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# ALCOHOL INVOLVEMENT IN MICHIGAN FATAL ACCIDENTS: 1968-1976

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16. Abstract

Nine years of Michigan fatal accident data, 1968-1976, were analyzed to assess the impact of lowering the minimum legal drinking age in Michigan from 21 to 18 on January 1, 1972. Driver age, sex, and the presence or absence of drinking were the key variables, and partitioning of the chi-square statistic into its degrees of freedom was the primary analytic technique.

It was found that a peak occurs in the age-specific, had-been-drinking (HBD) rate about one year after drinking becomes legal for a particular age group. This peak shifted from age 22 to age 19 when the drinking age was lowered and resulted in an average (by year) increase of 53% in the HBD rate for 18-20 year old drivers with some increase in the 17 year old HBD rate. The increased HBD rate of young drivers also caused an overall increase in the HBD rate of all drivers even though the HBD rate of older drivers remained unchanged or even decreased.

Female drivers were found to represent only a small proportion —2.5%— of drinking drivers during the 9-year period, but this proportion had increased to 4% in 1975-76. The HBD rate of 18-20 year old female drivers increased from 8.4% to 18.6% after the drinking age was lowered.

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## SUMMARY

This is the first interim report of a project sponsored by Michigan's Office of Highway Safety Planning entitled "Drinking Driver Analysis." The results of work performed from October, 1977 through March, 1978 are presented.

The purpose of this study was to extend the analysis of alcohol involvement in Michigan fatal accidents. Previous studies showed that the alcohol involvement of young drivers increased when the legal drinking age was lowered to 18 in 1972. One aim was to determine whether this increase was a transient effect or whether it has continued. An additional goal was to add the 1976 accident experience to the 1968-1975 analytic files. An impetus for this was the near certainty that the legal drinking age would be raised to 19 effective in December of 1978. Other specific goals of the study were to evaluate the involvement of females in alcohol-related crashes, to extend further the age/drinking analysis, and to incorporate other analytic techniques in the methodology.

The analytic data consist of a census of all police-reported fatal accidents occurring in the State of Michigan from 1968 through 1976. Accidents investigated by the Michigan State Police or by officers of a local governmental unit are recorded on the official police report form (UD-10) used by all agencies throughout the state. The reports are computerized by the Department of State Police, and tape copies of the data were made available to HSRI for the present study.

The analyses deal primarily with the proportion of drivers in fatal crashes who had been drinking (HBD). These rates were compared for different aged drivers within each year to obtain a profile of alcohol involvement by age. The nine-year trends in rates were followed for a number of driver cohorts having a common birth year to determine changes in the HBD rates with increasing age. A technique of partitioning an overall chi-square statistic into its individual degrees of freedom was used to isolate significant changes in these rates. A separate analysis was carried out for female drivers. Finally, a linear model using weighted least

squares for the analysis of HBD rates was used. This separated the year-to-year effects (common to the 15-26 ages over the nine-year period) from the particular changes which affected the young drivers.

Findings

1. The drivers aged 18 to 20 who were involved in fatal accidents experienced a 53% increase in their reported HBD rate from the pre-law (1968-1971) period to the post-law (1972-1976) period. This was a change in the average proportion of HBD from 0.269 to 0.413. The higher rates have been maintained through 1976. In fact, the HBD rates for the last two years are even higher. A similar increase from 0.162 to 0.250 was found for the 17-year-old drivers. None of the older age groups showed a significant increase in HBD rate during this period.

2. The relationship of HBD rate to driver age is strong. The general pattern is that it is low for drivers younger than the legal drinking age. The rate rises sharply to a peak (somewhat above 0.5) for ages a year or so older than the legal drinking age, and then declines linearly with age. In the early fifties the rate has decreased to about half that of the early twenties. This same pattern occurred in 1968-1971 and in 1972-1976, but during the latter period the peak shifted to younger drivers. In the earlier period, the peak came approximately at age 22, while in the latter period the peak is at age 19.

3. Cohorts of drivers—those born in the same year—followed over time showed a consistent pattern for their HBD rate to increase sharply at the year when they first could drink legally. This was true for the older cohorts who first could drink legally at 21 (those who were 21 in 1972 or earlier). The same pattern held for younger cohorts, except that the increase showed up at age 18. Cohort drivers who were between 18 and 21 in 1972 showed large increases in 1972, when they all could first drink legally.

4. Females represent only a small portion—about 2.5% (nine-year mean)—of the HBD drivers. In addition, they are a small proportion —about 18%—of all drivers in the Michigan fatal files. As a consequence, the number of female drivers is too small to provide reliable findings. However, the average rate of HBD among females of all ages increased from

0.121 to 0.148 coincident with the lower legal drinking age. In addition, the HBD rate among 18- to 20-year-old females more than doubled, from 0.084 (1968-1971) to 0.186 (1972-1976). These increases have resulted in 4% of the 1975-1976 HBD drivers being female. Thus females remain a small proportion of the drivers in HBD fatal accidents, but there may be a trend for this to increase.

5. The younger drivers experienced an increase in their HBD rate during the 1972-1976 period compared with 1968 to 1971, while older drivers' HBD rates remained unchanged or declined slightly. As a result, the overall HBD rate in fatal accidents showed a 13% increase from an average of 0.295 to 0.335 for drivers in Michigan fatal accidents.

## Conclusions

A sharp increase in the HBD rate for drivers in the 18-20 age range occurred. This increase took place at the time of the lowering of the drinking age, and has been maintained or increased in recent years. Since only those age groups affected by the law change showed the increase, the data are consistent with interpreting the change in the legal drinking age as the cause of the increase. However, the data cannot prove causation or exclude other causes.

Primarily as a consequence of the increase in HBD rate among the young drivers, the general rate of HBD among all drivers in Michigan fatal accidents has increased. Some of this increase is artifactual in that it is also associated with a reduction in the missing data on the HBD variable. However, it is clear that much of the increase is associated with the lower legal drinking age.

Some increase in HBD rate among females has been noted. However, since females remain a rather small proportion of the drivers in fatal accidents, the significance of this increase is in doubt.

A reasonable conclusion is that the lowering of the legal drinking age from 21 to 18 in 1972 resulted in a large increase in the proportion of HBD among drivers of these ages. In addition, this increase caused, in part, the increase in HBD among the totality of the drivers. There is some indication of a spill-over effect to 17-year-old drivers.

One could speculate that a further lowering of the legal drinking age would be followed by a corresponding increase in the HBD rate among drivers under 18. Such an effect would likely be smaller than the effect found from lowering the age to 18 for a number of reasons. Drivers under age 18 may be under more parental restraint. In addition, they may not have as ready access to cars. Finally, assuming that the legal driving age remains fixed, a further lowering of the age would not affect as many drivers.

The effect of raising the legal drinking age from 18 to 19 is problematical. It is unlikely that a sudden effect on the HBD rate among 18-year-old drivers would be found. If enforcement of the higher legal drinking age were effective, then one might see a reduction in the HBD rate for the affected age within two or three years. However, no data or historical experience are available to indicate the trends to be expected from increasing the legal drinking age.

## Recommendations

The research reported herein has confirmed that young, male drivers are a valid target group for countermeasure activities. This holds whether alcohol involvement is considered or not. If countermeasures are specifically directed to drinking drivers, then young males are even more strongly identified as an appropriate target group. Although it would be useful to know whether they are overrepresented in the accident population relative to their numbers in the exposed population, lack of this information should not deter action. The central fact is that young, male drivers have a great many fatal accidents, both involving and not involving alcohol.

Older, male drivers also are valid target groups for countermeasures designed to reduce driving-after-drinking, but less so than their younger counterparts. This is a corollary to the simple fact that there is no "correct" legal drinking age from the traffic safety perspective.

Better measures of alcohol involvement among drivers in all accidents, and particularly in fatal accidents, are desirable for more precise identification of drinking-driving problems. Operating and policy-making organizations concerned with traffic safety should press for 100% collection and analysis of blood specimens for alcohol content from all traffic

fatalities. Similarly, all surviving drivers in accidents fatal to others should be tested for blood alcohol content by analysis of breath or other body substance.

The results of breath tests administered in connection with DUIL arrests, whether coincident with an accident or not, should be analyzed thoroughly. The data should be computerized and placed into analytic files. Initial analyses should focus on age-blood alcohol concentration (BAC) relationships, and subsequent analyses should compare BAC findings with accident data of the type analyzed here. A particularly important research topic is to determine the extent to which DUIL arrestees subsequently appear in the population of HBD, accident-involved drivers.

The efforts which reduced the missing-data rate on the HBD variable to its current value of about 0.02 among drivers in fatal accidents should be continued. This will facilitate subsequent analyses of HBD trends over long periods of time.

Accident data for 1977 and subsequent years should be processed and analyzed like those reported here. A continued effort will permit a sound evaluation of the effects of increasing the legal drinking age from 18 to 19, if that occurs, and will assist in the evaluation of countermeasures designed to reduce alcohol-related crashes.[1]

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[1] During preparation of this report, the legal drinking age was increased from 18 to 19 effective December 3, 1978.

# 1. INTRODUCTION

This is the first interim report of a project sponsored by Michigan's Office of Highway Safety Planning (OHSP) entitled "Drinking Driver Analysis" (OHSP Project Number MAL-77-001A). Presented are results of the work conducted from October, 1977 through March, 1977 concerning fatal accidents.

This report is one of several dealing with Michigan's alcohol-related traffic accident experience from 1968 through the early and mid-1970's. Douglass, Filkins, and Clark [1] included Michigan as part of their seven-state study to determine the effects of lowered legal drinking ages on youth crash involvement.[1] Included in that time-series analysis were data from January, 1968 through August, 1973. Michigan lowered its legal drinking age from 21 to 18, effective January 1, 1972. The present authors, in late 1976 and early 1977, analyzed the eight years of Michigan data from 1968-1975. OHSP, in connection with its advisory and policy-making roles, issued a report based on those data and analyses early in 1977 [2]. Douglass and Freedman, under sponsorship of Michigan's Office of Substance Abuse Services, also analyzed data from the same years [3]. They, however, broadened the inquiry considerably by examining the phenomena in terms of the changes in availability of beverage alcohol to the affected age group. (Readers wishing a review of research on this topic covering jurisdictions other than Michigan are referred to Whitehead's excellent presentation [4]).

As this report is being prepared (March, 1978) it is a near certainty that Michigan will raise its legal drinking from age 18 to age 19, effective December, 1978. Current thinking is that a three-year trial period of the 19-year legal drinking age will be undertaken, with a re-assessment of the entire situation subsequently.

Apart from the impetus for further analysis provided by the legal drinking age issue is the central fact that alcohol continues to be the factor most frequently identified as causing traffic accidents. Much research has shown the extent of alcohol involvement to increase as accident

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[1] Numbers in brackets [ ] refer to References at end of report.

severity increases, being most frequently implicated in fatal accidents. For this reason OHSP has continued its interest in developing a base of information and knowledge. The hope is, of course, that further insight into the nature and extent of the problem will lead to ameliorative measures. Further, it is recognized that the building of a sound data base now will facilitate the evaluation of future countermeasures designed to reduce the number of alcohol-related accidents.

Several specific purposes are to be served by the project. Foremost of these is the addition of Michigan's 1976 traffic accident experience to the 1968-1975 data base now in analytic form at the Highway Safety Research Institute (HSRI). Second, the analytic work reported in [3] showed the desirability of creating more single-year age groups than has been done heretofore. The advantage is that the one-year cohort groups studied before can be tracked over a longer time period. This has the additional advantage of sharpening the comparisons between younger drivers and their older counterparts within a specific year. Third, it was believed by both OHSP and HSRI staff that the alcohol-related traffic experience of females should be determined and monitored. Fourth, the further analysis of the entire data set by computer-based models was considered a logical extension of the earlier work. Finally, the preparation of a Fortran program to facilitate use of the chi-square partitioning technique in both the present and future analyses was to be completed.

