ANENCEPHALUS IN NORTH CAROLINA: A REVIEW OF THE LITERATURE AND A DESCRIPTION OF ITS OCCURRENCE, 1972-1991

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INTRODUCTION

Turnbull (1) has reported that many fetal and infant deaths result from congenital anomalies, among which are neural tube defects (NTD) such as anencephalus, spina bifida, and hydrocephalus. Most studies of NTDs have focused on anencephalus since it is easily recognizable at birth by the absence of the cranial vault of the skull. The frontal lobes of the brain are completely missing or are reduced to small masses attached at the base of the skull. One study found that 25-45% of anencephalic cases are live born. Of these only 15% survive more than 3 days and the remainder die within 2 weeks. (2)

Studies of the epidemiology of anencephalus have shown it to be more prevalent among lower classes, (3, 4) females, (4, 5, 6, 7, 8) and whites. (7, 8) Studies have also reported associations of risk with urbanites. (1) Geographically, a decreasing east to west gradient in the United States, (8) the United Kingdom, (6) and a north to south gradient on the islands of New Zealand (4) has been reported. However, two variables, maternal age and seasonality, show very conflicting results. Some studies show an association between anencephalus and maternal age (1, 9, 10) while others do not. (4, 11) Studies which show seasonality generally found anencephalus associated with May or June (12) but other studies show no association. (4, 6) No study found maternal cold and flu, (13, 14) pesticides, (15) and radiation, (5) to have any effects on the occurrence of anencephalus.

The incentive for this research began in the fall of 1995 after a discussion with my BSPH Program Director, Dr. Craig Turnbull. During this discussion, I learned of his prior research on anencephalus (1, 16) and I developed an interest in this subject matter. Turnbull reported trends of anencephalus for 1946-1970 and for 1946-1976. I wondered if his findings still held for the past 25 years. This incentive led to a literature search on anencephalus.

The initial objective of this study was to review the current literature and to compare Turnbull's findings for the years 1946 to 1976 to the rates of anencephalus in the current literature. However, midway throughout the effort, it was discovered through contact with the North Carolina State Center for Health and Environmental Statistics (SCHES) that their vital statistics data files were available on the World Wide Web (WWW). These raw data files included all coded variables from birth and death certificates, marriage certificates, and other events. From this data, rates of anencephalus could be calculated. The focus of this research was expanded to include North Carolina's data on the rates of anencephalus for the years 1972-1991 which could be compared to the rates stated by Turnbull (1, 16).

Thus, the additional objective of this study was to determine if the trends of anencephalus reported by Turnbull for North Carolinians during 1946-1970 (1) and for 1946-1976 (16) remained essentially the same for 1972-1991. This study compared the rates of anencephalus by year, sex, race, sex by race, and maternal age for the time periods aforementioned. Trimester in which prenatal care began and number of prenatal visits, were also included in this study. These variables were of interest since results from other studies have suggested that the currently declining rates of anencephalus are partially due to better prenatal screening and detection as well as selective abortion. (17, 18, 19)

Turnbull (1) also reported rates of anencephalus for urban vs. rural areas and for degree of urbanization by mother's county of residence. However, these variables are not included in this study since it is unlikely that the definitions of these variables have remained unchanged for the 45 years included in this study. The variable geographic variation is also not included due to the limited time available for the research conducted for this study.

METHODS

Data from North Carolina's Vital Statistics Records for resident North Carolinians were employed in this study. North Carolina's State Center for Health and Environmental Statistics (SCHES) has made this information available to the public through the World Wide Web. Three separate raw data files were downloaded from the WWW for use in this study: the birth files, fetal death files, and matched birth/death files.

Information on the vital statistics of North Carolinians can be obtained from the World Wide Web by any person who has access to a computer with a modem by the following process which was employed in this study. The Web was accessed through Netscape. Once in Netscape, I entered in the University of North Carolina at Chapel Hill's Sunsite homepage using the address: "http://sunsite.unc.edu". Using the search icon, I began a search using the Lycos search engine with the key words "vital statistic". Searching through the queries from the search I found the North Carolina Vital Statistics located at: "gopher://uncmvs.oit.unc.edu". In this gopher menu, there is a folder entitled: "North Carolina Vital Statistics", inside of which, there is a list of introduction files, codebook files, and raw data files. I obtained the raw data used in this study from the raw data files.

In this study, the following formula was used to calculate rates of anencephalus:

$$\text{Rate} = (a / b) * k$$

where "a" is the number of cases in a population at risk, "b" is the total number of people in the population who are at risk, and "k" is a constant (a multiplier for the rate). This rate also relates to a specified time period. In this study, the numerator (a) includes the anencephalic cases found in live birth and fetal death records for resident North Carolinians during selected time periods. The denominator (b) is also derived from fetal death and live birth records for North Carolina residents. In this study "k" is 10,000, meaning that the rates mentioned in this study are the number of cases of anencephalus out of 10,000 live births and fetal deaths for selected time periods. It should be noted that in some previous studies, ratios, not rates, were analyzed since fetal deaths were not included in the denominators.

The denominators for the rates in this study were acquired as follows. The data for births and fetal deaths from 1972 to 1991 were obtained from the birth and fetal death records on the WWW and entered into a separate data set for that year. The totals for selected subsets of variables for each year or year groups were then obtained.

Obtaining information for the numerators (i.e., the number of cases) was more complicated. Less than half of the cases (42%) were identified by using the cause of death variable in the matched birth/death records. The remainder of the cases were located from the cause of death variable in the fetal death files. However, there was no cause of death variable coded in the WWW records for the years 1972 to 1987. Therefore, for these years, Turnbull (20) obtained from the SCHES a listing of the pertinent data for the anencephalus cases. This information was obtained from the original data tapes archived at the SCHES. These cases were entered into separate data sets for each specified year.

Since anencephalic events are readily detectable at the time of delivery and all such deliveries die soon after birth, (2, 21) it was felt that North Carolina's vital statistics records provided reasonably complete information. As Table 1 shows, less than 2% of the cases of anencephalus for North Carolina residents had missing data during the years 1972-1991. The denominators had even smaller percentages of missing data. Because the overall number of cases is large, this amount of missing data does not substantially affect the overall calculated rate of anencephalus, but this may not be true for rates by year or by other subgrouping of the data, since the number of cases in such categories may be small. Table 2 illustrates the number of live births, fetal deaths, and the number of cases for each year, 1972-1991, for resident North Carolinians.

RESULTS

There were 773 cases of anencephalus identified in North Carolina via the matched birth/death records, fetal death records, and supplemented records provided by North Carolina's SCHES for a total population at risk of 1,793,482 live births and fetal deaths between 1972-1991. The overall rate of anencephalus for this time period was 4.3 cases per 10,000 births. As Figure 1 shows, the rate decreased from 7.4 cases per 10,000 events for 1972 to 1.7 cases per 10,000 events for 1991.

