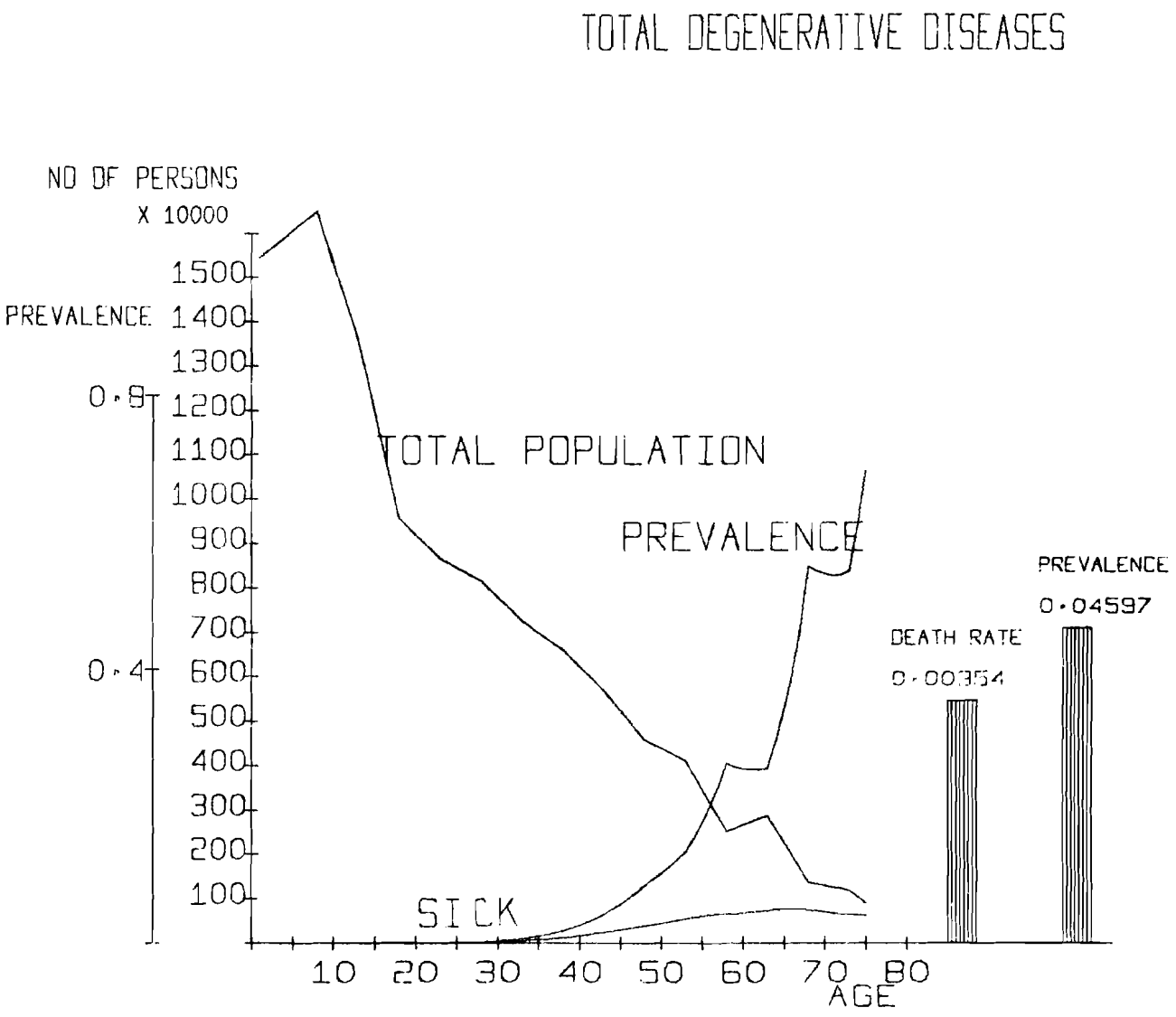

Figure 11. Total degenerative diseases: India, 1971.