Section 2 identifies, in general terms, the data set as currently constituted. The variables from the data set selected for analysis are described, and the analytic techniques employed are outlined.

The main analyses and findings of the study are reported in Section 3. The topics addressed are those given earlier in this Introduction.

# 2. METHODOLOGY

This section contains a brief description of the data set which was analyzed. The variables selected for analysis are given, and the analytical techniques employed are reviewed.

## 2.1 Data Set

The data set consists of a census of all police-reported fatal accidents occurring in the State of Michigan from 1968 to 1976. Accidents are investigated by the Michigan State Police or by officers of a local unit of government—county, city, or, occasionally, township. Data from the investigations are recorded on the official police report form (UD-10) in use by all agencies throughout the state. The reports and data are collected and computerized by the Safety and Traffic Division and by the Criminal Justice Data Center of the Department of State Police for many purposes. Tape copies of the data were made available to HSRI for analytical work in the present study.

Table 1 shows the number of fatal accidents, the number of traffic units in these accidents, and the number of traffic units included in the present analysis. The analyzed traffic units consist of all drivers of passenger cars, trucks, and motorcycles involved in all fatal accidents. Not included are pedestrians and pedalcyclists, drivers of school buses and commercial buses, and operators of construction equipment and farm equipment. However, the drivers of cars, trucks, and motorcycles involved in accidents fatal to such traffic units are included.

## 2.2 Analytic Variables

The focus of the current study is on the role of alcohol among drivers involved in fatal accidents. The HBD (Had Been Drinking) variable has been used to examine the extent to which drivers had been using alcohol, since it is by far the best indicator of alcohol use appropriate for analysis.

In the earlier lower legal drinking age analyses [1,2] the HBD variable had been supplemented by a "3FS" variable, a three-factor surrogate

Table 1

Number of Fatal Accidents and Traffic Units

| Year | Accidents | Traffic Units | |
|---|---|---|---|
| | | Total | Analyzed |
| 1968 | 2015 | 3057 | 3000 |
| 1969 | 2154 | 3265 | 3203 |
| 1970 | 1863 | 2815 | 2742 |
| 1971 | 1890 | 3289 | 2705 |
| 1972 | 1997 | 3453 | 2878 |
| 1973 | 1949 | 3386 | 2820 |
| 1974 | 1651 | 2845 | 2350 |
| 1975 | 1611 | 2776 | 2246 |
| 1976 | 1730 | 3051 | 2519 |
| Total | 16,860 | 27,937 | 24,463 |

variable. The three components of the variable are the number of vehicles involved in the accident, the sex of the driver, and the time of occurrence of the accident. Both prior research and the data below show that single-vehicle, male, night-time (9:00 p.m. - 6:00 a.m.) accidents are highly correlated with reported alcohol involvement. That fact made the 3FS variable an attractive addition to the analytic data set, particularly for comparing alcohol involvement in accidents from jurisdictions not using a commonly defined measure. Further, the 3FS variable was useful within Michigan because the definition and recording of the HBD variable underwent a substantial change between 1970 and 1971.

Table 2 shows the proportion of HBD drivers among the 3FS drivers — that is, the number of drivers meeting both the HBD and 3FS criteria, divided by the total number of 3FS drivers. The proportion of 3FS drivers who were identified as HBD ranges from a low of 0.417 (10-17 age group in 1973) to a high of 0.938 (21-23 age group in 1975), with an overall proportion of 0.723 for all drivers in the six years from 1971-1976. There is a general tendency for the proportion to increase from 1971 to 1976. The data in this table demonstrate clearly that a high proportion of drivers

Table 2

Proportion of HBD Drivers among 3FS Drivers

| Age Group | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | ALL |
| 10-17 | .538 | .647 | .417 | .750 | .731 | .618 | .628 |
| 18-20 | .614 | .667 | .716 | .787 | .808 | .890 | .755 |
| 21-23 | .623 | .714 | .667 | .800 | .938 | .914 | .778 |
| 24-26 | .590 | .563 | .778 | .850 | .848 | .897 | .758 |
| 27-29 | .583 | .667 | .762 | .765 | .708 | .926 | .734 |
| 30-32 | .900 | .560 | .591 | .739 | .714 | .667 | .690 |
| 33-35 | .875 | .727 | .636 | .750 | .889 | .727 | .758 |
| 36-94 | .576 | .537 | .767 | .652 | .822 | .680 | .661 |
| ALL | .619 | .628 | .686 | .759 | .831 | .814 | .723 |

satisfying the three-factor criteria of male, single-vehicle, and night-time are involved in alcohol-related accidents. The use of this surrogate variable is thus justified in those special applications where its use is indicated.

On the other hand it is the case that, just as not all 3FS drivers had been drinking prior to their accident, not all drivers who had been drinking satisfy the surrogate criteria. Table 3 presents the data for the same years and same age groups as in Table 2, but in this case the table shows the proportion of HBD drivers who are male, involved in single-vehicle accidents, and who had their crash between 9:00 p.m. and 6:00 a.m.

These proportions are much lower. For all years and all ages, the proportion is 0.303. In 1972, only 15% of the oldest age group (36-94) met the three surrogate criteria, whereas 57.4% of the 10- to 17-year-old drivers met the criteria in 1974. There is a definite trend for the proportion to decrease among older drivers. These data by themselves do not speak to the reason why this should occur, but a difference in the underlying exposure is to be expected. That is, we would expect that a lower percentage of the driving by older drivers is done during the late night hours, and hence a lower proportion of accidents involving these older drivers, including the HBD accidents, occur at night.

Table 3

Proportion of 3FS Drivers among HBD Drivers

| Age Group | Year | | | | | | ALL |
|---|---|---|---|---|---|---|---|
| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | |
| 10-17 | .538 | .537 | .333 | .574 | .373 | .429 | .463 |
| 18-20 | .407 | .458 | .423 | .432 | .491 | .367 | .428 |
| 21-23 | .414 | .385 | .377 | .315 | .497 | .340 | .390 |
| 24-26 | .307 | .243 | .277 | .378 | .322 | .367 | .319 |
| 27-29 | .219 | .274 | .302 | .210 | .236 | .263 | .251 |
| 30-32 | .409 | .280 | .232 | .288 | .204 | .170 | .262 |
| 33-35 | .212 | .200 | .132 | .265 | .205 | .211 | .198 |
| 36-94 | .170 | .150 | .192 | .200 | .192 | .177 | .180 |
| ALL | .295 | .287 | .281 | .316 | .341 | .295 | .303 |

Another variable considered for analytic use is that containing the results of chemical tests that were given. For the same drivers and years discussed above, the percentage of not tested drivers is 76.4%, with a minimum of 70.2% in 1975 and a maximum of 79.6% in 1972. A comparison of the test results with the HBD variable shows good agreement, of course, but the percentage of untested cases is too high for this variable to be of much analytic use.

The final result of the considerations discussed above is that only the HBD variable has been used as a measure of alcohol involvement in subsequent analyses. The definition and recording of the variable have not changed since 1971, the missing-data rate is acceptable as will be seen below, and it identifies more of the alcohol-related accidents than do the alternative measures.

## 2.3 Analytic Techniques

The analytical work following in Section 3 relies heavily on the use and analysis of age-specific rates of the HBD variable. Changes in these rates, or proportions, are analyzed by the chi-square partitioning technique [5] and by the general linear model analysis of categorical data [6].

The age-specific HBD rate is simply the frequency of drivers of some specific age, or age group, judged to have been drinking, divided by the total number of HBD plus HNBD—Had Not Been Drinking—drivers of the same age or age group. If it were not for missing data on the HBD variable, the denominator of the HBD rate would be the total number of accident-involved drivers. For the last three years—1974-1976—the number of cases with missing data on this variable has been sufficiently low to be of little practical difficulty.

However, as Table 4 shows, the missing-data rate—the number of drivers for whom no drinking determination was made divided by the total number of accident-involved drivers of the same age—has changed substantially. For the three years from 1968-1970, drinking information was missing for over 20% of the drivers. This dropped to about 11% for the 1971-1973 period, and then dropped further to about 2% for the 1974-1976 period.

Table 4

Proportion of HBD Missing Data among All Drivers

| Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
| .268 | .240 | .201 | .122 | .110 | .114 | .012 | .027 | .039 |

The large drop from 1970 to 1971 in the missing-data rate occurred because of changes made on the UD-10 accident report form. A 5-level variable was changed to a 2-level variable with no explicit provision for "influence not known." The drop from 1973 to 1974 occurred because of the start up of FARS, the Fatal Accident Reporting System undertaken in cooperation with the National Highway Traffic Safety Administration.

To be noted is that the reported <u>frequency</u> of HBD drivers would increase as missing data decreased, even if the total number of accident-involved drivers and the HBD rate remained constant. The true HBD rate among the missing-data drivers can not be determined, of course. However,

evidence from the 3FS variable suggests that the HBD experience is higher among the missing-data drivers than among those for whom a drinking determination was recorded.[1]

The result is that HBD frequencies were almost surely under-reported in the earlier years, and their correct reporting in later years gives rise to an artifactual increase.

For these reasons we have been careful to draw inferences and base the study findings primarily on age-specific rates rather than on frequencies. The frequencies need to be considered, but their growth, just because of the reduction of the HBD missing-data rate, should be remembered when considering all nine years. The last three years are not affected by such changes.

Partitioning of the chi-square statistic, a technique used extensively in the analysis, is an extension of the well known chi-square method of analysis. The overall chi-square statistic is a method for deciding whether a set of proportions, or rates, are different from the average proportion across the whole table. Thus, for example, the overall chi-square test would determine whether the HBD rates for, say, 18-year-old drivers differed among the nine years. This chi-square statistic would have eight degrees of freedom. These may be partitioned into each single degree of freedom in such a way that the individual chi-squares sum to the overall chi-square statistic. Each single degree of freedom measures whether the difference between two subgroups of the whole table is significant.

When the groups of interest can be determined by consideration of external influences, as is the case here—the change in the legal drinking age is an example—a set of partitions can be defined which will provide tests of most of the appropriate comparisons. The numerical calculations of this procedure, together with a worked example and instructions for use of a computer program, are presented in Appendix A.

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[1] Of the 14,366 car, truck, and motorcycle drivers involved in 1971-1976 fatals for whom the HBD variable had been filled out, 12.2% met the 3FS criteria. Of the 1152 comparable drivers for whom the data were missing on this variable, 17.3% met the 3FS criteria. This, coupled with the high correlation between alcohol and the 3FS variable, suggests that the HBD rate is higher among the missing-data drivers than among those reported.

Another technique used subsequently is the general linear model analysis of categorical data. This is a method of relating differences in rates (or functions of rates) to explanatory, categorical variables in a manner analogous to regression analysis or analysis of variance techniques for continuous data. This model has the advantage of considering several variables simultaneously. However, it is more computationally complex and is restricted in the number of variables which can be compared in a single analysis.

In the present context, the general linear model can be used to estimate changes in HBD rates separately by years and by age groups. Further, possible interactions between these variables—differing patterns of changes by years within different age groups—can also be studied. A computer program to accomplish this type of analysis is GENCAT. The program, together with additional discussion of the analytical method, is documented in Landis et al. [6].

## 3. ANALYSIS

A general overview of the overall HBD experience during the nine years from 1968 through 1976 is provided by Figures 1-4. These three-dimensional plots show the number of HBD, accident-involved drivers by age and year. In Figure 1, the reader is viewing the data array from the southwest and is looking toward the northeast. The block nearest the viewer gives the relative frequency of the 34-year-old drivers in 1968. The years increase from left to right, 1968 to 1976. The age groups in Figure 1 increase from back to front, 15 to 34. Figures 2-4 provide other views of the same data array, each 90 degrees clockwise from the preceding view.