This decreasing trend is similar to that reported in many areas of the world. The trends in this study agree with data reported for the US for 1970-1989 (8) as shown in Figure 2. Ratios of anencephalus for the US decreased from 12.7 cases per 10,000 births in 1970 to 6 cases per 10,000 in 1989. In addition, similar trends for Iceland (1955-1981), Glasgow (1974-1985, 1964-1989), and England (1964-1985) were noted. (17, 18, 22, 23).

Year of Occurrence

Figure 3 shows the rates of anencephalus reported by Turnbull (1) for resident North Carolinians for 1946-1970. He noted an increasing trend in the rates: from 4.6 per 10,000 events in 1946 to 9.8 in 1970. Figure 4 shows Turnbull's data (1) which is plotted along with the data in this study. At present, these differences in the trends cannot be explained The rate was 7.4 in 1972; the rate decreased until 1976 when it jumped from 6.4 to 7.5. This jump was also reported by Turnbull (16). The rates calculated in this study decreased from a high of 7.5 in 1976 to a low of 1.6 in 1990.

This decreasing trend of anencephalus, is relatively linear as shown in Figure 5. The regression formula for the annual rates for this study has a slope of -0.3 with a p value $< .0001$.

Sex

Rates of anencephalus for North Carolina by sex for two year intervals are depicted in Figure 6. Between 1972 and 1991 the overall rate was 2.8 (253/917785) cases per 10,000 live births and fetal deaths for males and 5.9 (518/875697) for females. Turnbull reported the rate was 3.9 for males and 9.2 for females for 1947 to 1970. (1) These rates show an increase in anencephalus by sex in 1946-1970 and then the decrease ending in 1991. Again, we cannot explain why the rates increased between 1947 to 1970 and decreased between 1972-1991.

Figure 6 shows that the rates of anencephalus for males decreased from a maximum value of 4.9 in 1976-1977 to a minimum value of 0.7 in 1990-1991.

The highest rate for females, 11.1 occurred in 1972-1973 and decreased to a low of 2.8 for 1990-1991. The trends for both males and females depict the reversal noted above. It is interesting to note that, as reported by Turnbull, (1, 16) the rates for females are consistently higher than those for males.

This data also agrees with most of the findings in current literature. Some studies only show a higher percentage of females cases to males cases (4, 5, 8) and others show that the rates for females are decreasing (6, 7). Only one study shows that the rates for the males were relatively stable, (6) whereas another shows they were decreasing. (8)

Race

Rates of anencephalus for North Carolina by race for 1972-1991 are given in Figure 7 in two year intervals. The overall rate for whites was 5.2 per 10,000 events (633/1221775) and that for nonwhites was 2.4 (139/570721). For 1947-1970, Turnbull reported a rate of 8.2 for whites and 2.3 for nonwhites. (1) This shows an overall decreasing trend for whites in North Carolina since 1947. However, the rates for nonwhites have remained relatively stable.

Figure 7 shows that the rates of anencephalus in whites decreased from a maximum value 9.4 in 1972-1973 to a minimum value of 1.7 in 1990-1991. The rates for nonwhites has not varied much from a maximum rate of about 3.0 in 1974-1975, 1980-1981, and 1986-1987 to a minimum rate of 1.6 in 1990-1991. It is interesting to note the large decrease in the white rates since 1972 and the relatively unchanged distribution of the nonwhite rates since 1947-1948. This trend has also been noted in the literature (7) but there is no explanation for this at this point. Another study has reported that both the rates for whites and nonwhites are decreasing, but the rates for whites are decreasing at a much higher rate. (8).

Sex by Race

Figure 8 shows the distributions of rates of anencephalus by race and sex in four year intervals. These four year groups were chosen because of the small numbers of cases in each sex by race subgroup. The overall rates for these subgroups are: 7.2 per 10,000 events for white females, 3.2 for white males, 3.1 for nonwhite females, 1.8 for nonwhite males. It was interesting to note the sex effect for these sex by race rates. Namely, the white female rate was more than twice as large as the white male rate, and the nonwhite female rate was almost twice as large as the nonwhite male rate.

Most of these rates are lower than those observed by Turnbull for 1946-1970, yet they reveal similar trends. Turnbull reported that the white female rate was 12.1 and the white male rate was 4.8 for the years 1947-1970. (1) Although both of these values have decreased since then, the white female rate is still much higher than the white male rate. The rates for both the nonwhite females and nonwhite males have remained relatively stable across both studies although the nonwhite male rate has increased slightly. The nonwhite female rates in Turnbull's study ranged from 4.7 to 4.1 in 1947-1970 (1) and have decreased slightly to the range 2.8 to 3.5 for 1972-1991. The nonwhite male rates in Turnbull's study have increased from a range of 0.6 to 0.7 in 1946-1970 (1) to a range of 2.4 to 1.4 in 1972-1991.

Figure 8 shows how the trend for the rates of nonwhite females and nonwhite males are essentially unchanged for 1972-1975 through 1988-1991. However, although the rates for the white females are decreasing drastically and the rates for the white males slightly, the rates for the females are still higher. These trends for the sex-race subgroups agrees with previous studies. (7) Since this decreasing trend for white females is significant (slope of -0.61, p value <

0.0031) and shows the greatest decrease for the four subgroups, this group has a large influence on the overall decrease in the rates.

Maternal age

Some studies of anencephalus by maternal age have suggested a U-shaped curve in which the rates for older and younger women are higher than those for middle age women. (1, 9, 10) However, other studies have reported that there is no effect of maternal age on rates of anencephalus. (4, 11)

The results for this study are shown in Table 3. We used similar maternal age intervals as were employed in the Turnbull study. (1) However, the last two age categories (35-39 and 40-44) were combined due to small numbers of cases in these age groupings. The overall picture in North Carolina for 1972-1991 indicates that the rates of anencephalus decreased as the age of the mother increases. The rates ranged from a 4.7 per 10,000 events for the youngest mothers (15-19), to a 2.5 for the oldest mothers (35 and up). These rates contrasted with the results from some of the previous findings (1, 9, 10) since we did not observe the U-shaped distribution noted above.

A U-shaped distribution was not observed for any of the four year intervals listed in Table 3. In fact, these five different year periods did not display any consistent pattern at all.

Trimester Prenatal Care Began (by race)

An objective of this study was to determine if the rates of anencephalus increased with the trimester the mother's prenatal care began. Also, it was questioned if the group of mothers who did not receive any prenatal care showed the highest rates of anencephalus. In this study the month of pregnancy that prenatal care began were grouped by trimester.