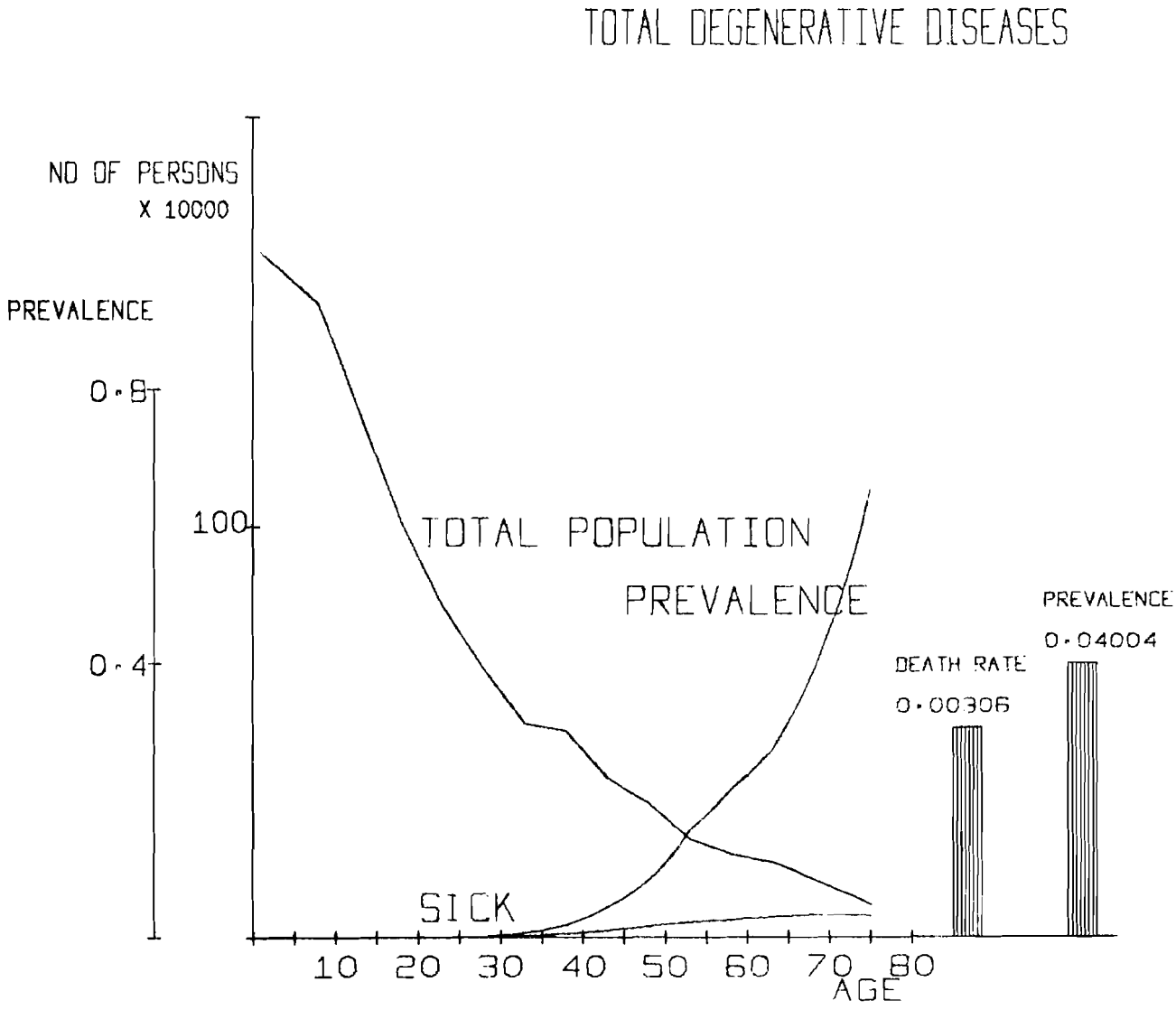

Figure 12. Total degenerative diseases: Mexico, 1970.

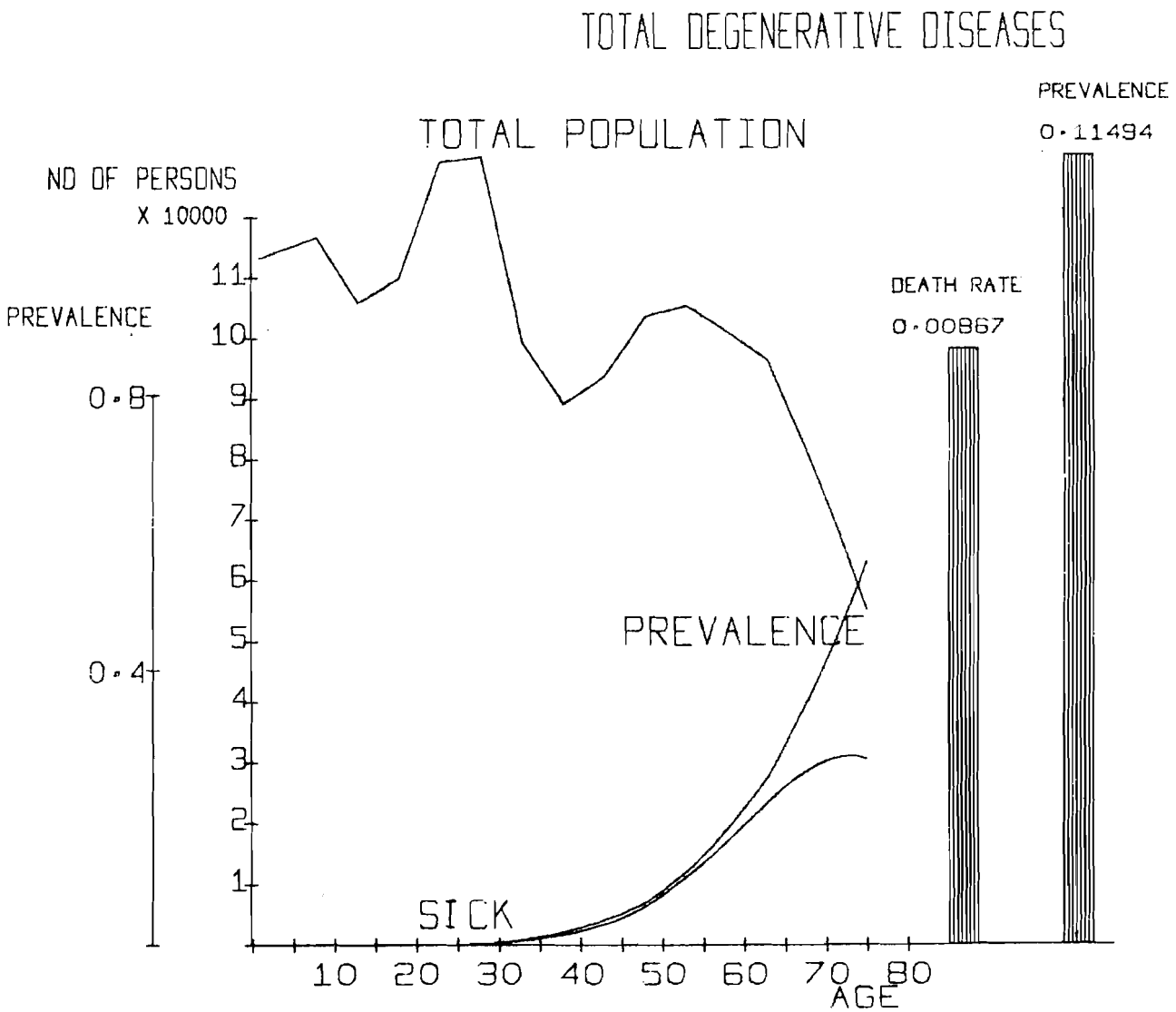

Figure 13. Total degenerative diseases: Sweden, 1971.