Several patterns can be seen in the data. All of the figures show that more young HBD drivers are involved in fatal accidents than older drivers on a single-age-year basis for all nine calendar years. Figure 2 shows that the 21-year-old drivers were the most numerous in 1968, with a steady increase from age 15 and a subsequent decline as age increases. Figure 3, with 1968 now on the right and the younger drivers nearest the viewer, shows only a modest increase for the age 15 and younger drivers from 1968 to 1976. The 17-year olds show a relatively flat plateau from 1968 through 1971, and then a jump occurs in 1972 to a new plateau that remains relatively steady through 1976. The 18-year-old experience—shaded in Figures 2 and 3—is seen generally to increase from 1968 on, peaking in 1976.

In Figure 4 the 1976 data are nearest the viewer, with the 15 and younger drivers to the far right and the 34-year-old drivers to the far left. The general pattern matches that of Figure 2, with a sharp build-up to a peak followed by a generally steady decline. In 1976, however, the peak very distinctly occurs at age 19 as compared to the 21-year-old peak in 1968. This feature of the data is highlighted in Figure 5, which details the HBD experience for 1968 and 1976.

The analytic relationship between age and HBD rate is conveniently summarized by a linear model. For the years 1971-1976 and for ages 18-98, a weighted, least-squares regression gives a constant term of 0.612 and a coefficient of -0.00711. (R-square for this model is 0.948.) This

indicates that, on the average, the HBD rate is about 0.48 for drivers in their late teens. The rate decreases, uniformly, to about 0.24 at age 50 and declines further to 0.1 for drivers in their early seventies.

Figure 6 presents a three-dimensional plot of a different data array, in this case the HBD rates. These data are from Table 11. The orientation is the same as that in Figure 4; that is, the 1976 data are nearest the viewer with the older age groups on the left and the younger drivers on the right. The rates for twenty-seven age groups are presented here, the under-15 group, the 19 single-year age groups from 16 through 34, the six 5-year groups (35-39, 40-44,..., 60-64), and the 65-98 group. Figure 7 combines the HBD frequencies and rates in a single plot for 1976 and details the 18-34 experience.

The general pattern of HBD rates by age and year is similar to that for the HBD frequencies. The peaks occur at the younger ages, in this case at 19, 21, and 22. The rates fall off rapidly with decreasing age, but they decline gradually as age increases. Notably different is the peak at age 27 in 1976, the highest peak in the whole array, which does not follow the general pattern. This peak--reference to Table 11 shows that 63% of the 27-year-old drivers involved in fatal accidents had been drinking -- illustrates that HBD rates must also be considered with some care. The increase in the percentage of HBD involvements--from 36% in 1975 to 63% in 1976--is not caused by a proportionately large increase in the number of HBD involvements. Indeed, the HBD frequencies for 1974-1976 are 29, 29, and 32. The frequencies of HNBD involvements for the same three years, however, are 34, 51, and 19. Therefore the denominator of the 1976 fraction--the sum of the HBD and HNBD frequencies--is much lower than usual, thus accounting for the elevated HBD rate.

We now turn to a more detailed look at these age-year patterns among drivers involved in fatal accidents.

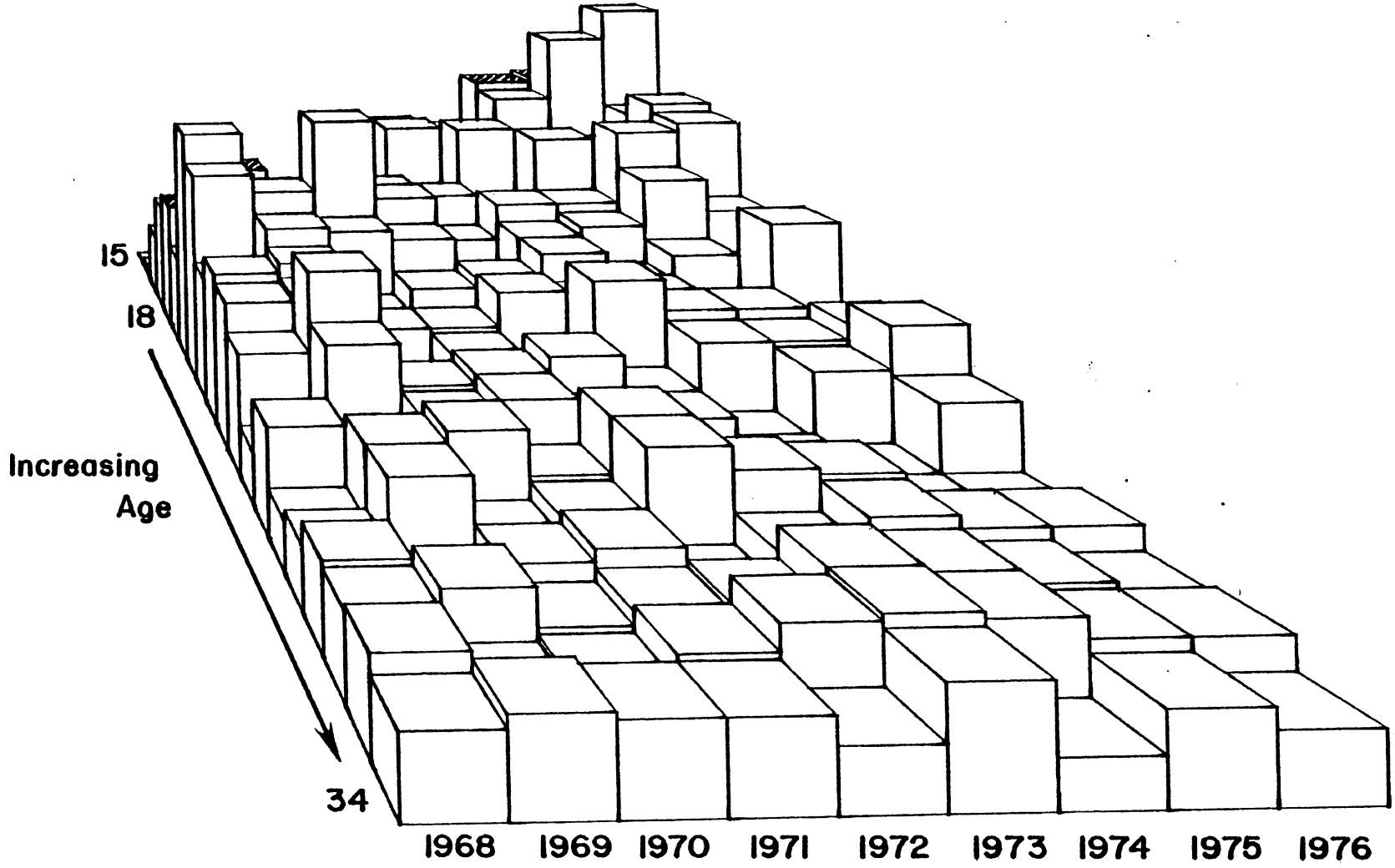



FIGURE 1. Overview of HBD frequencies by age and year.

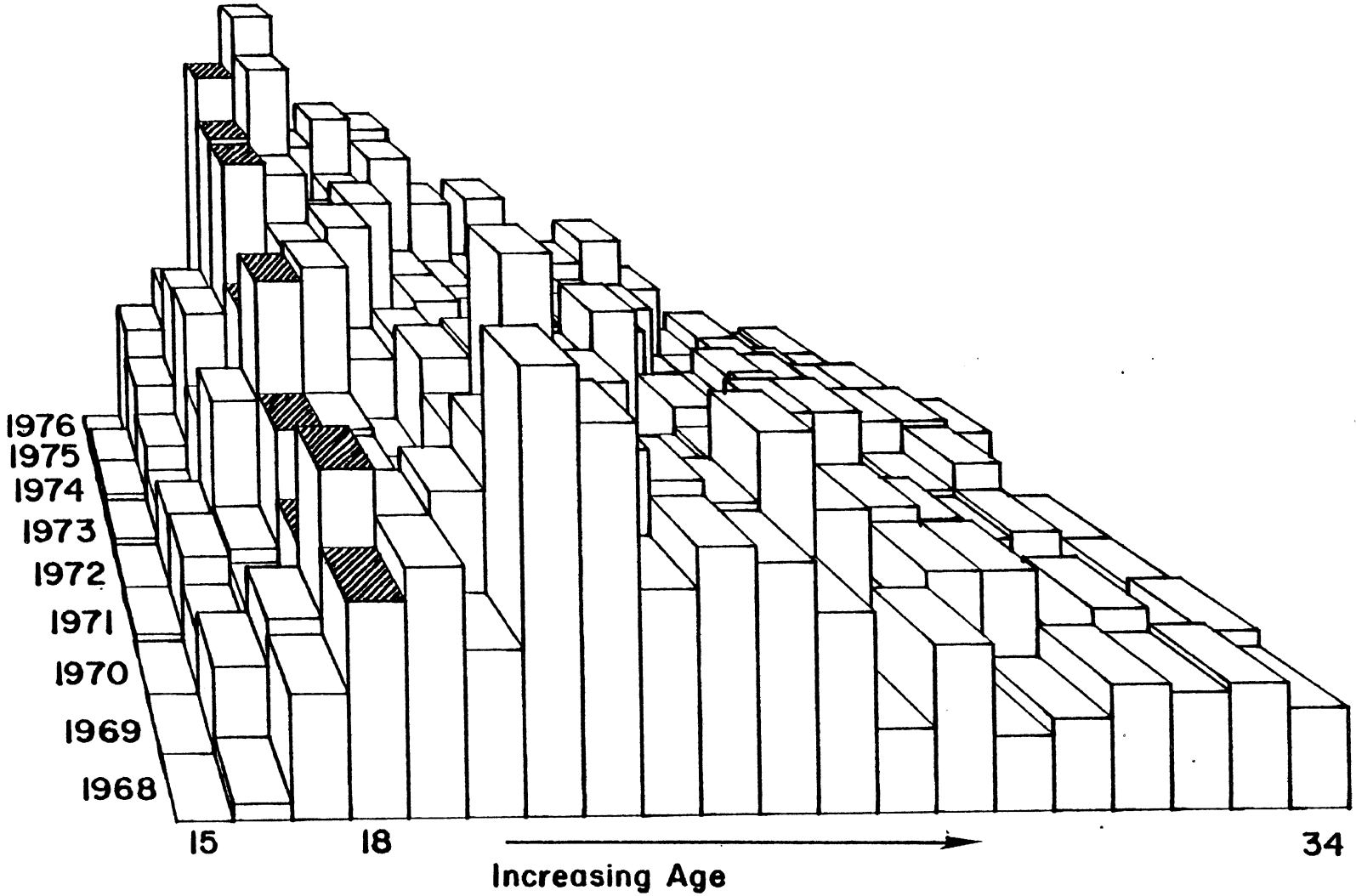



FIGURE 2. Second overview of HBD experience (relative frequencies).