The findings for this variable are shown in Tables 4 and 5. The overall rate for those mothers who received no prenatal care had the highest rate, 6.6 per 10,000 events. This rate was about 1.5 times larger than the rate for each of the three trimesters. The rates for the three trimesters were essentially similar: the group who first received prenatal care in the second trimester had the next highest rate, 4.5; the other rates were 4.2 for the first trimester and 3.8 for the second trimester. This pattern reflects an upside-down U-shaped distribution of the rates for the first through third trimester groups.

This same pattern did not hold for most of the year subgroups. Except for 1976-1979, as above, the highest rates were noted for mothers who had no prenatal visits. Rates for the four year intervals did not show any consistent patterns. The rates for 1980-1983 and 1988-1991 revealed the upside-down U-shaped distribution noted above; and the rates for the 1972-1975 and 1976-1979 had a decreasing relationship with the trimester the mother's prenatal care began. The other year group, 1984-1987 revealed an increasing trend with the trimester the mothers prenatal care began. These findings are somewhat tentative due to the small number of cases of anencephalus for the four year intervals.

When the data were further subgrouped by race groups the results were similar to those noted above for both races. As a whole, the groups who received no prenatal care had the largest rates for their racial category (10.6 for white and 4.3 for nonwhites) and these rates were double those for the three trimester groupings. Again the rates for the second trimester had the second highest rates (6.4 for whites and 2.5 for nonwhites). The race specific rates for the four year time periods did not show any consistent patterns by trimester of first prenatal visit; but these findings are again tempered by the probable affects of small numbers of cases of anencephalus in the subgroupings.

Number of Prenatal Visits (by race)

This variable was discovered to be coded incorrectly in the fetal death files provided by the North Carolina's SCHES. After further research, this variable was discovered to be miscoded in the original data tapes at SCHES as well for years prior to 1988. Therefore, this variable was analyzed only for the years 1988-1991 for which the cause of death variable was coded in the vital statistics data and the number of visits was coded correctly.

This study examined the relationship between the rate of anencephalus and the number of prenatal care visits. Table 6 shows that the deliveries with the distinctly high rates were those with 9 or fewer prenatal visits (ranging from 3.2 to 11.4) versus those deliveries with lower rates having more than 9 visits (ranging from 0.7 to 1.6). Surprisingly, those deliveries with no prenatal visits experienced a rate of only 4.1.

When these data were subdivided by race, similar results were found. For both racial groups higher rates were found for deliveries with 9 or less prenatal visits (ranging from 3.7 to 21.3 for whites and 2.5 to 6.3 for nonwhites) versus lower rates for deliveries with more than 9 prenatal visits (ranging from 0.7 to 1.4 for whites and 0.7 to 2.5 for nonwhites). The rate for no prenatal visits was 3.8 for whites and 4.3 for nonwhites. These no prenatal care rates and the rates for more than 9 visits are very similar across the races. The only major differences between the races are in the 9 or fewer number of visit groups where the rates for whites are much higher.

DISCUSSION

No explanations are offered as to why rates in this study for certain groups are falling, while the rates for other groups are inconsistent or remaining stable.

However, some studies have presented evidence for a major gene being responsible for anencephalus. (22, 24) They claim that this defect is either an autosomal recessive gene or an X-linked recessive gene. However, this does not hold all the time because others who should be afflicted by this gene are not. These studies then say that there may be other genetic and/or environmental influences which cause these supposed 'cases' not to develop the neural tube defect (NTD). (22, 24) Another study suggests that genetic causes may be responsible for female and male cases, however, genetics may be responsible for the additional female cases. (25)

Another explanation is suggested by the recent changes in prenatal care. Studies have attributed the decreasing trends in the occurrence of anencephalus to better prenatal screening and selective abortion. (17, 18, 19) Due to better screening, doctors are able to detect these cases earlier and many woman opt to terminate their pregnancies. However, according to these studies, although better screening probably accounts for some of the decrease it cannot account for all of it since the rates were already decreasing.

Along with prenatal care comes a woman's knowledge of taking better care of herself during her pregnancy. Although no cause has been found for anencephalus, there are some preventative measures. Since women who have had a previous NTD birth are at greater risk for having another one; as of 1991, the Centers for Disease Control recommended that these women take 4 mg of folic acid starting before conception and into the pregnancy which can reduce their risk of having another NTD birth up to 71% (26). However, this high dosage could have negative side effects which are not fully understood as of yet. By 1993, studies have shown that if all women took 0.4 mg of folic acid before and during their pregnancies, the rate of NTDs could fall 50%. (27) This dose has also been shown to have the same beneficial effect as 4 mg for women with previous NTD births. Therefore, because of this important effect, many public health activists are trying to ensure that all women of child bearing age consume 0.4 mg of folic acid daily.

Acknowledgment

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TABLE 1

Missing observations

Variable	Numerators (cases) #	Numerators (cases) %	Denominators (live births and fetal deaths) #	Denominators (live births and fetal deaths) %
Sex	2	0.3	0	0.0
Race	1	0.1	986	0.1
Maternal Age	2	0.3	2,531	0.1
Trimester Prenatal Care Began	12	1.6	6,318	0.4
Number of Prenatal Visits	11	1.4	1,573	0.1
Total Missing	28	3.6	11,408	0.6

TABLE 2

Total Counts

Year	Live Births	Fetal Deaths	Cases
1972	88,894	1,338	67
1973	85,729	1,324	62
1974	84,246	1,204	53
1975	80,885	1,018	52
1976	80,549	1,036	61
1977	84,562	1,030	38
1978	82,407	923	38
1979	83,782	932	40
1980	84,481	877	48
1981	83,752	864	46
1982	85,908	863	37
1983	83,854	818	36
1984	85,986	766	36
1985	89,391	775	23
1986	90,228	800	26
1987	93,481	814	32
1988	97,560	872	24
1989	102,091	899	19
1990	104,439	911	17
1991	102,309	884	18
Totals	1,774,534	18,948	773