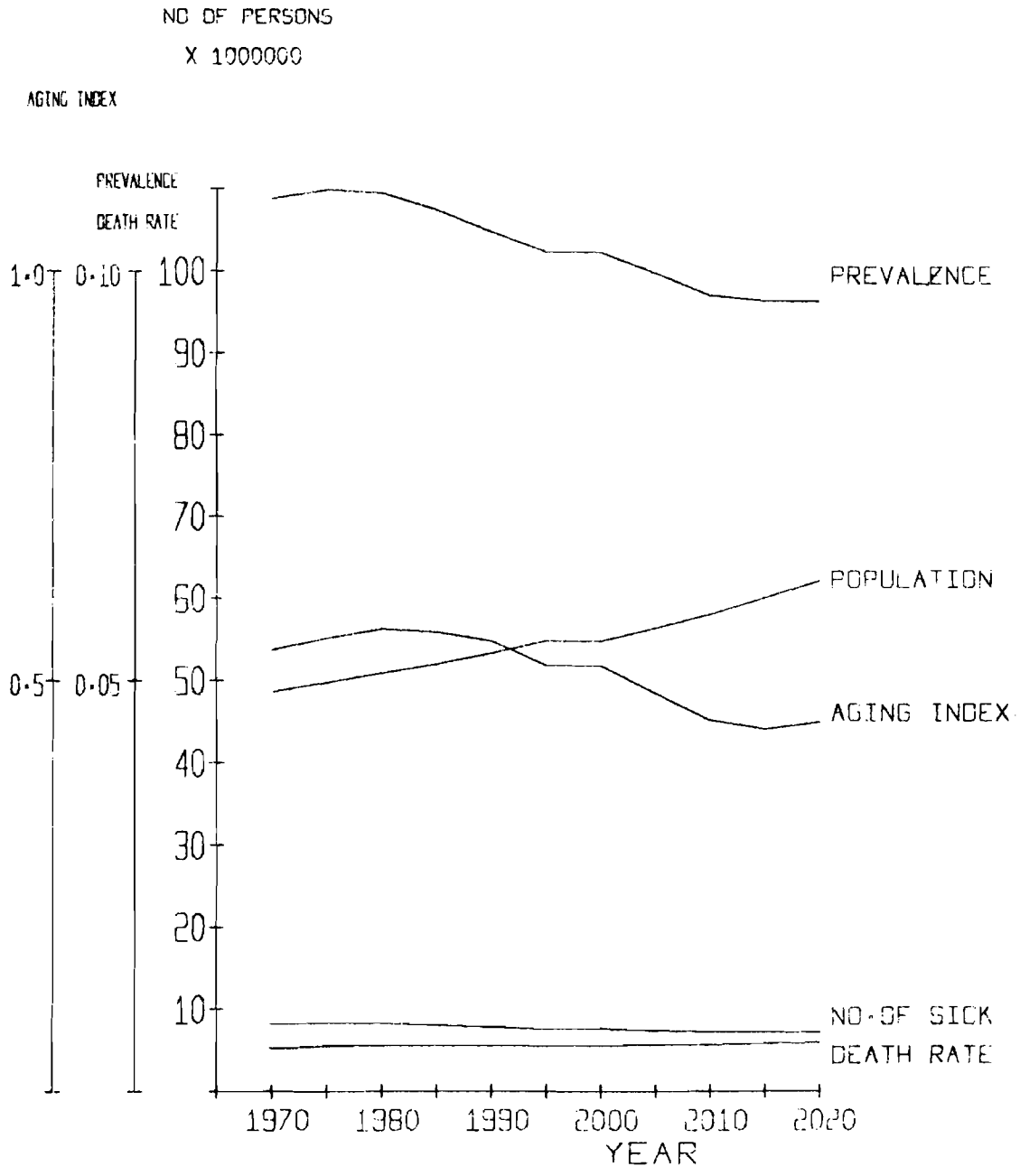

Figure 14a. Estimation of future trend in total degenerative diseases: England and Wales.

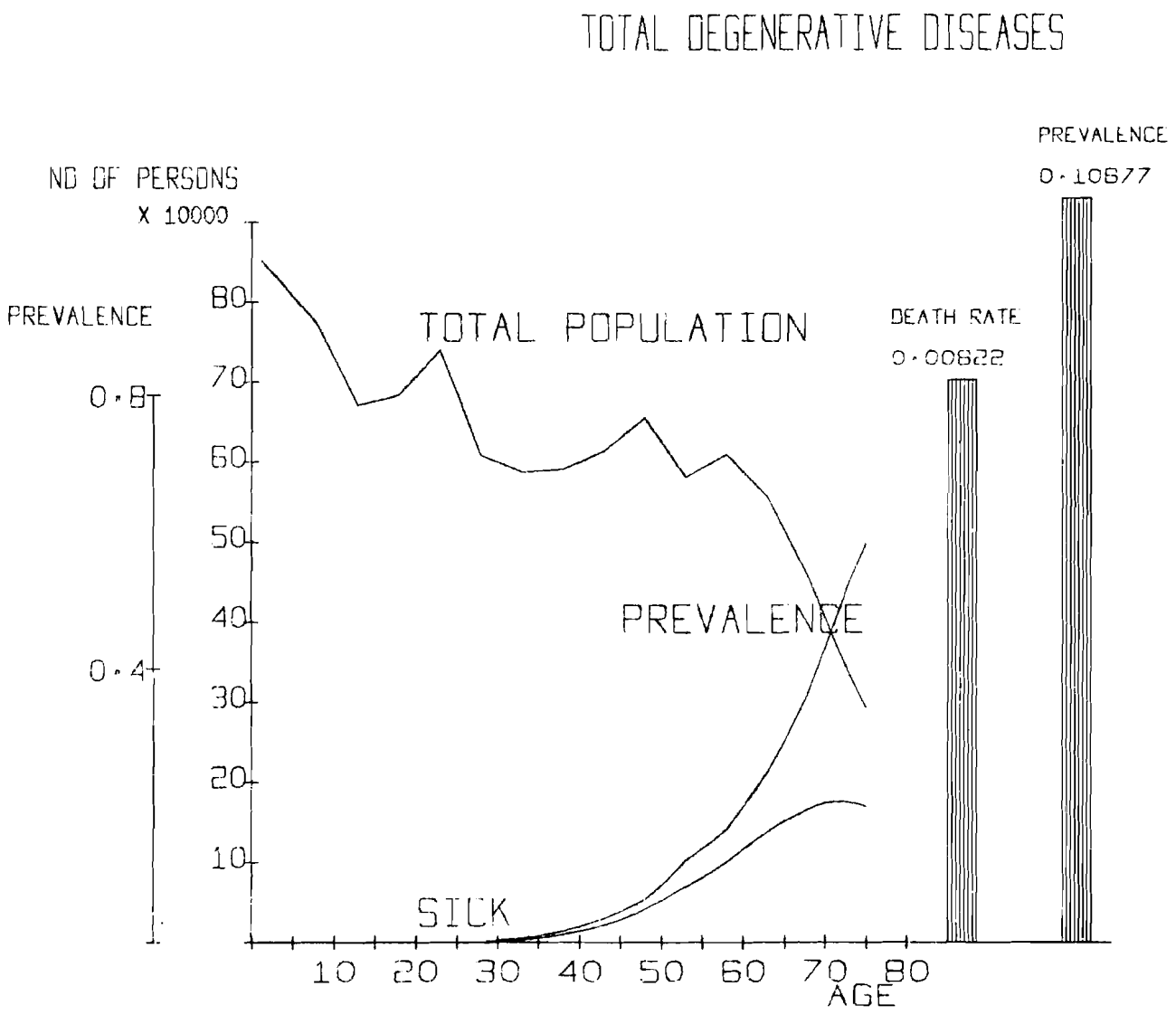

Figure 14b. Estimation of future trend in total degenerative diseases: England and Wales.