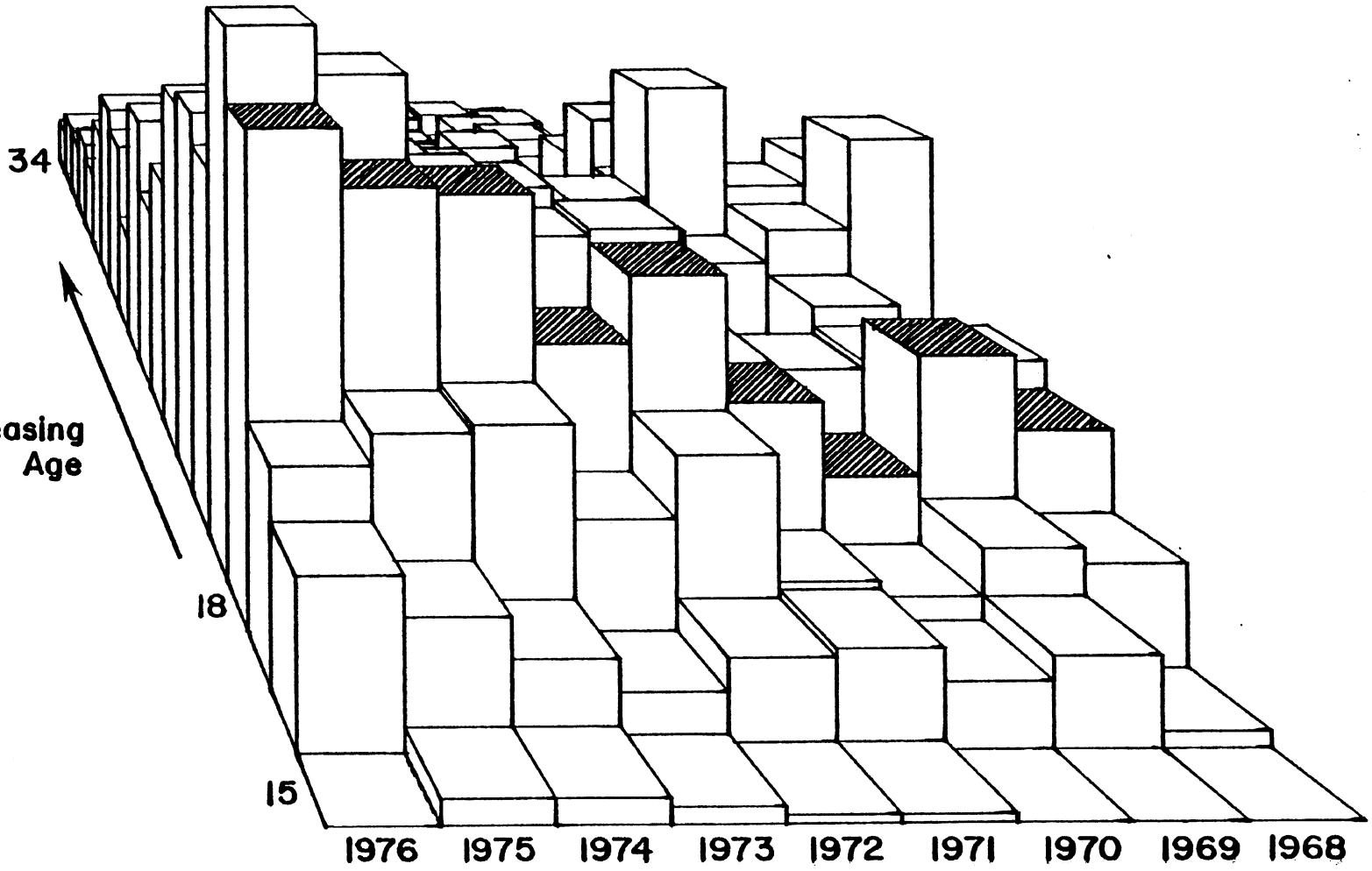



FIGURE 3. Third overview of HBD experience (relative frequencies).

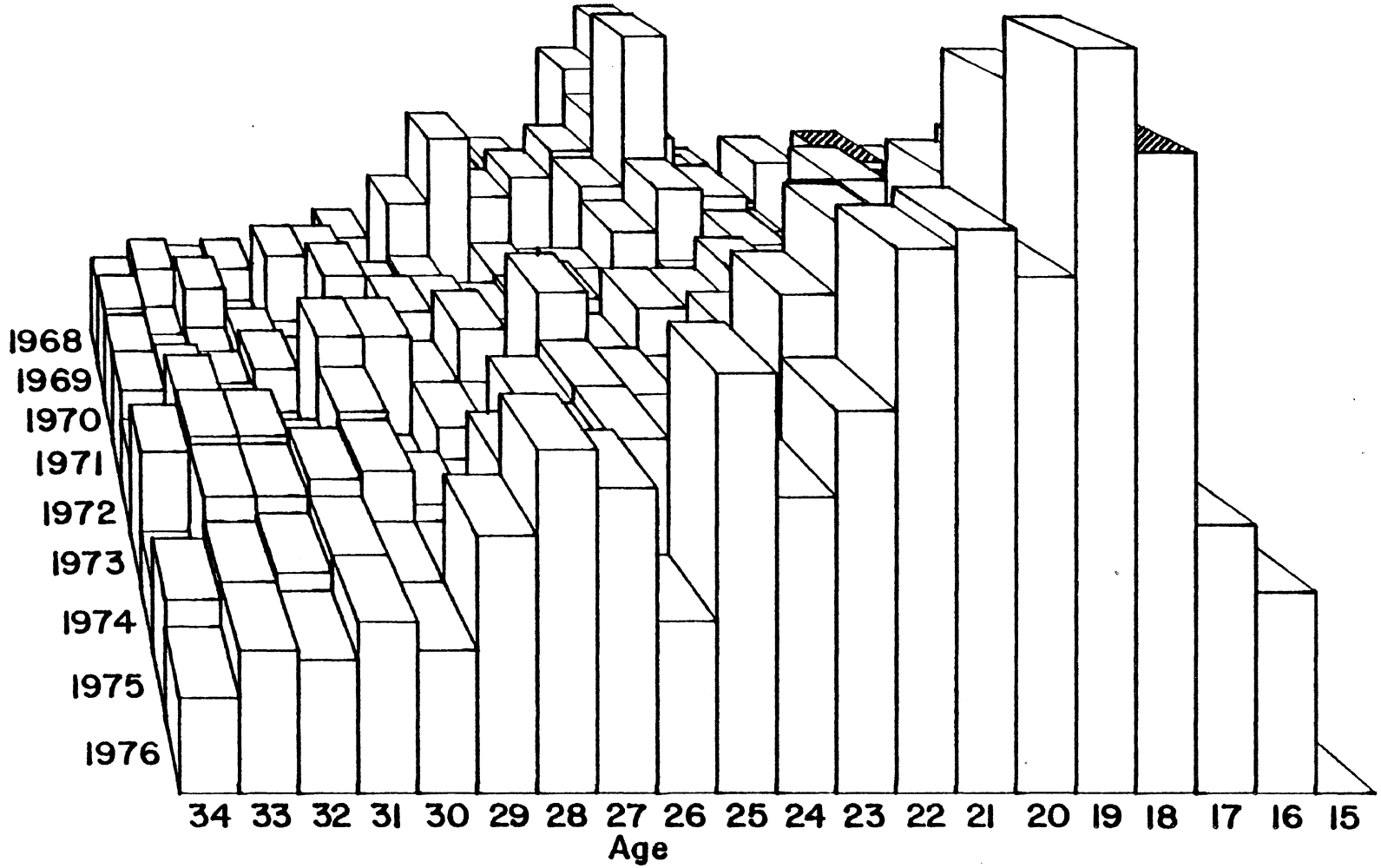



FIGURE 4. Fourth overview of HBD experience (relative frequencies).

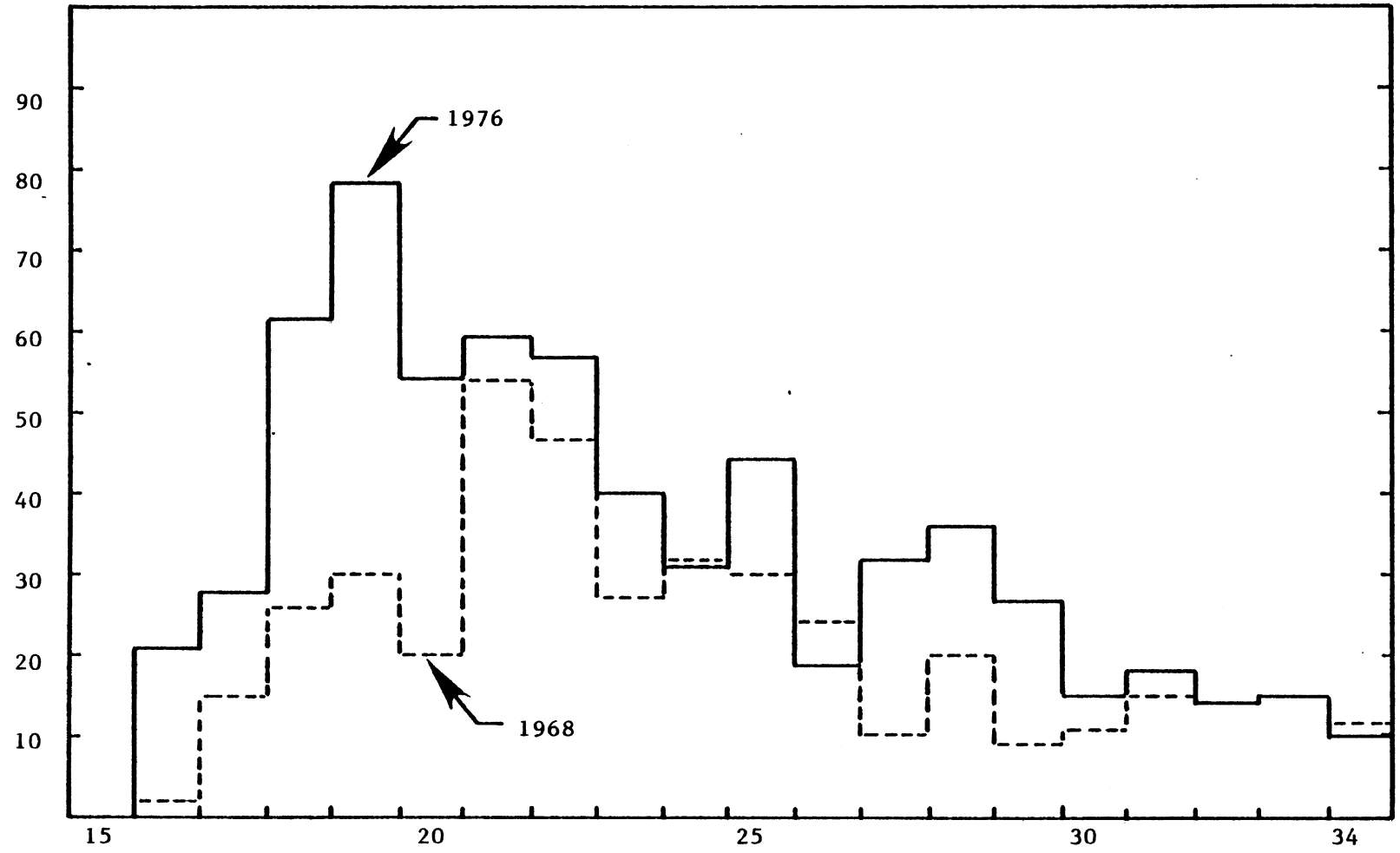



FIGURE 5 HBD Frequencies for 1968 and 1976 Fatal Drivers Aged 15-34
1968 and 1976 Fatals