Figure 1. Rates of Anencephalus, 1972–1991

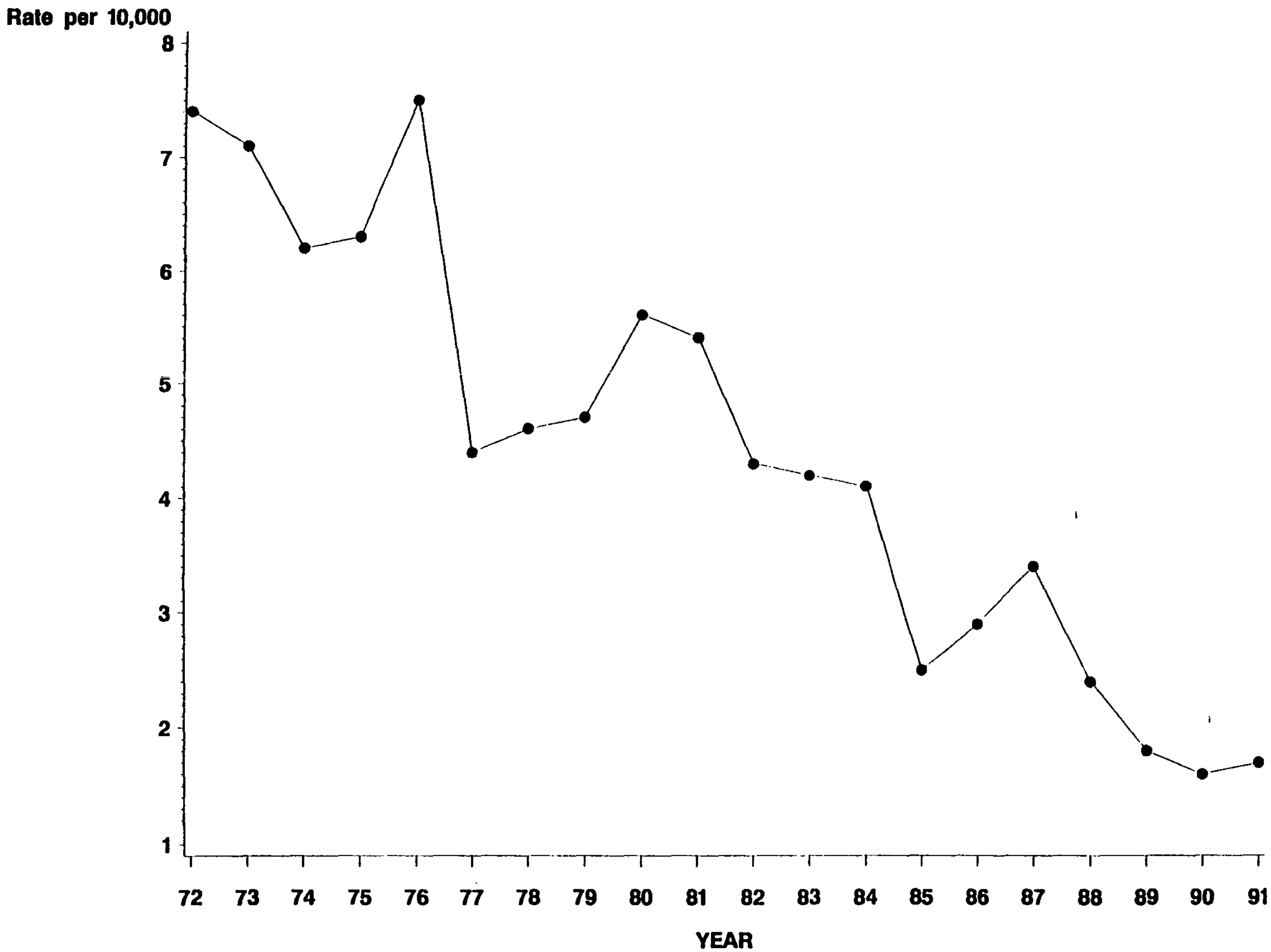

Figure 2. Occurrence of Anencephalus, 1970 – 1991

For the United States and North Carolina

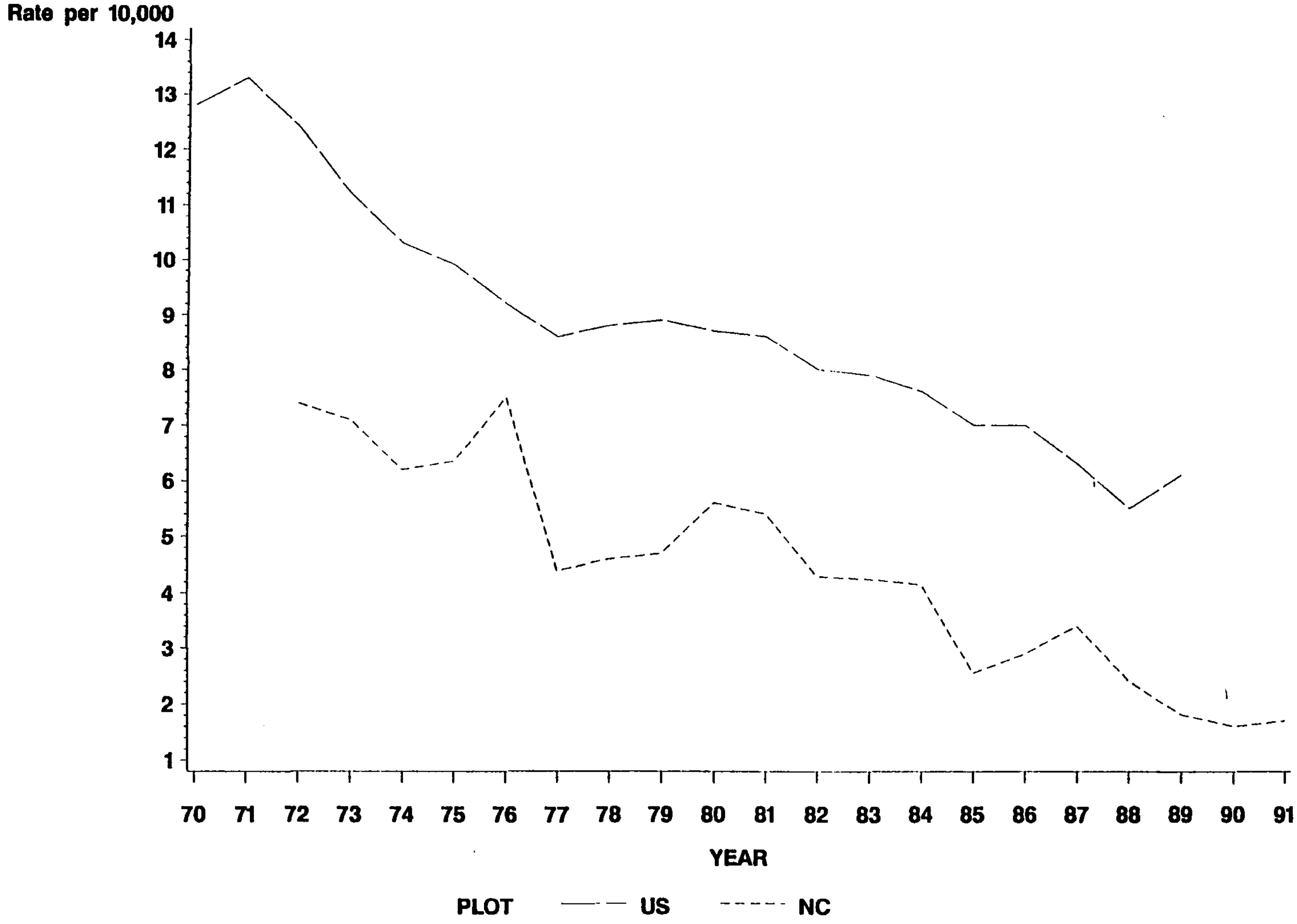

Figure 3. Rates of Anencephalus, 1946–1970

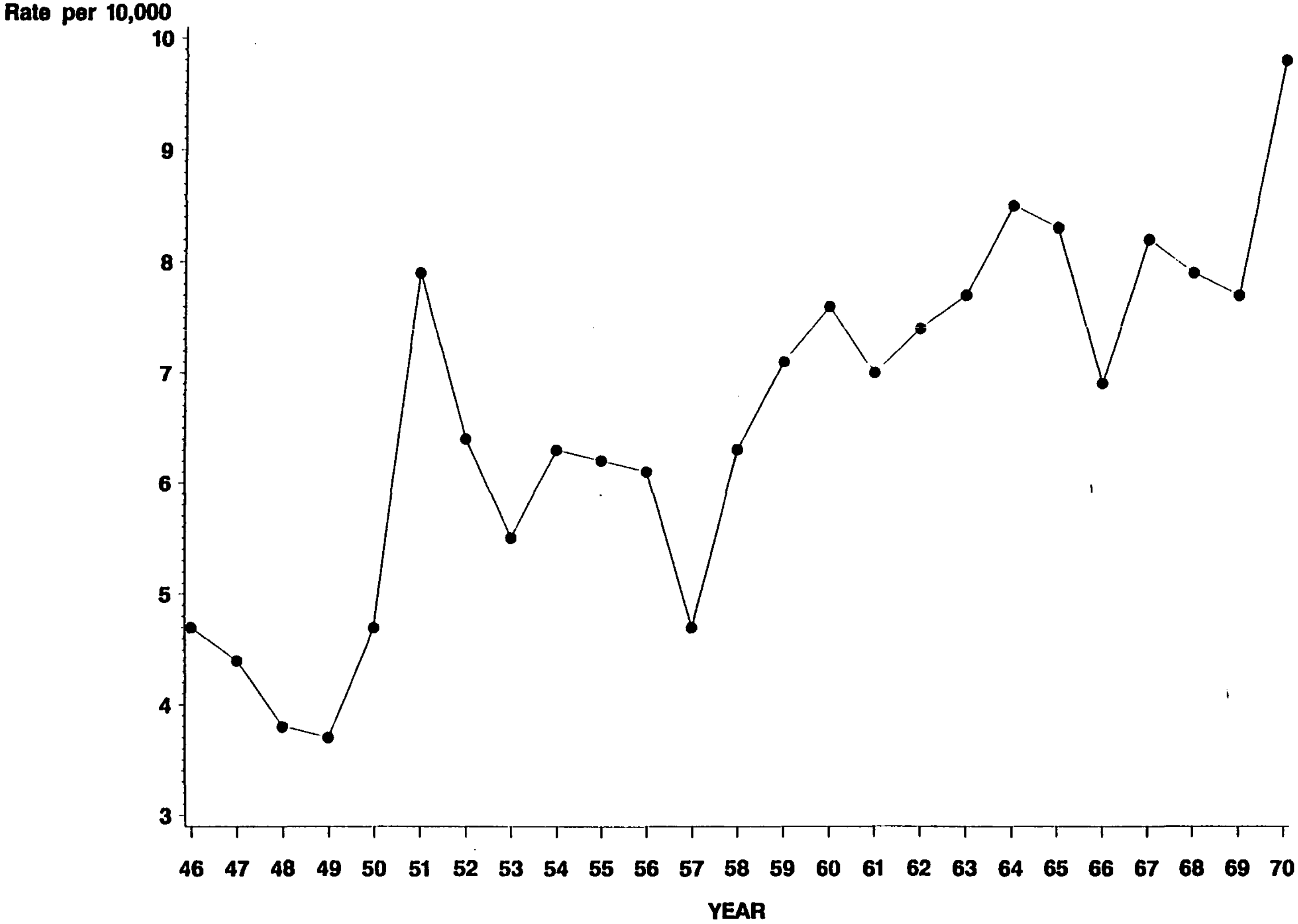

Figure 4. Rates of Anencephalus, 1946–1991

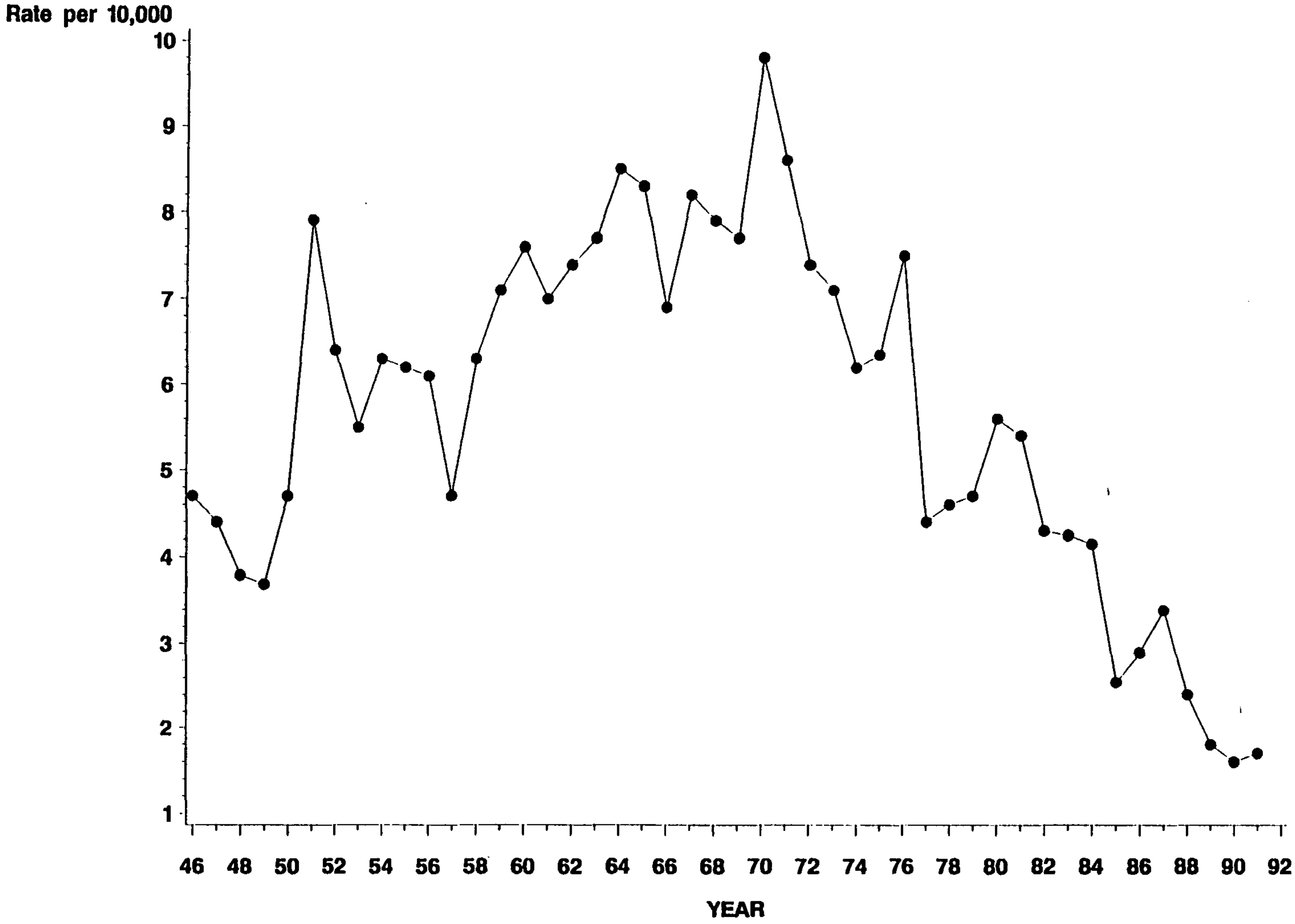

Figure 5. Rates of Anencephalus, 1972 – 1991

Fitted Regression Line

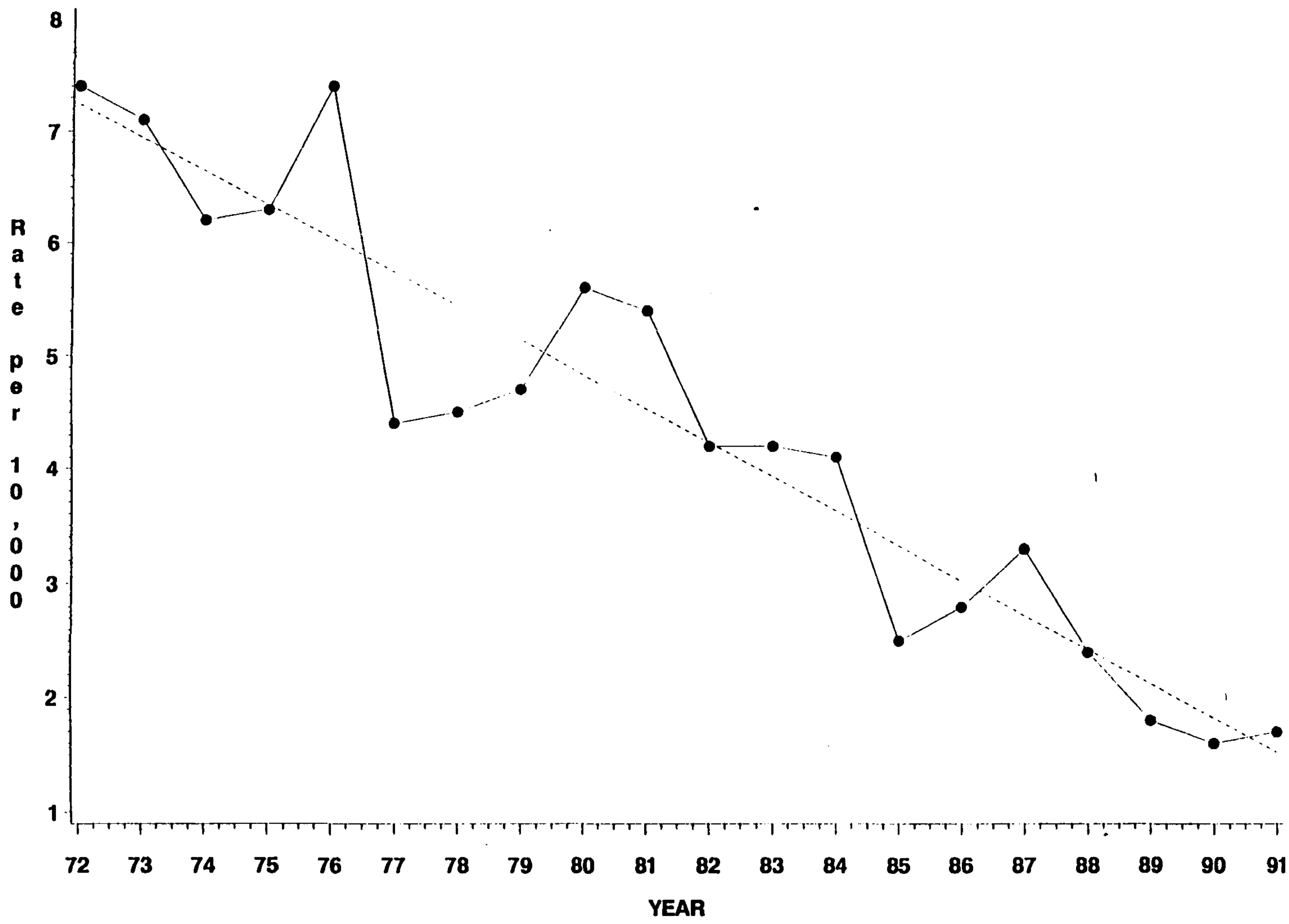