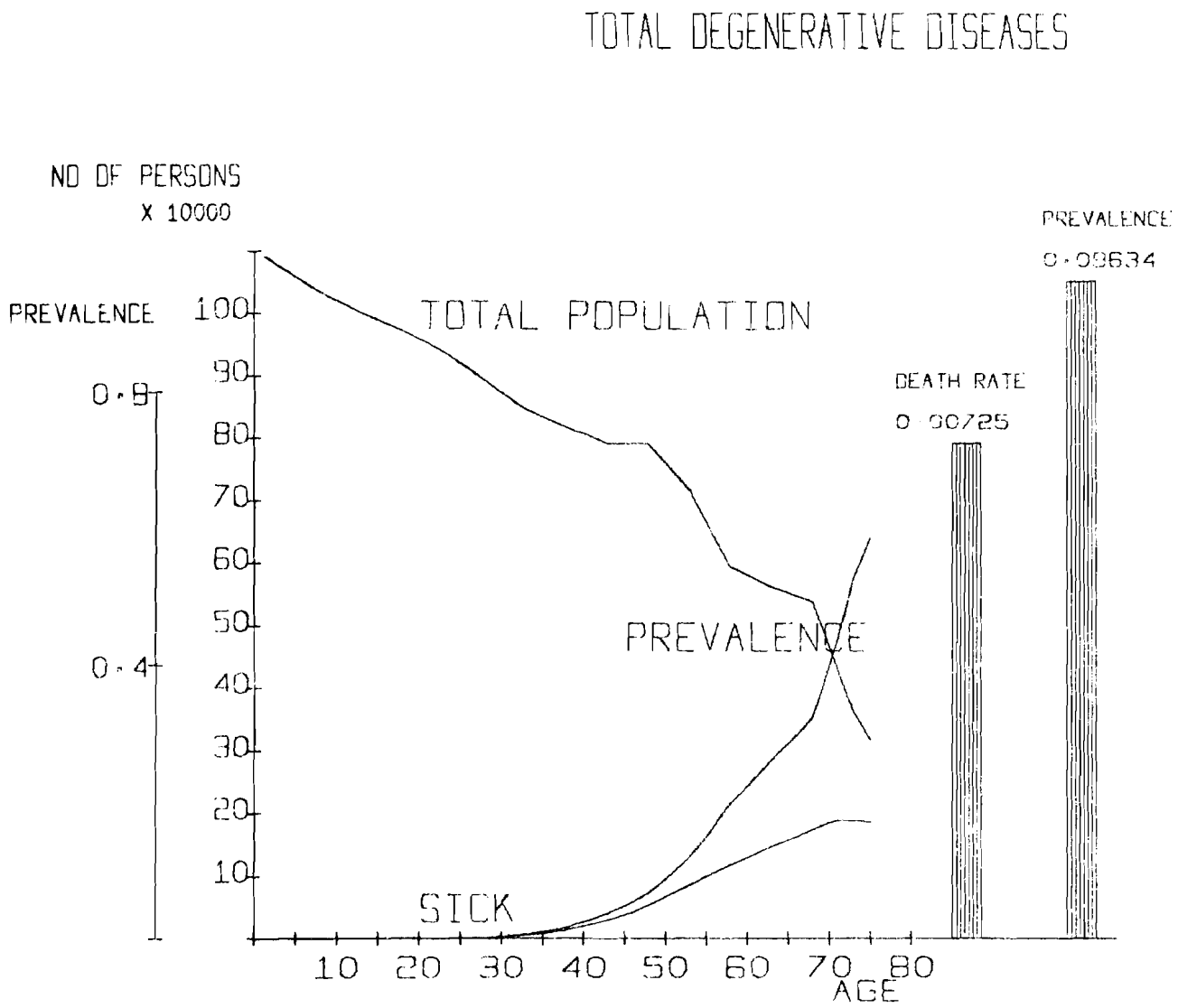

Figure 14c. Estimation of future trend in total degenerative diseases: England and Wales.

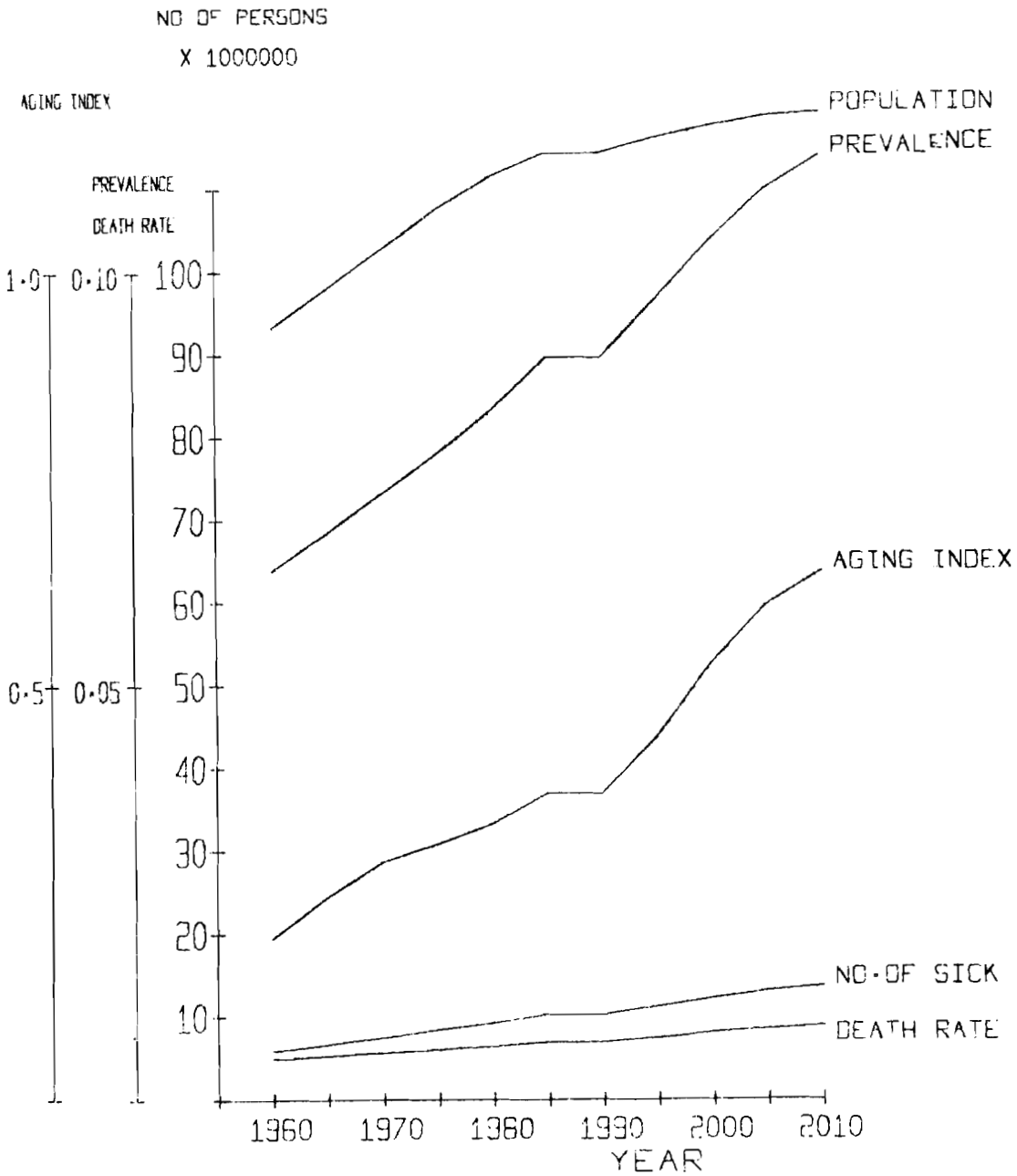

Figure 15a. Estimation of future trend in degenerative diseases: Japan.