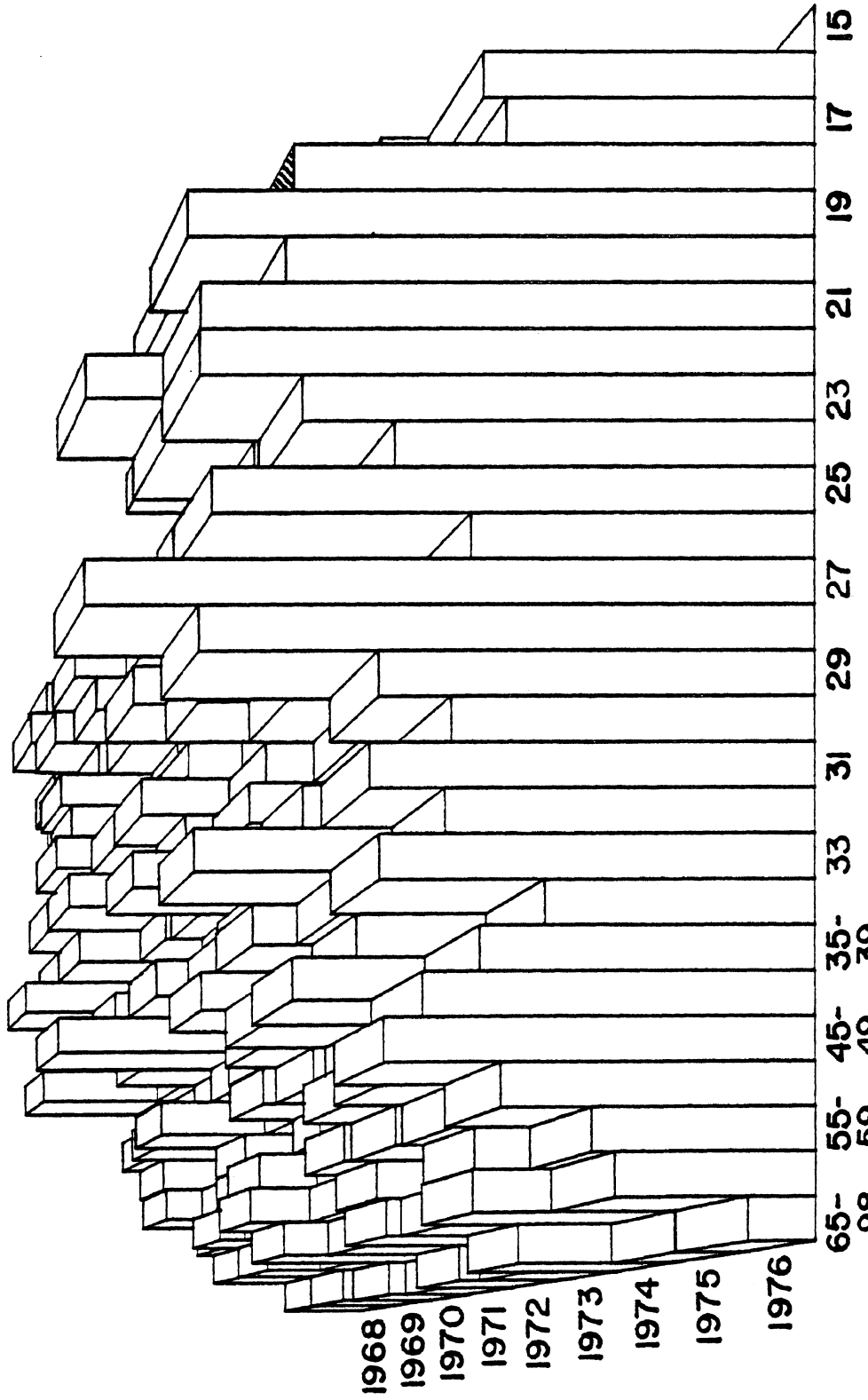



FIGURE 6. Overview of HBD rates by age and year.

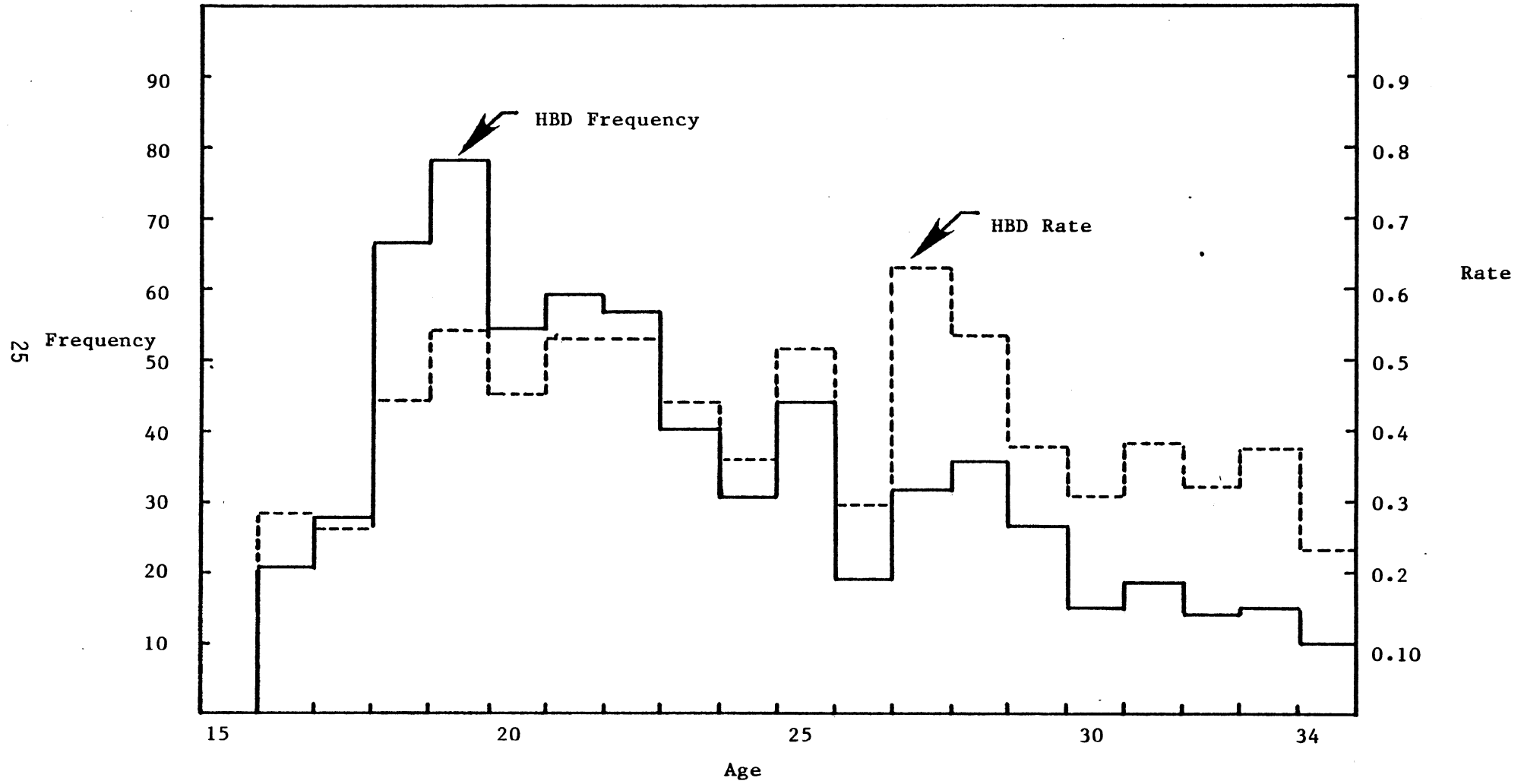



FIGURE 7 HBD Frequencies and Rates for 1976 Fatal Drivers

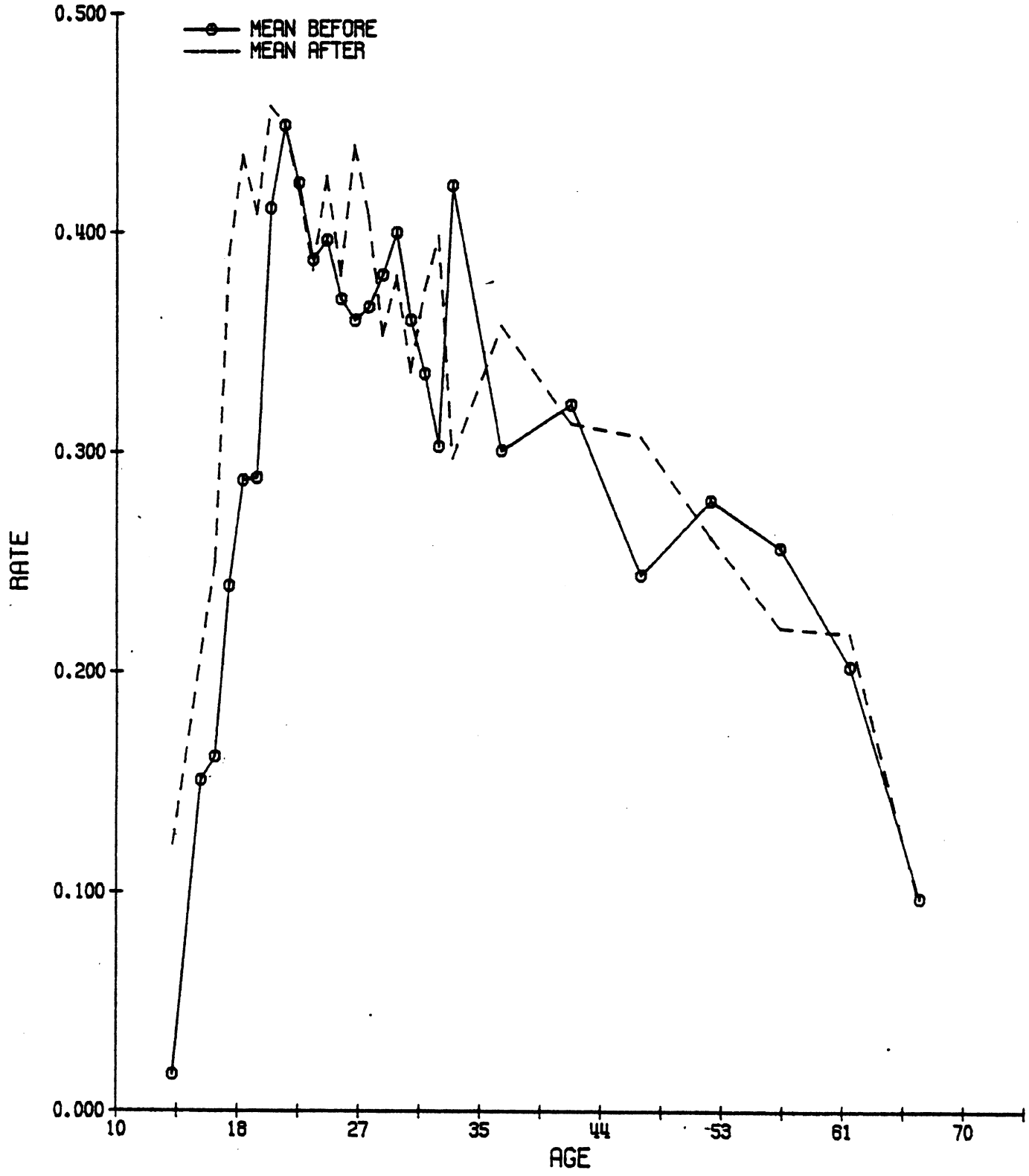
## 3.1 Overall HBD Rates among Drivers in Fatal Accidents

During the years 1968 to 1971 the overall rate of HBD among drivers involved in fatal accidents in Michigan averaged 29.6%. During the period from 1972 to 1976, this rate averaged 33.5%. This represents a 13.2% increase or a raising of the HBD rate by 3.9%. These rates were calculated from the set of drivers involved in fatal crashes in Michigan, excluding cases for which information about the drinking status of the driver was missing or unknown. There were some noticeable changes in the amount of missing data on the HBD variable over the period from 1968 to 1976. During the period prior to the change in the legal drinking age, the missing-data rate averaged 20.7% of the drivers, while in the post-law period this dropped to 6%. Much of this decrease took place with the introduction of the FARS in 1974—missing-data rates from 1968 through 1970 were similar, then dropped in 1971 and again in 1974.

The relationship between the HBD rate and the age of the driver is of interest. The traditionally reported view is that drivers in their early twenties are the worst—that is, have the highest HBD rate. While this is not contradicted, it is useful to attempt to describe the relationship of alcohol crash involvement and age in more detail. In addition, an important question is what—if any—changes in this relationship coincided with the enactment of the lower legal drinking age law. The HBD rates for single ages or single years were found to vary considerably. Plots of the HBD rates across ages for each year are presented as Figures B1-B9 in Appendix B.