Figure 6. Rates of Anencephalus by Sex, 1972-1991

Two Year Intervals

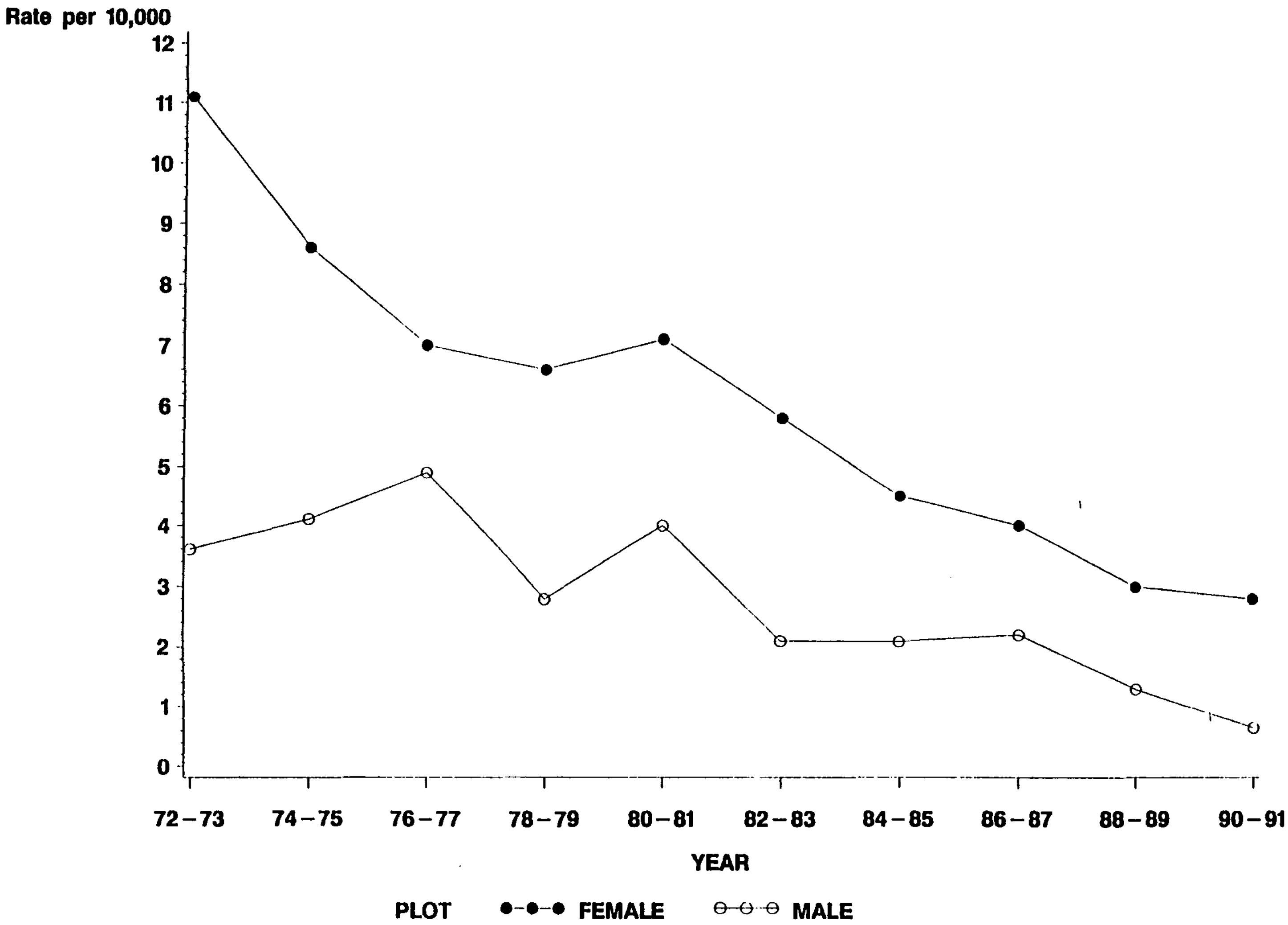

Figure 7. Rates of Anencephalus by Race, 1972–1991

Two Year Intervals

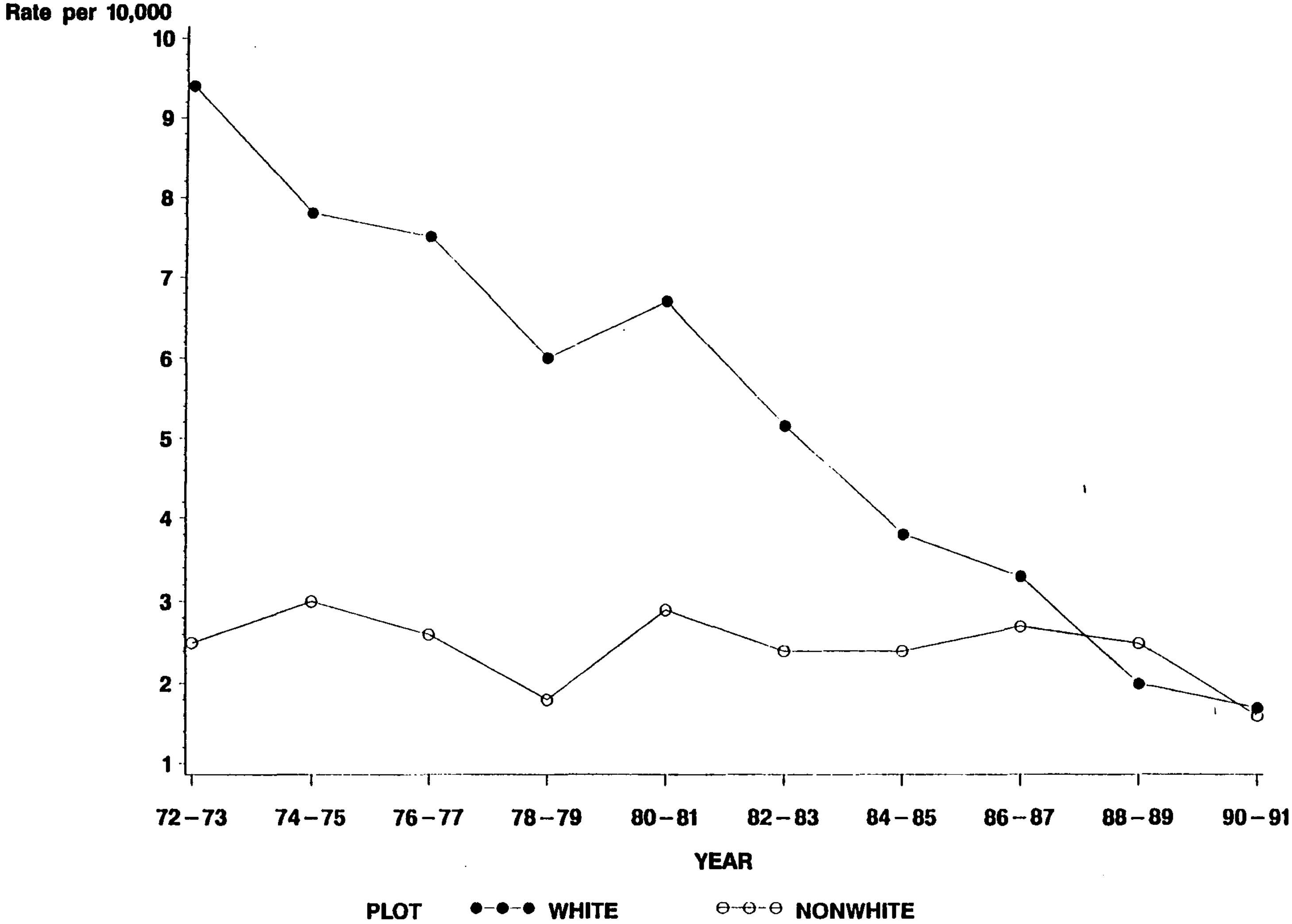

Figure 8. Rates of Anencephalus by Sex and Race, 1972–1991

Four Year Intervals

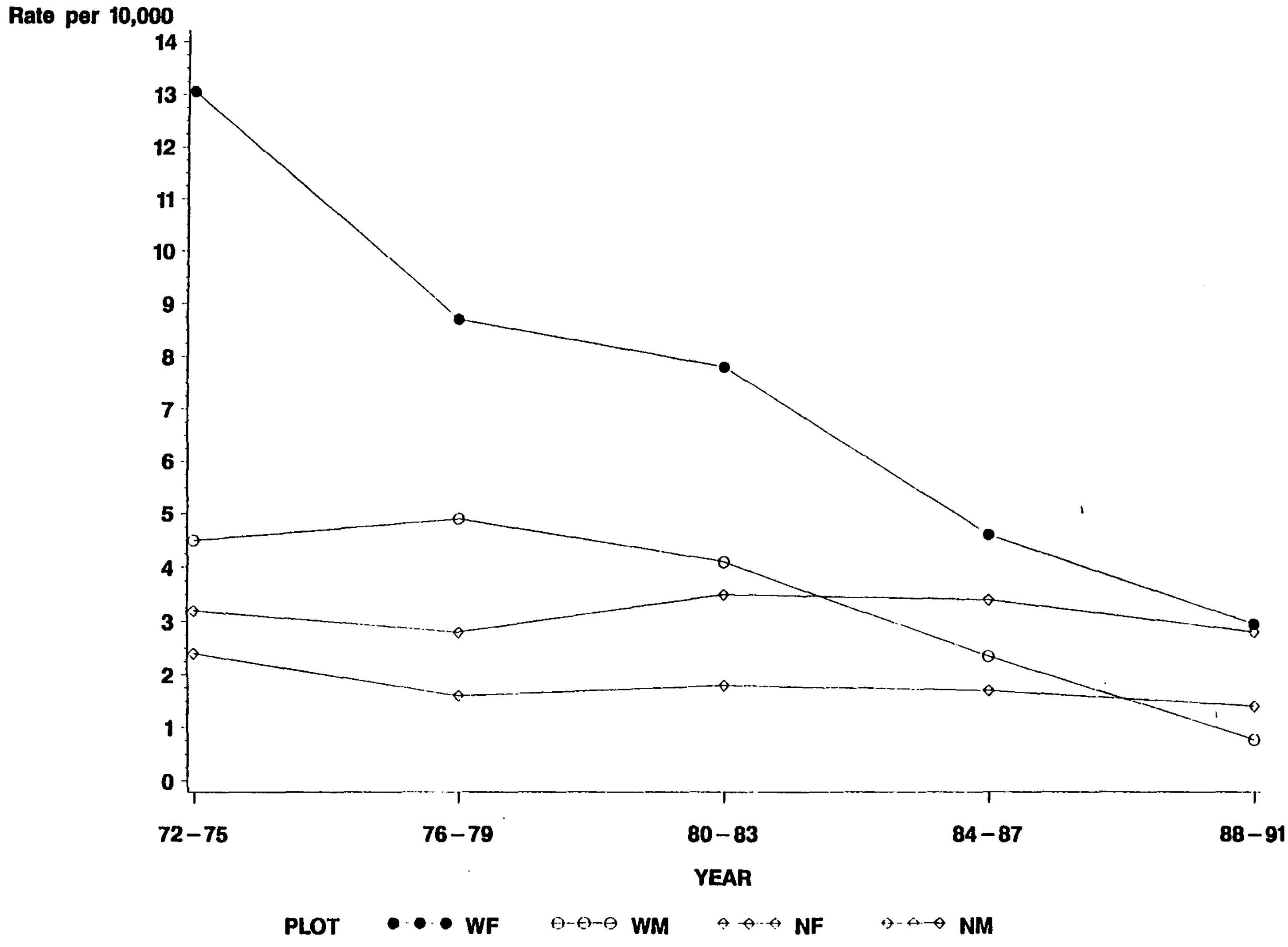

TABLE 3

Rate* of anencephalus by maternal age and period of occurrence

Period of occurrence	Maternal age 15-19	20-24	25-29	30-34	35 +
1972-1975	6.5	7.2	7.1	5.9	4.9