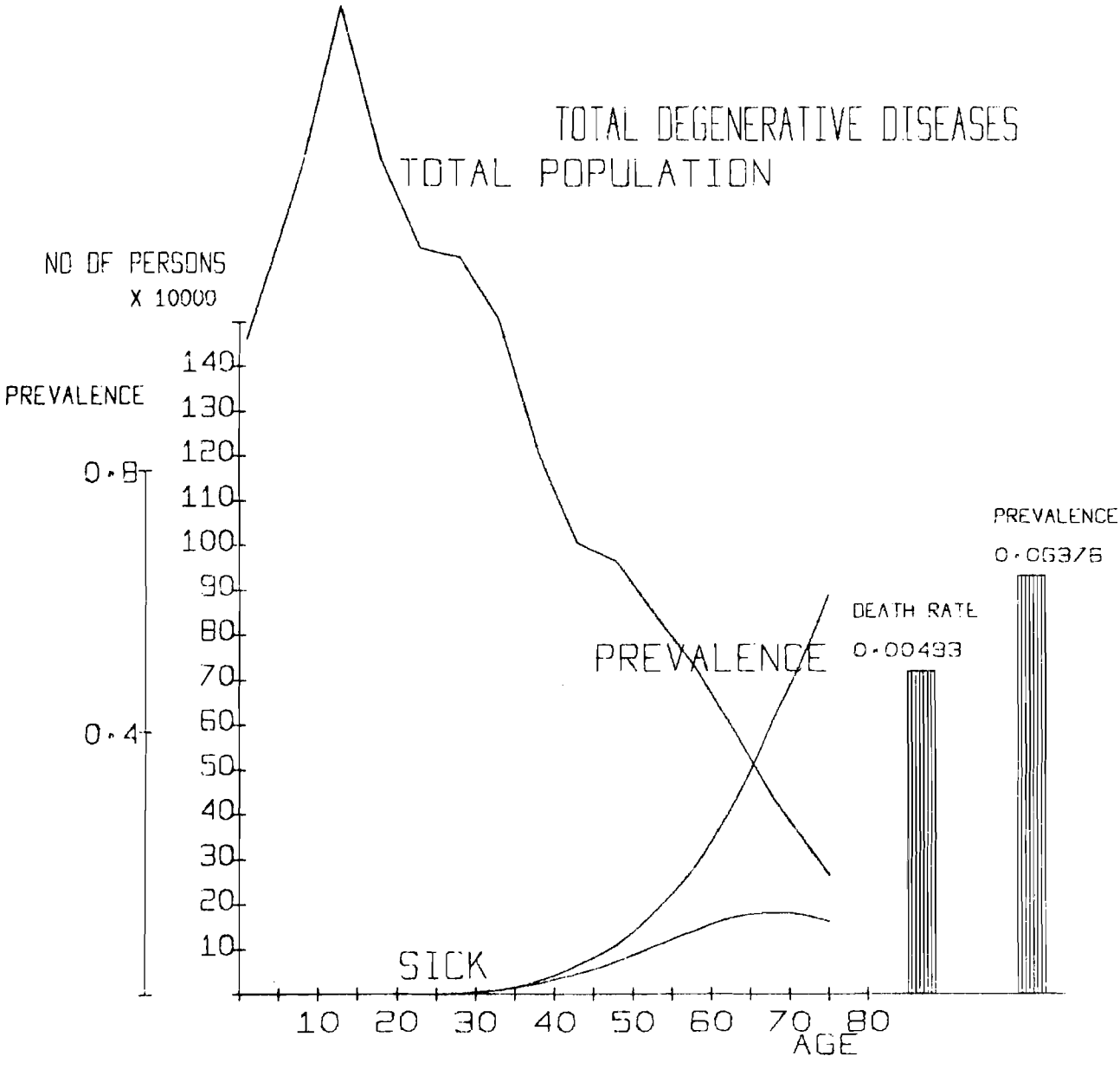

Figure 15b. Estimation of future trend in degenerative diseases: Japan.