In order to stabilize the rates somewhat and to illustrate the changes better, data were collapsed into two periods: pre-law, or 1968-71, and post-law, or 1972-76. Figure 8 plots the average rates for each age for these two periods. Single years of age are used from ages 16 to 34, while the remainder are in 5-year intervals. The general pattern is for a low HBD rate for young, neophyte drivers, followed by a rapid increase with the age of the driver to a pronounced peak. The HBD rate then begins to decline steadily. The decline, however, is not so rapid with age as is the initial increase. The HBD rate appears to peak in the early twenties, then to decline with age, slowly at first, then more rapidly after age 35 or so.

The most noticeable difference in the two curves is that the sharp




RATE OF HBD (NO MISSING DATA)
MEAN RATE BEFORE AND AFTER LAW CHANGE
FATAL FILE

FIGURE 8

increase takes place at younger ages in the post-law period. Ages 18, 19, and 20 have nearly the same HBD rates in the post-law period as do ages 21, 22, and 23, while in the pre-law period, these ages had substantially lower HBD rates than the 21, 22, and 23 ages. The HBD rates for all ages less than 22 are higher in the post-law period than in the pre-law period. Differences in older ages show no consistent pattern. Many of the differences are not noticeably different from zero, and those which are, are as likely to be negative as positive.

As mentioned before, the missing-data rates changed significantly during this period. This could affect the HBD rates. Figure 9 plots the missing-data rates against the age of the driver for three time periods: 1968-71, 1972-73, and 1974-76. Some reduction occurred between the first two periods, and an additional reduction occurred between the second two periods. The missing-data rates seem to be fairly stable across the ages. Since the introduction of the FARS in 1974 seemed to reduce the missing data, the relationship of the HBD rates to the age of the driver was examined for the three time periods. This is presented in Figure 10. The same general pattern is observed as before. The main difference is that the young drivers have higher HBD rates in the 1974-76 period than in the 1972-73 period, which are still increased over the pre-law period.

The energy crisis, with a reduction in the availability of gasoline, occurred at approximately the same time as the introduction of the FARS. Thus changes at that time may be associated with the effects of the energy crisis as well as with the reduction in the missing data. Table 5 presents the frequencies of drivers involved in fatal crashes by age and year. A generally decreasing trend in the total number of such involvements is seen over the nine-year period. A particularly sharp drop occurred in 1974 and maintained in 1975, with some increase noted in 1976. This drop may be related to the reduction in travel associated with the energy crisis.

Table 6 presents the frequencies of drivers who had been drinking by age and year. An increase in these frequencies is noted in 1973, followed by a further increase in 1974 and possibly one in 1976. These increases are paralleled by and may be primarily due to increases in the frequencies of HBD drivers in the 18 to 20 ages. Thus, over the period in question, the number of drivers involved in fatal crashes has declined, while the number

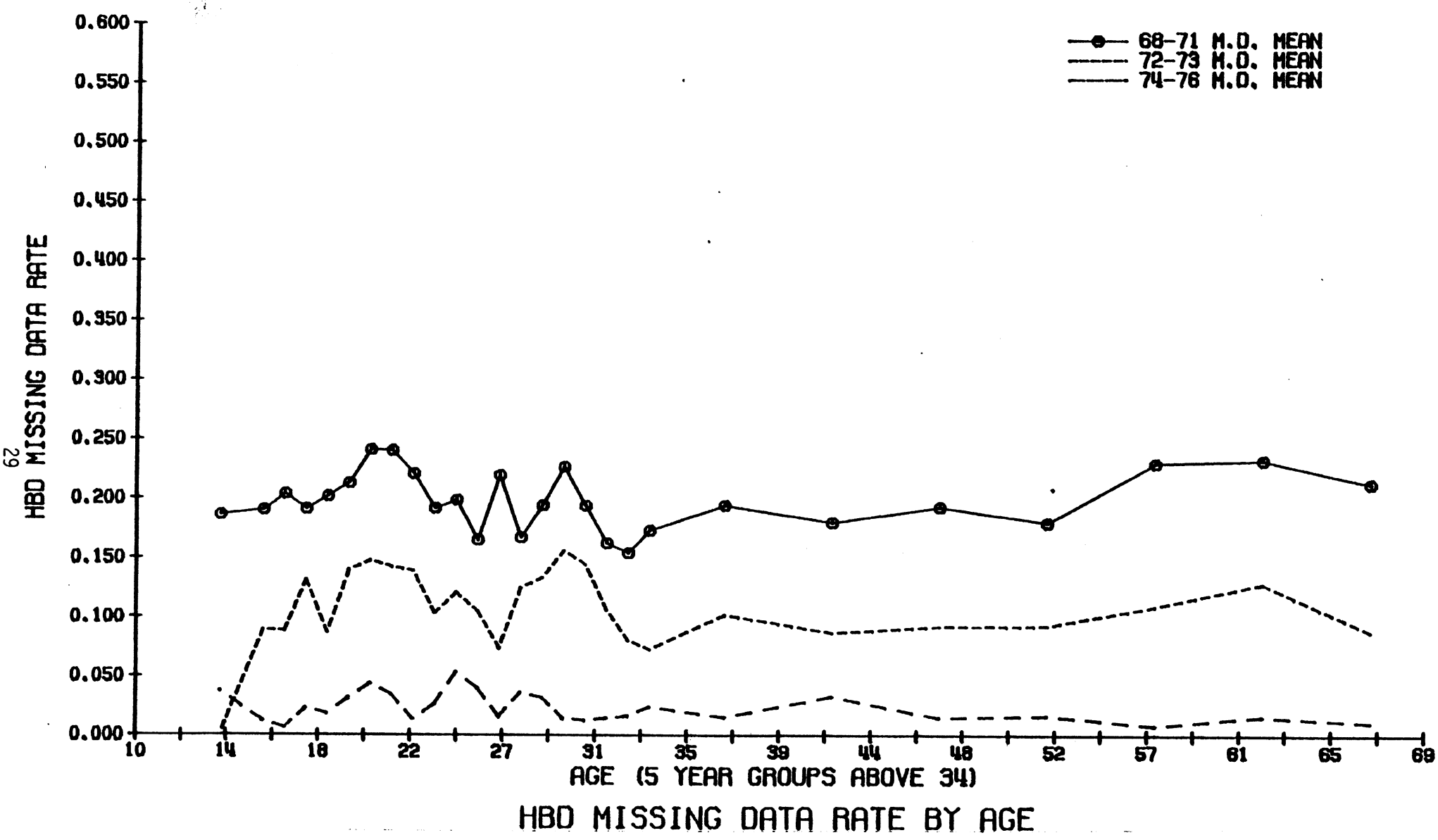

68-71 M.O. MEAN
72-73 M.O. MEAN
74-76 M.O. MEAN
HBD MISSING DATA RATE
0.600
0.550
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
10
14
18
22
27
31
35
39
44
48
52
57
61
65
69
AGE (5 YEAR GROUPS ABOVE 34)
HBD MISSING DATA RATE BY AGE

FIGURE 9

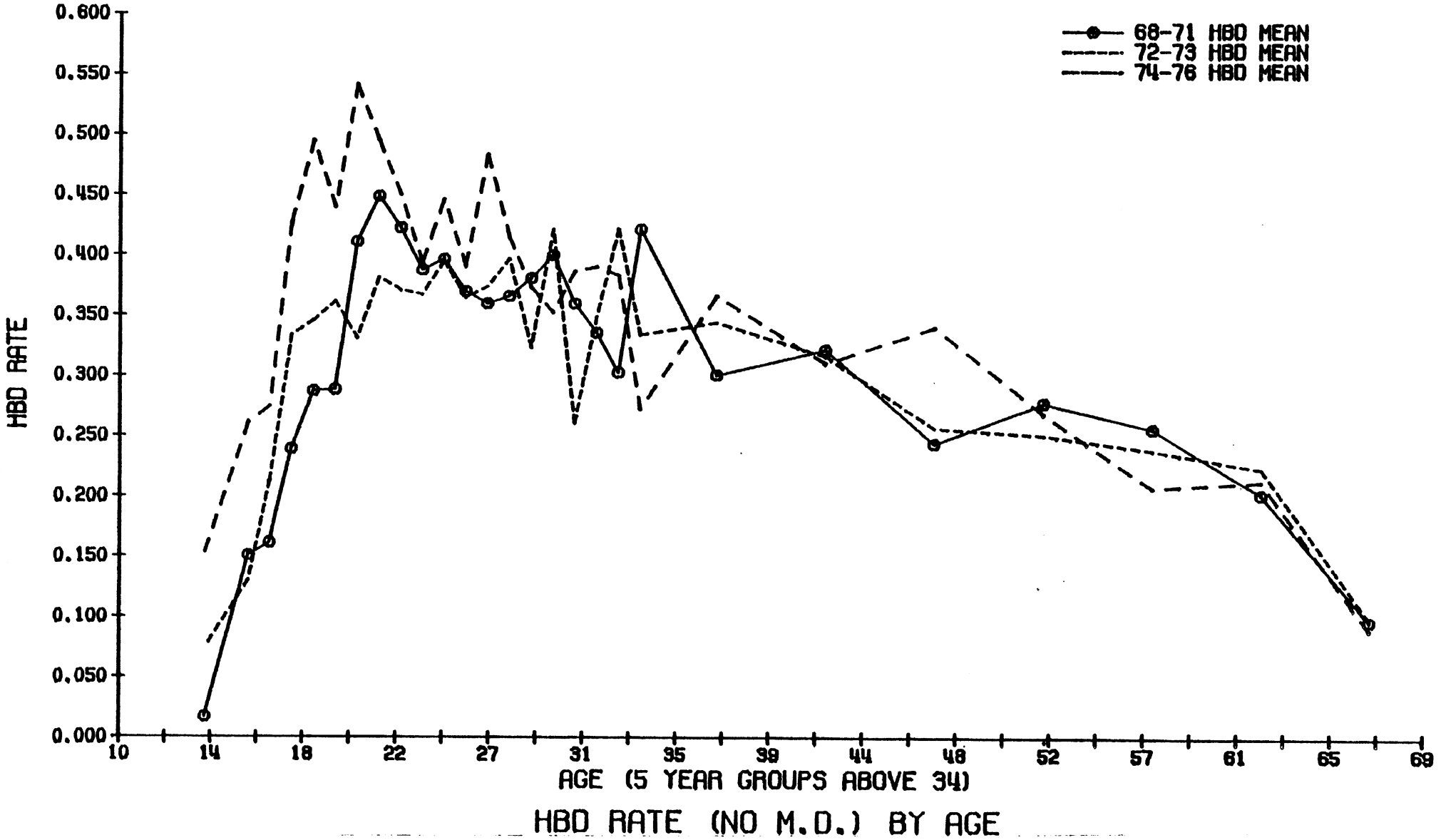

68-71 HBD MEAN
72-73 HBD MEAN
74-76 HBD MEAN
HBD RATE
0.600
0.550
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
10
14
18
22
27
31
35
39
44
48
52
57
61
65
69
AGE (5 YEAR GROUPS ABOVE 34)
HBD RATE (NO M.D.) BY AGE