1976-1979	4.8	4.8	6.7	4.5	4.9
1980-1983	5.2	6.0	3.7	5.4	0.7
1984-1987	4.0	3.0	2.9	4.1	1.6
1988-1991	2.3	2.6	1.3	1.4	1.5
Total	4.7	4.7	4.1	3.9	2.5

* Rate per 10,000 live births and fetal deaths

TABLE 4

Rate* of anencephalus by trimester prenatal care began and period of occurrence

	Trimester prenatal care began			
Period of occurrence	no visits	first trimester	second trimester	third trimester
1972-1975	7.9	7.0	6.5	2.6
1976-1979	3.1	5.4	5.2	4.0
1980-1983	5.8	4.9	5.0	3.8
1984-1987	12.4	2.9	3.0	8.1
1988-1991	4.1	1.5	2.4	1.9
Total	6.6	4.2	4.5	3.8

* Rate per 10,000 live births and fetal deaths

TABLE 5

Rate* of anencephalus by trimester prenatal care began, race, and period of occurrence

Period of occurrence	White: no visits	White: first trimester	White: second trimester	White: third trimester	Nonwhite: no visits	Nonwhite: first trimester	Nonwhite: second trimester	Nonwhite: third trimester
1972-1975	14.7	8.3	10.0	4.4	4.1	2.7	2.9	1.1
1976-1979	8.1	6.5	8.2	3.5	0.0	2.1	2.2	4.4
1980-1983	7.5	5.7	6.8	6.3	4.7	2.6	3.1	1.7
1984-1987	20.9	3.1	3.6	13.8	6.8	2.4	2.3	3.3
1988-1991	3.8	1.5	2.6	1.5	4.3	1.8	2.1	2.3
Total	10.6	4.8	6.4	5.5	4.3	2.3	2.5	2.5

* Rate per 10,000 live births and fetal deaths

TABLE 6

Rate* of anencephalus by number of prenatal visits and race, 1988-1991

	Number of prenatal visits						
	0	**1 to 3**	**4 to 6**	**7 to 9**	**10 to 12**	**13 to 15**	**16 +**
White	3.8	21.3	8.7	3.7	0.7	0.7	1.4
Nonwhite	4.3	6.3	3.6	2.5	1.4	0.6	2.5
Total	4.1	11.4	5.7	3.2	0.9	0.7	1.6

* Rate per 10,000 live births and fetal deaths