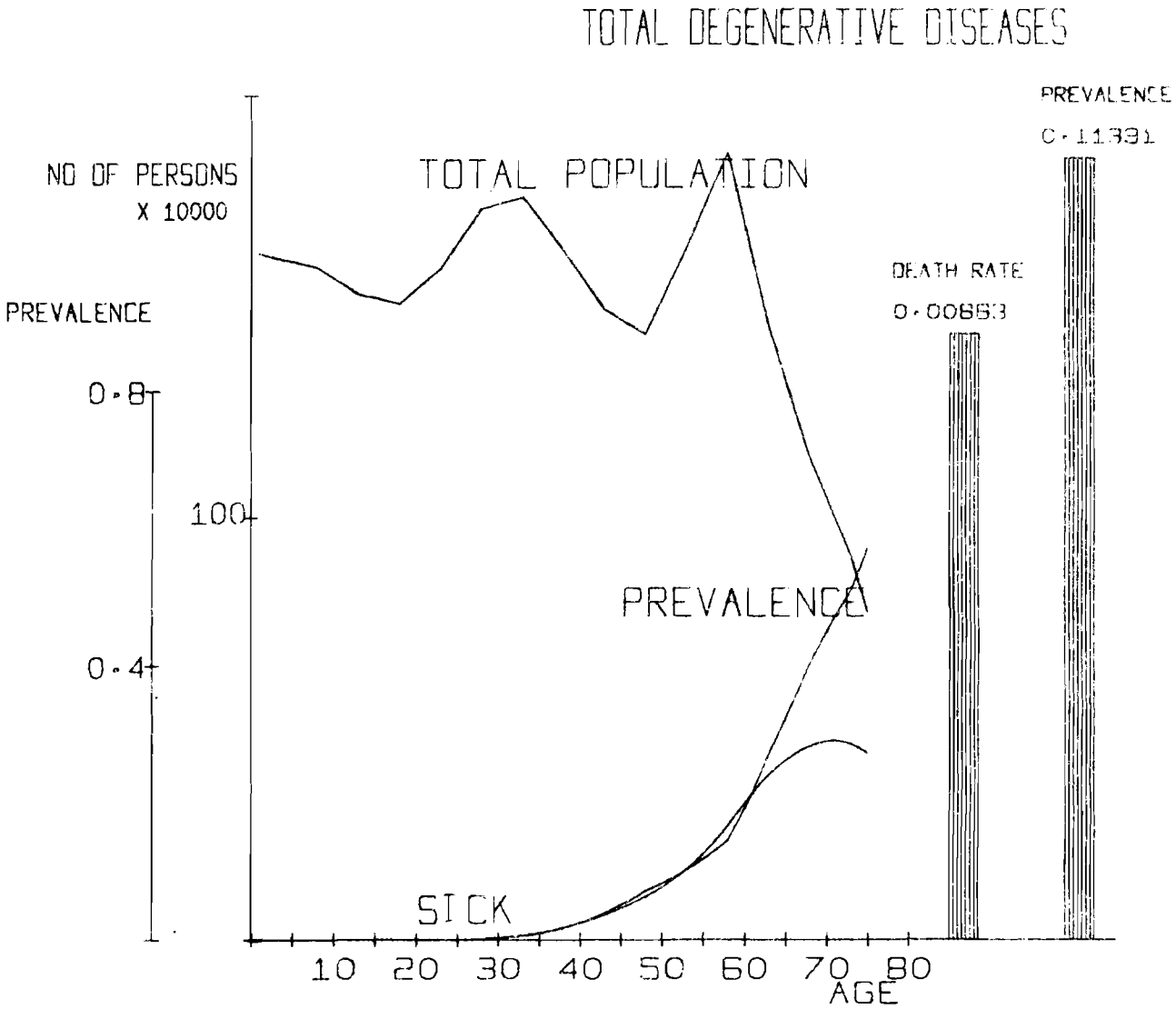

Figure 15c. Estimation of future trend in degenerative diseases: Japan.

The aging index used in the figure is defined as follows:

$$\text{aging index} = \frac{\text{number of people older than 65 years}}{\text{number of people younger than 15 years}} \quad . \quad (6)$$

For these examples, two representative countries were taken. As is easily seen in the figures, the prevalence of degenerative diseases in England decreases gradually, while that of Japan sharply increases toward the year 2000.

The third application of the model may be the evaluation of treatments for degenerative diseases. At present, there is no effective treatment that prolongs the life of these patients. However, if such treatments are developed, the model will be useful for assessing the decrease of death rate or the increase of the number of patients before the treatments are actually introduced.

Conclusion

Using the data of the World Health Organization, the morbidity model of degenerative diseases, developed at the national level as the first step of the health care model, showed its validity. The model was used for international comparison and for prediction at the national level of future trends in degenerative diseases. These results show that this type of approach is feasible in health planning.

REFERENCES

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Appendix A

The following notation is used in this study. The names of the variables are kept the same in text and computer programs.

I - number of sex-age group.

PN(i) - population, or number of persons.

HP(i) - healthy or non-sick persons.

TS(i) - total sick persons.

LS(i) - latent or non-registered sick in total sick.

RS(i) - registered sick in total sick.

UAS(i) - unaware sick in latent sick.

AS(i) - aware sick in latent sick.

MR(i) - morbidity rate, or number of persons who transfer from HP to TS per unit of time.

DR(i) - death rate, or mortality rate from TS.

AR(i) - awareness rate.

RECOV(i) - recovery rate.

RPR(i) - patient registration rate.

DRPN(i) - death rate per population.

T - duration of sickness.