FIGURE 10

Table 5

Frequency of Drivers in the Michigan Fatal Files, 1968-1976

| AGE | YEAR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| 1-15 | 8 | 16 | 11 | 16 | 21 | 20 | 11 | 16 | 9 |
| 16 | 59 | 82 | 54 | 69 | 84 | 66 | 65 | 50 | 74 |
| 17 | 119 | 124 | 104 | 92 | 136 | 120 | 124 | 109 | 108 |
| 18 | 164 | 163 | 137 | 120 | 150 | 142 | 147 | 138 | 156 |
| 19 | 137 | 137 | 126 | 122 | 165 | 143 | 132 | 138 | 151 |
| 20 | 91 | 124 | 96 | 117 | 130 | 144 | 107 | 85 | 122 |
| 21 | 173 | 139 | 119 | 114 | 140 | 109 | 105 | 87 | 117 |
| 22 | 137 | 150 | 156 | 116 | 97 | 117 | 92 | 109 | 113 |
| 23 | 105 | 100 | 105 | 107 | 84 | 94 | 79 | 108 | 93 |
| 24 | 94 | 100 | 76 | 108 | 93 | 104 | 67 | 90 | 91 |
| 25 | 93 | 91 | 84 | 77 | 91 | 82 | 68 | 64 | 91 |
| 26 | 89 | 112 | 62 | 70 | 62 | 83 | 77 | 69 | 65 |
| 27 | 63 | 83 | 69 | 81 | 73 | 62 | 64 | 81 | 52 |
| 28 | 68 | 60 | 72 | 62 | 54 | 63 | 55 | 70 | 71 |
| 29 | 48 | 55 | 62 | 61 | 73 | 63 | 44 | 45 | 74 |
| 30 | 37 | 63 | 43 | 49 | 67 | 68 | 51 | 46 | 49 |
| 31 | 44 | 37 | 58 | 55 | 53 | 58 | 55 | 45 | 47 |
| 32 | 52 | 59 | 45 | 41 | 49 | 56 | 52 | 32 | 45 |
| 33 | 51 | 45 | 39 | 51 | 43 | 53 | 44 | 42 | 41 |
| 34 | 41 | 52 | 36 | 28 | 40 | 43 | 30 | 38 | 45 |
| 35-39 | 238 | 224 | 211 | 196 | 211 | 194 | 155 | 157 | 155 |
| 40-44 | 221 | 234 | 216 | 187 | 187 | 183 | 139 | 123 | 143 |
| 45-49 | 201 | 216 | 169 | 206 | 176 | 184 | 122 | 109 | 123 |
| 50-54 | 172 | 195 | 162 | 144 | 130 | 156 | 123 | 106 | 123 |
| 55-59 | 143 | 163 | 121 | 118 | 144 | 106 | 97 | 82 | 85 |
| 60-64 | 98 | 112 | 85 | 89 | 99 | 96 | 91 | 59 | 76 |
| 65-98 | 218 | 242 | 201 | 189 | 214 | 190 | 140 | 134 | 174 |
| Unk. | 36 | 25 | 23 | 20 | 12 | 21 | 14 | 14 | 26 |
| 15-17 | 186 | 222 | 169 | 177 | 241 | 206 | 200 | 175 | 191 |
| 18-20 | 392 | 424 | 359 | 359 | 445 | 429 | 386 | 361 | 429 |
| 21-23 | 415 | 389 | 380 | 337 | 321 | 320 | 276 | 304 | 323 |
| 24-26 | 276 | 303 | 222 | 255 | 246 | 269 | 212 | 223 | 247 |
| All | 3000 | 3203 | 2742 | 2705 | 2878 | 2820 | 2350 | 2246 | 2519 |

of drivers involved in fatal crashes who have been drinking has increased. The HBD rate then increases both because the numerator is increasing and the denominator is decreasing. Table 7 presents the frequencies of drivers who had not been drinking by age and year, and Table 8 presents the frequencies of the drivers with missing data on the HBD variable by the same categories.

Table 6

Frequency of HBD Drivers in the Michigan Fatal Files, 1968-1976

| AGE | YEAR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| Age 1-15 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 0 |
| Age 16 | 2 | 11 | 8 | 12 | 11 | 7 | 11 | 16 | 21 |
| Age 17 | 15 | 17 | 11 | 13 | 29 | 21 | 33 | 32 | 28 |
| Age 18 | 26 | 36 | 20 | 30 | 47 | 38 | 58 | 59 | 67 |
| Age 19 | 30 | 30 | 29 | 30 | 49 | 48 | 56 | 71 | 78 |
| Age 20 | 20 | 33 | 19 | 26 | 35 | 51 | 48 | 33 | 54 |
| Age 21 | 54 | 40 | 35 | 40 | 38 | 32 | 51 | 49 | 59 |
| Age 22 | 47 | 43 | 59 | 41 | 31 | 39 | 39 | 55 | 57 |
| Age 23 | 27 | 38 | 37 | 35 | 22 | 35 | 37 | 47 | 40 |
| Age 24 | 32 | 34 | 23 | 28 | 30 | 35 | 29 | 34 | 31 |
| Age 25 | 30 | 31 | 24 | 24 | 31 | 29 | 30 | 22 | 44 |
| Age 26 | 24 | 40 | 17 | 23 | 13 | 37 | 31 | 31 | 18 |
| Age 27 | 10 | 30 | 22 | 24 | 27 | 20 | 29 | 29 | 32 |
| Age 28 | 20 | 15 | 21 | 24 | 20 | 20 | 16 | 28 | 36 |
| Age 29 | 9 | 22 | 24 | 16 | 26 | 13 | 17 | 15 | 27 |
| Age 30 | 11 | 22 | 12 | 15 | 26 | 22 | 21 | 15 | 15 |
| Age 31 | 15 | 10 | 14 | 16 | 10 | 15 | 20 | 18 | 18 |
| Age 32 | 14 | 17 | 11 | 13 | 14 | 19 | 18 | 16 | 14 |
| Age 33 | 15 | 9 | 10 | 14 | 18 | 19 | 18 | 15 | 15 |
| Age 34 | 12 | 14 | 13 | 13 | 9 | 17 | 7 | 13 | 10 |
| Age35-39 | 56 | 51 | 50 | 53 | 62 | 63 | 62 | 64 | 43 |
| Age40-44 | 55 | 62 | 67 | 42 | 55 | 52 | 41 | 35 | 46 |
| Age45-49 | 48 | 40 | 35 | 31 | 40 | 44 | 39 | 35 | 45 |
| Age50-54 | 39 | 39 | 36 | 38 | 26 | 40 | 33 | 28 | 32 |
| Age55-59 | 23 | 31 | 22 | 31 | 30 | 23 | 18 | 20 | 16 |
| Age60-64 | 15 | 15 | 9 | 21 | 18 | 20 | 20 | 14 | 13 |
| Age65-98 | 17 | 20 | 15 | 13 | 22 | 15 | 21 | 8 | 10 |
| Age Unk | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 5 |
| Age15-17 | 17 | 28 | 19 | 26 | 41 | 30 | 47 | 51 | 49 |
| Age18-20 | 76 | 99 | 68 | 86 | 131 | 137 | 162 | 163 | 199 |
| Age21-23 | 128 | 121 | 131 | 116 | 91 | 106 | 127 | 151 | 156 |
| Age24-26 | 86 | 105 | 64 | 75 | 74 | 101 | 90 | 87 | 93 |
| All Ages | 666 | 750 | 643 | 668 | 741 | 776 | 806 | 807 | 874 |

In summary, among drivers in fatal crashes during the post-law period, there has been an increase in the HBD rates for drivers of age 21 and younger, while the HBD rates for drivers older than 21 have remained essentially unchanged as compared to the rates during the pre-law period. As a result, the overall rate of HBD among drivers involved in fatal crashes

Table 7

Frequency of HNBD Drivers in the Michigan Fatal Files, 1968-1976

| AGE | YEAR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| 1-15 | 6 | 12 | 9 | 14 | 20 | 18 | 8 | 13 | 8 |
| 16 | 45 | 49 | 39 | 46 | 67 | 52 | 53 | 33 | 53 |
| 17 | 73 | 73 | 73 | 71 | 100 | 84 | 91 | 77 | 78 |
| 18 | 93 | 94 | 96 | 74 | 87 | 82 | 89 | 75 | 83 |
| 19 | 68 | 73 | 78 | 77 | 99 | 85 | 76 | 65 | 67 |
| 20 | 44 | 70 | 54 | 74 | 75 | 75 | 58 | 47 | 65 |
| 21 | 65 | 69 | 51 | 56 | 80 | 62 | 51 | 33 | 53 |
| 22 | 52 | 55 | 66 | 59 | 55 | 58 | 51 | 50 | 51 |
| 23 | 40 | 43 | 46 | 59 | 53 | 43 | 42 | 59 | 51 |
| 24 | 40 | 48 | 34 | 69 | 51 | 61 | 38 | 54 | 55 |
| 25 | 40 | 36 | 45 | 45 | 47 | 45 | 37 | 37 | 41 |
| 26 | 43 | 49 | 34 | 45 | 42 | 38 | 45 | 35 | 43 |
| 27 | 34 | 34 | 35 | 43 | 40 | 38 | 34 | 51 | 19 |
| 28 | 38 | 30 | 42 | 29 | 24 | 39 | 37 | 40 | 32 |
| 29 | 26 | 24 | 26 | 36 | 38 | 41 | 26 | 28 | 45 |
| 30 | 14 | 28 | 21 | 27 | 30 | 36 | 30 | 30 | 33 |
| 31 | 16 | 19 | 34 | 34 | 35 | 35 | 33 | 27 | 29 |
| 32 | 29 | 26 | 27 | 26 | 29 | 32 | 33 | 16 | 30 |
| 33 | 27 | 27 | 22 | 34 | 23 | 28 | 26 | 26 | 25 |
| 34 | 14 | 31 | 20 | 12 | 28 | 23 | 23 | 24 | 33 |
| 35-39 | 126 | 125 | 119 | 118 | 129 | 110 | 93 | 92 | 106 |
| 40-44 | 113 | 118 | 114 | 129 | 115 | 116 | 97 | 83 | 90 |
| 45-49 | 110 | 134 | 95 | 148 | 119 | 124 | 83 | 71 | 76 |
| 50-54 | 91 | 115 | 98 | 93 | 90 | 104 | 89 | 78 | 86 |
| 55-59 | 79 | 86 | 72 | 72 | 99 | 71 | 79 | 62 | 67 |
| 60-64 | 59 | 58 | 56 | 59 | 67 | 65 | 71 | 43 | 62 |
| 65-98 | 145 | 162 | 139 | 155 | 177 | 155 | 118 | 125 | 161 |
| Unk. | 0 | 3 | 2 | 3 | 2 | 4 | 5 | 4 | 6 |
| 15-17 | 124 | 134 | 121 | 131 | 187 | 154 | 152 | 123 | 139 |
| 18-20 | 205 | 237 | 228 | 225 | 261 | 242 | 223 | 187 | 215 |
| 21-23 | 157 | 167 | 163 | 174 | 188 | 163 | 144 | 142 | 155 |
| 24-26 | 123 | 133 | 113 | 159 | 140 | 144 | 120 | 126 | 139 |
| All | 1530 | 1691 | 1547 | 1707 | 1821 | 1724 | 1516 | 1378 | 1548 |

has increased. The number of drivers in this group who had been drinking has increased generally since the law change, while the number of drivers involved in fatal accidents has tended to decline. The increase in the number of drivers involved in fatal accidents who had been drinking has been