Appendix B

```
C       THIS PROGRAM CALCULATES THE NEMBER OF SICK AND DEATH RATES OF DEGENERATIVE
C DISEASES, WHEN POPULATION STRUCTURE IS GIVEN.
C       INPUT       CARD 1          TITLE  (20A4)
C                   CARD 2-4        POPULATION OF MALE IN 5 YEAR AGE-GROUP (8F10.0)
C                   CARD 5-7        POPULATION OF FEMALE IN 5 YEAR AGE-GROUP (8F10.0)
C
C
      DIMENSION HP(90),TS(90),AMR(90),DR(90),PN(90),PP(90,2),
     1 IAGE(90),FS(90),PREV(90),DRPN(90),FD(90),TS1(90)
     2,HP2(90),TS2(90),FS2(90),FD2(90),TITLE(20)
      INDEX=1
      READ(5,27) TITLE
   27 FORMAT(20A4)
   11 FORMAT(1H1,20A4,12HAGING INDEX=,F6.2)
C
C SUBROUTINE POPSUP READS POPULATION IN 5 AGE-GROUP AND
C DIVIDE THEM INTO 1 YEAR AGE-GROUP
      CALL POPSUP(PN)
      DO 33 I=1,90
      PP(I,1)=PN(I)
   33 CONTINUE
      CALL POPSUP(PN)
      DO 34 I=1,90
      PP(I,2)=PN(I)
   34 CONTINUE
C ADDITION OF MALE AND FEMALE POPULATION
      DO 26 I=1,90
      IAGE(I)=I-1
      PN(I)=PP(I,1)+PP(I,2)
      IF(PN(I).EQ.0.) PN(I)=1.
   26 CONTINUE
C CALCULATION OF AGING INDEX
      YOUNG=0.
      DO 14 I=1,15
      YOUNG=YOUNG+PN(I)
   14 CONTINUE
      OLD=0.
      DO 15 I=66,90
      OLD=OLD+PN(I)
   15 CONTINUE
      OLDCO=OLD/YOUNG*100.
  202 CONTINUE
C CALCULATION OF VARIABLES OF DEGENERATIVE DISEASES
C CADIOVASCULAR DISEASES BY SUBROUTINE SUBCVD
C MALIGNANT DISEASES BY SUBTOUTINE SUBCAN
      DO 32 I=1,90
      HP(I)=PN(I)
      TS(I)=0.
      DR(I)=0.
      DRPN(I)=0.
   32 CONTINUE
      GO TO (200,201,209,12),INDEX
  200 CALL SUBCVD(PN,AMR,HP,TS,DR,DRPN,FS,FD)
C VARIABLES FOR CARDIOVASCULAR DISEASES ARE RETAINED FOR THE
C CALCULATION OF TOTAL DEGENERETATIVE DISEASES.
      DO 500 I=1,90
      HP2(I)=HP(I)
      TS2(I)=TS(I)
      FS2(I)=FS(I)
      FD2(I)=FD(I)
```

```
  500 CONTINUE
      WRITE(6,11) TITLE,OLDCO
      WRITE(6,400)
  400 FORMAT(1H0,'CARDIOVASCULAR DISEASES')
      GO TO 204
  201 CALL SUBCAN(PN,AMR,HP,TS,DR,DRPN,FS,FD)
      WRITE(6,11) TITLE,OLDCO
      WRITE(6,401)
  401 FORMAT(1H0,'MALIGNANT DISEASES')
      DO 502 I=1,90
      TS1(I)=TS(I)
  502 CONTINUE
      GO TO 204
  209 CONTINUE
C CALCULATION OF TOTAL DEGENERATIVE DISEASES
      DO 501 I=1,90
      TS(I)=TS1(I)+TS2(I)
      IF(TS(I).GE.PN(I)) TS(I)=PN(I)
      HP(I)=PN(I)-TS(I)
      FS(I)=FS(I)+FS2(I)
      FD(I)=FD(I)+FD2(I)
      IF(TS(I).EQ.0.0) GO TO 600
      DR(I)=FD(I)/TS(I)
      GO TO 601
  600 DR(I)=0.
  601 CONTINUE
      DRPN(I)=FD(I)/PN(I)
      AMR(I)=FS(I)/PN(I)
  501 CONTINUE
      WRITE(6,11) TITLE,OLDCO
      WRITE(6,402)
  402 FORMAT(1H0,'TOTAL - CARDIOVASCULAR + MALIGNANCY')
  204 CONTINUE
      DO 28 I=1,90
      IF(HP(I).EQ.0.0) GO TO 95
      PREV(I)=TS(I)/PN(I)
      GO TO 28
   95 PREV(I)=0.
   28 CONTINUE
      THP=0.0
      TTS=0.0
      TPN=0.0
      TD=0.0
      DO 8 I=1,90
      TPN=TPN+PN(I)
      TD=TD+TS(I)*DR(I)
      THP=THP+HP(I)
      TTS=TTS+TS(I)
    8 CONTINUE
      TDRPN=TD/TPN
      TPREV=TTS/TPN
      TAMR=TTS/TPN
      IF(TTS.EQ.0.) GO TO 300
      TDR=TD/TTS
       GO TO 301
  300 TDR=999.
  301 CONTINUE
      WRITE(6,103)
  103 FORMAT(//1H ,' AGE   POPULATION      HEALTHY   TOTAL SIC
     1K  PREVALENCE   MORBIDITY        DEATH RATES    '/
```

```
      21H  ,9X,4H(PN),11X,4H(HP),7X,4H(TS),8X,7H(TS/PN),4X,4H(MR),8X,
      34H(DR),4X,6H(DRPN) /)
       DO 29 I=1,90
       WRITE(6,100) IAGE(I),PN(I),HP(I),TS(I),PREV(I),AMR(I),DR(I)
      1,DRPN(I)
  100 FORMAT(1H ,I4,1X,3(F12.0,1X),3X,F5.2,3X,F10.6,2F10.4)
   29 CONTINUE
      WRITE(6,101)TPN,THP,TTS,TPREV,TAMR,TDR,TDRPN
  101 FORMAT(/6H TOTAL,3(F12.0,1X),3X,F5.2,3X,F10.6,2F10.4)
   10 FORMAT(8F10.0)
 1111 IF(INDEX.EQ.3) GO TO 1112
      GO TO 1113
C
C  OUTPUT FOR GRAPHIC PLOTTER
 1112 WRITE(7,13) TITLE
   13 FORMAT(20A4)
      WRITE(7,111) PN
      WRITE(7,111)TS
      WRITE(7,112) PREV
      WRITE(7,112) TDRPN,TPREV
  112 FORMAT(8F10.6)
  111 FORMAT(8F10.0)
 1113 CONTINUE
      INDEX=INDEX+1
      GO TO 202
   12 STOP
      END
C
C
C
      SUBROUTINE SUBCVD(PN,AMR,HP,TS,DR,DRPN,FS,FD)
      DIMENSION HP(90),TS(90),DR(90),PN(90),FD(90),FS(90),
     1 DRPN(90),AMR(90),AX(90)
C DATA STATEMENT CONTAINS THE MORBIDITY RATES FOR CVD
      DATA AX/23*0.0,0.00011,0.00020,0.00030,0.00043,0.00054,0.00064,
     10.00080,0.00100,0.0012,0.0015,0.0017,0.0020,0.0023,0.0027,
     20.003,0.0035,0.004,0.0044,0.005,0.0057,0.0063,0.007,0.0077,
     30.0085,0.0094,0.0105,0.0115,0.0120,0.013,0.0135,0.0145,0.016,
     40.017,0.0185,0.02,0.0215,0.023,0.0245,0.026,0.0275,0.029,
     50.031,0.033,0.035,0.037,0.039,0.041,0.043,0.045,0.0475,
     60.05,0.053,15*0.056/
      DO 1 I=1,90
      AMR(I)=AX(I)
    1 CONTINUE
      DO 30 I=16,90
      I3=I-15
      I1=I-1
      TS(I)=0.
      DO 31 J=I3,I1
      TS(I)=TS(I)+HP(J)*AMR(J)
   31 CONTINUE
      IF(TS(I).GE.PN(I)) TS(I)=PN(I)
      HP(I)=PN(I)-TS(I)
      IF(TS(I).EQ.0.) GO TO 99
      DR(I)=HP(I3)*AMR(I3)/TS(I)
      GO TO 98
   99 DR(I)=0.
   98 CONTINUE
      IF(PN(I).EQ.0.0) GO TO 97
      DRPN(I)=HP(I3)*AMR(I3)/PN(I)
```

```
      GO TO 96
   97 DRPN(I)=0.
   96 CONTINUE
   30 CONTINUE
      DO 100 I=1,90
      FS(I)=HP(I)*AMR(I)
      FD(I)=TS(I)*DR(I)
  100 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE SUBCAN(PN,AMR,HP,TS,DR,DRPN,FS,FD)
      DIMENSION HP(90),TS(90),DR(90),PN(90),
     1 DRPN(90),FS(90),FD(90),AMR(90),AX(90)
C DATA STATEMENT CONTAINS THE MORBIDITY RATES FOR MALIGNANCY
      DATA AX/22*0.,20.,40.,60.,80.,100.,120.,140.,160.,180.,
     1200.,238.,278.,318.,358.,397.,458.,518.,578.,638.,698.,
     2797.,897.,997.,1097.,1197.,1350.,1509.,1668.,1828.,1988.,
     32227.,2466.,2707.,2947.,3188.,3549.,3910.,4273.,4637.,
     45001.,5407.,5813.,6220.,6628.,7037.,7350.,7806.,8261.,
     58715.,9167.,9120.,9655.,10116.,10456.,10599.,13122.,13787.,
     614410.,14985.,15426.,17797.,18165.,18534.,18913.,17614.,
     719868.,19985.,20000./
      DO 55 I=1,90
      AMR(I)=AX(I)/1000000.
   55 CONTINUE
      DO 30 I=5,90
      I3=I-4
      I1=I-1
      TS(I)=0.
      DO 31 J=I3,I1
      TS(I)=TS(I)+HP(J)*AMR(J)
   31 CONTINUE
      IF(TS(I).GE.PN(I)) TS(I)=PN(I)
      HP(I)=PN(I)-TS(I)
      IF(TS(I).EQ.0.) GO TO 99
      DR(I)=HP(I3)*AMR(I3)/TS(I)
      GO TO 98
   99 DR(I)=0.
   98 CONTINUE
      IF(PN(I).EQ.0) GO TO 1111
      DRPN(I)=HP(I3)*AMR(I3)/PN(I)
      GO TO 1112
 1111 DRPN(I)=0.
 1112 CONTINUE
   30 CONTINUE
      DO 100 I=1,90
      FS(I)=HP(I)*AMR(I)
      FD(I)=TS(I)*DR(I)
  100 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE POPSUP(PP)
      DIMENSION P(18),PP(90)
      READ(5,25) (P(I),I=1,18)
   25 FORMAT(8F10.0)
      DO 3 I=1,17
```

```
      DO 2 J=1,5
      K=(I-1)*5+2+J
      PP(K)=P(I)+(P(I+1)-P(I))/5.0*FLOAT(J-1)
    2 CONTINUE
    3 CONTINUE
      PP(1)=P(1)-(P(2)-P(1))/5.0*2.0
      PP(2)=P(1)-(P(2)-P(1))/5.0*1.0
      PP(88)=P(18)+(P(18)-P(17))/5.*1.
      PP(89)=P(18)+(P(18)-P(17))/5.*2.
      PP(90)=P(18)+(P(18)-P(17))/5.*3.
      DO 4 K=1,90
      PP(K)=PP(K)/5.0
    4 CONTINUE
      DO 9 I=1,90
      IF(PP(I).LT.0.0) PP(I)=0.0
    9 CONTINUE
      RETURN
      END
```

```
SEP  1 18:00 1976  JAPAN1960 PAGE 1

JAPAN 1960
  4012565.  4702331.  5620478.  6677764.  4125267.  4094657.  3746899.  2763209.
  2274345.  2256805.  2040675.  1802183.  1437575.  1026994.   693566.   376706.
   169144.    56453.
  3831872.  4502305.  5397062.  4630776.  4193185.  4114705.  3770907.  3274823.
  2744787.  2559756.  2160717.  1839025.  1494044.  1133410.   870238.   577972.
   313781.   131547.
```

Examples of Input

JAPAN 1960 AGING INDEX= 19.40

TOTAL = CARDIOVASCULAR + MALIGNANCY

AGE	POPULATION (PN)	HEALTHY (HP)	TOTAL SICK (TS)	PREVALENCE (TS/PN)	MORBIDITY (MR)	DEATH RATES (DR)	(DRPN)
0	1460072.	1460072.	0.	0.00	0.000000	0.0000	0.0000
1	1514480.	1514480.	0.	0.00	0.000000	0.0000	0.0000
2	1568887.	1568887.	0.	0.00	0.000000	0.0000	0.0000
3	1623295.	1623295.	0.	0.00	0.000000	0.0000	0.0000
4	1677703.	1677703.	0.	0.00	0.000000	0.0000	0.0000
5	1732111.	1732111.	0.	0.00	0.000000	0.0000	0.0000
6	1786519.	1786519.	0.	0.00	0.000000	0.0000	0.0000
7	1840927.	1840927.	0.	0.00	0.000000	0.0000	0.0000
8	1913444.	1913444.	0.	0.00	0.000000	0.0000	0.0000
9	1985960.	1985960.	0.	0.00	0.000000	0.0000	0.0000
10	2058476.	2058476.	0.	0.00	0.000000	0.0000	0.0000
11	2130992.	2130992.	0.	0.00	0.000000	0.0000	0.0000
12	2203508.	2203508.	0.	0.00	0.000000	0.0000	0.0000
13	2135148.	2135148.	0.	0.00	0.000000	0.0000	0.0000
14	2066788.	2066788.	0.	0.00	0.000000	0.0000	0.0000
15	1998428.	1998428.	0.	0.00	0.000000	0.0000	0.0000
16	1930068.	1930068.	0.	0.00	0.000000	0.0000	0.0000
17	1861708.	1861708.	0.	0.00	0.000000	0.0000	0.0000
18	1822105.	1822105.	0.	0.00	0.000000	0.0000	0.0000
19	1782501.	1782501.	0.	0.00	0.000000	0.0000	0.0000
20	1742898.	1742898.	0.	0.00	0.000000	0.0000	0.0000
21	1703294.	1703294.	0.	0.00	0.000000	0.0000	0.0000
22	1663690.	1663690.	0.	0.00	0.000020	0.0000	0.0000
23	1659327.	1659294.	33.	0.00	0.000150	0.0000	0.0000
24	1654963.	1654681.	282.	0.00	0.000260	0.0000	0.0000
25	1650600.	1649887.	712.	0.00	0.000380	0.0000	0.0000
26	1646236.	1644897.	1339.	0.00	0.000530	0.0248	0.0000
27	1641872.	1639694.	2178.	0.00	0.000659	0.0305	0.0000
28	1614210.	1611016.	3195.	0.00	0.000779	0.0311	0.0001
29	1586548.	1582195.	4353.	0.00	0.000958	0.0303	0.0001
30	1558886.	1553145.	5741.	0.00	0.001177	0.0287	0.0001
31	1531224.	1523813.	7410.	0.00	0.001395	0.0266	0.0001
32	1503561.	1494212.	9349.	0.01	0.001730	0.0242	0.0002
33	1444370.	1432646.	11724.	0.01	0.001965	0.0216	0.0002
34	1385179.	1370871.	14309.	0.01	0.002299	0.0196	0.0002
35	1325988.	1308776.	17213.	0.01	0.002630	0.0178	0.0002
36	1266797.	1246403.	20395.	0.02	0.003057	0.0175	0.0003
37	1207607.	1183697.	23909.	0.02	0.003402	0.0168	0.0003
38	1166850.	1139234.	27617.	0.02	0.003940	0.0225	0.0005
39	1126094.	1094503.	31592.	0.03	0.004472	0.0255	0.0007
40	1085338.	1049516.	35823.	0.03	0.004901	0.0278	0.0009
41	1044582.	1004438.	40145.	0.04	0.005516	0.0314	0.0012
42	1003826.	959180.	44647.	0.04	0.006257	0.0334	0.0015
43	995724.	946285.	49438.	0.05	0.006900	0.0340	0.0017
44	987621.	932993.	54627.	0.06	0.007629	0.0358	0.0020
45	979518.	919314.	60204.	0.06	0.008347	0.0379	0.0023
46	971415.	905316.	66099.	0.07	0.009147	0.0398	0.0027
47	963312.	890956.	72356.	0.08	0.010078	0.0433	0.0033
48	938706.	859774.	78931.	0.08	0.011169	0.0433	0.0036
49	914099.	828102.	85997.	0.09	0.012139	0.0444	0.0042
50	889492.	796214.	93278.	0.10	0.012631	0.0447	0.0047
51	864885.	764544.	100341.	0.12	0.013554	0.0465	0.0054

Examples of Output