Table 8

Frequency of HBD Missing Data on Drivers

in the Michigan Fatal Files, 1968-1976

| AGE | YEAR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| 1-15 | 2 | 4 | 2 | 1 | 0. | 0. | 0. | 0. | 1 |
| 16 | 12 | 22 | 7 | 11 | 6 | 7 | 1 | 1 | 0. |
| 17 | 31 | 34 | 20 | 8 | 7 | 15 | 0. | 0. | 2 |
| 18 | 45 | 33 | 21 | 16 | 16 | 22 | 0. | 4 | 6 |
| 19 | 39 | 34 | 19 | 15 | 17 | 10 | 0. | 2 | 6 |
| 20 | 27 | 21 | 23 | 17 | 20 | 18 | 1 | 5 | 3 |
| 21 | 54 | 30 | 33 | 18 | 22 | 15 | 3 | 5 | 5 |
| 22 | 38 | 52 | 31 | 16 | 11 | 20 | 2 | 4 | 5 |
| 23 | 38 | 19 | 22 | 13 | 9 | 16 | 0. | 2 | 2 |
| 24 | 22 | 18 | 19 | 11 | 12 | 8 | 0. | 2 | 5 |
| 25 | 23 | 24 | 15 | 8 | 13 | 8 | 1 | 5 | 6 |
| 26 | 22 | 23 | 11 | 2 | 7 | 8 | 1 | 3 | 4 |
| 27 | 19 | 19 | 12 | 14 | 6 | 4 | 1 | 1 | 1 |
| 28 | 10 | 15 | 9 | 9 | 10 | 4 | 2 | 2 | 3 |
| 29 | 13 | 9 | 12 | 9 | 9 | 9 | 1 | 2 | 2 |
| 30 | 12 | 13 | 10 | 7 | 11 | 10 | 0. | 1 | 1 |
| 31 | 13 | 8 | 10 | 5 | 8 | 8 | 2 | 0. | 0. |
| 32 | 9 | 16 | 7 | 2 | 6 | 5 | 1 | 0. | 1 |
| 33 | 9 | 9 | 7 | 3 | 2 | 6 | 0. | 1 | 1 |
| 34 | 15 | 7 | 3 | 3 | 3 | 3 | 0. | 1 | 2 |
| 35-39 | 56 | 48 | 42 | 25 | 20 | 21 | 0. | 1 | 6 |
| 40-44 | 53 | 54 | 35 | 16 | 17 | 15 | 1 | 5 | 7 |
| 45-49 | 43 | 42 | 39 | 27 | 17 | 16 | 0. | 3 | 2 |
| 50-54 | 42 | 41 | 28 | 13 | 14 | 12 | 1 | 0. | 5 |
| 55-59 | 41 | 46 | 27 | 15 | 15 | 12 | 0. | 0. | 2 |
| 60-64 | 24 | 39 | 20 | 9 | 14 | 11 | 0. | 2 | 1 |
| 65-98 | 56 | 60 | 47 | 21 | 15 | 20 | 1 | 1 | 3 |
| Unk. | 36 | 22 | 21 | 16 | 9 | 17 | 9 | 8 | 15 |
| 15-17 | 45 | 60 | 29 | 20 | 13 | 22 | 1 | 1 | 3 |
| 18-20 | 111 | 88 | 63 | 48 | 53 | 50 | 1 | 11 | 15 |
| 21-23 | 130 | 101 | 86 | 47 | 42 | 51 | 5 | 11 | 12 |
| 24-26 | 67 | 65 | 45 | 21 | 32 | 24 | 2 | 10 | 15 |
| All | 804 | 762 | 552 | 330 | 316 | 320 | 28 | 61 | 97 |

particularly noticeable among younger (ages 18-20) drivers. This young group has also showed an increase in the number of involvements in fatal accidents while the overall trend, for all ages, has been downward.

## 3.2 HBD Rates by Age of Driver

In order to determine whether differences in proportions of HBD are significantly different across the nine years, the chi-square statistic is used. The overall chi-square test measures whether there are differences in the year-to-year HBD rates from the nine-year average HBD rate which are too large to have arisen because of chance fluctuations in the data. However, somewhat more detailed information about the differences in the HBD rates is needed. That is, there is a need to compare the HBD rates for various groups of years to determine whether significant changes in the HBD rates occurred at the same times as the known occurrences which are of interest, such as the law change or the form change.

A method of investigating whether changes in the HBD rates occurred at specific time points defined by external events is available through the technique of partitioning the overall chi-square into its individual degrees of freedom. The formula for this computation and an example for the two by k table are presented in Appendix A. A computer program which will accomplish the required calculations also is documented in Appendix A.

The divisions of the time period from 1968 to 1976 which were made and used to partition the overall chi-square are given in Table 9. These eight partitions can be used to investigate whether a significant change in the HBD rate occurred between the two time periods defining the partition. Each age of driver and some combined age groups were investigated in this manner. The results indicate which age groups showed significant changes in their HBD rates and which events these changes coincided with. Within each age or age group, an overall type one error probability of 5% was used. That is, considering all eight partitions for, say, the 18-year-old drivers, the probability of declaring any one (or more) of these partitions to be significant when actually due merely to chance is only 5%.

Table 10 lists all the partitions which were found to be significant by this method. The partitions are listed for each age or age group in order of increasing age. The average proportion of HBD for each of the groups in the partition is presented. The HBD rates for each age, age group, and each year are presented in Table 11, while the frequencies of HBD, HNBD, and missing data for the fatals are presented by age group and year in Tables 6, 7, and 8, respectively.

Table 9

Definition of Partitions

| Partition Number | Dates | Interpretation |
|---|---|---|
| 1 | 1968-71 vs 1972-76 | Before and after the change in legal drinking age. |
| 2 | 1972-73 vs 1974-76 | After the change in legal drinking age, before and after the introduction of FARS: also coincides with the energy crisis. |
| 3 | 1972 vs 1973 | Compares the first two years after the change in the legal drinking age. |
| 4 | 1974 vs 1975-6 | Compares the year of maximum impact of the energy crisis with the two most recent years. |
| 5 | 1975 vs 1976 | Compares the two most recent years. |
| 6 | 1968-70 vs 1971 | Compares the years immediately prior to the first year with a new data form—all before the law change. |
| 7 | 1968 vs 1969 | No external criteria. |
| 8 | 1968-9 vs 1970 | No external criteria. |

Intuitively, 18 to 20 are the ages most obviously affected by the change in the legal drinking age. Drivers who were 18 at the time they were involved in a fatal accident showed a significant difference in the HBD rate only for the groups in partition 1. That is, the HBD rate changed significantly only concurrently with the lower legal drinking age. The average proportion of HBD before the law change was 30.5%, while in the period since the law change it has averaged 39.3%, nearly a 29% increase in the rate.

Table 10

Summary of Significant Partitions in the Fatal Data,

HBD vs HNBD

| Age Group | Partition Number | Years Partitioned | | | Percent Change |
|---|---|---|---|---|---|
| 16 | 2 | 1972-73 | vs | 1974-76 | 13.1% to 25.6% |
| 17 | 1 | 1968-71 | vs | 1972-76 | 16.2% to 25.0% |
| 18 | 1 | 1968-71 | vs | 1972-76 | 30.5% to 39.3% |
| 19 | 1 | 1968-71 | vs | 1972-76 | 28.7% to 43.5% |
| | 2 | 1972-73 | vs | 1974-76 | 34.5% to 49.6% |
| 20 | 1 | 1968-71 | vs | 1972-76 | 28.8% to 40.9% |
| 21 | 2 | 1972-73 | vs | 1974-76 | 33.0% to 53.7% |
| 26 | 3 | 1972 | vs | 1973 | 23.6% to 49.3% |
| 27 | 5 | 1975 | vs | 1976 | 36.3% to 62.8% |
| 15-17 | 1 | 1968-71 | vs | 1972-76 | 15.0% to 22.4% |
| | 2 | 1972-73 | vs | 1974-76 | 17.2% to 26.2% |
| 18-20 | 1 | 1968-71 | vs | 1972-76 | 26.9% to 41.3% |
| | 2 | 1972-73 | vs | 1974-76 | 34.8% to 45.6% |
| 21-23 | 2 | 1972-73 | vs | 1974-76 | 35.9% to 49.6% |

The overall chi-square statistic was significant for the 45- to 49-year olds but none of the individual partitions was significant.

Drivers aged 19 at the time of their accident showed two significant changes in their HBD rate over the years 1968-76. These coincided with partitions numbered 1 and 2. The former is the time at which the lower legal drinking age went into effect, while the latter coincides with the reduction of missing data associated with the FARS and with the onset of the energy crisis.

Table 11

HBD Rate of Drivers in the Michigan Fatal Files, 1968-1976

| AGE | YEAR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| 1-15 | 0. | 0. | 0. | .0667 | .0476 | .1000 | .2727 | .1875 | 0. |
| 16 | .0426 | .1833 | .1702 | .2069 | .1410 | .1186 | .1719 | .3265 | .2838 |
| 17 | .1705 | .1889 | .1310 | .1548 | .2248 | .2000 | .2661 | .2936 | .2642 |
| 18 | .2185 | .2769 | .1724 | .2885 | .3507 | .3167 | .3946 | .4403 | .4467 |
| 19 | .3061 | .2913 | .2710 | .2804 | .3311 | .3609 | .4242 | .5221 | .5379 |
| 20 | .3125 | .3204 | .2603 | .2600 | .3182 | .4048 | .4528 | .4125 | .4538 |
| 21 | .4538 | .3670 | .4070 | .4167 | .3220 | .3404 | .5000 | .5976 | .5268 |
| 22 | .4747 | .4388 | .4720 | .4100 | .3605 | .4021 | .4333 | .5238 | .5278 |
| 23 | .4030 | .4691 | .4458 | .3723 | .2933 | .4487 | .4684 | .4434 | .4396 |
| 24 | .4444 | .4146 | .4035 | .2887 | .3704 | .3646 | .4328 | .3864 | .3605 |
| 25 | .4286 | .4627 | .3478 | .3478 | .3974 | .3919 | .4478 | .3729 | .5176 |
| 26 | .3582 | .4494 | .3333 | .3382 | .2364 | .4933 | .4079 | .4697 | .2951 |
| 27 | .2273 | .4688 | .3860 | .3582 | .4030 | .3448 | .4603 | .3625 | .6275 |
| 28 | .3448 | .3333 | .3333 | .4528 | .4545 | .3390 | .3019 | .4118 | .5294 |
| 29 | .2571 | .4783 | .4800 | .3077 | .4063 | .2407 | .3953 | .3488 | .3750 |
| 30 | .4400 | .4400 | .3636 | .3571 | .4643 | .3793 | .4118 | .3333 | .3125 |
| 31 | .4839 | .3448 | .2917 | .3200 | .2222 | .3000 | .3774 | .4000 | .3830 |
| 32 | .3256 | .3953 | .2895 | .3333 | .3256 | .3725 | .3529 | .5000 | .3182 |
| 33 | .3571 | .2500 | .3125 | .2917 | .4390 | .4043 | .4091 | .3659 | .3750 |
| 34 | .4615 | .3111 | .3939 | .5200 | .2432 | .4250 | .2333 | .3514 | .2326 |
| 35-39 | .3077 | .2898 | .2959 | .3099 | .3246 | .3642 | .4000 | .4103 | .2886 |
| 40-44 | .3274 | .3444 | .3702 | .2456 | .3235 | .3095 | .2971 | .2966 | .3382 |
| 45-49 | .3038 | .2299 | .2692 | .1732 | .2516 | .2619 | .3197 | .3302 | .3719 |
| 50-54 | .3000 | .2532 | .2687 | .2901 | .2241 | .2778 | .2705 | .2642 | .2712 |
| 55-59 | .2255 | .2650 | .2340 | .3010 | .2326 | .2447 | .1856 | .2439 | .1928 |
| 60-64 | .2027 | .2055 | .1385 | .2625 | .2118 | .2353 | .2198 | .2456 | .1733 |
| 65-98 | .1049 | .1099 | .0974 | .0774 | .1106 | .0882 | .1511 | .0602 | .0585 |
| unk. | 0. | 0. | 0. | .2500 | .3333 | 0. | 0. | .3333 | .4545 |
| 15-17 | .1206 | .1728 | .1357 | .1656 | .1798 | .1630 | .2362 | .2931 | .2606 |
| 18-20 | .2705 | .2946 | .2297 | .2765 | .3342 | .3615 | .4208 | .4657 | .4807 |
| 21-23 | .4491 | .4201 | .4456 | .4000 | .3262 | .3941 | .4686 | .5154 | .5016 |
| 24-26 | .4115 | .4412 | .3616 | .3205 | .3458 | .4122 | .4286 | .4085 | .4009 |
| All | .3033 | .3073 | .2936 | .2813 | .2892 | .3104 | .3471 | .3693 | .3609 |

The 19-year-old drivers showed an increase in HBD rate from 28.7% to 43.5% coincident with the lower legal drinking age. This represents more than a 51% increase. In addition, these drivers showed an increase in their HBD rate of from an average of 34.5% to 49.6% in comparing the years 1972 and 1973 with the years 1974-6. This represents nearly a 44% increase.

This latter increase is associated with the reduction in missing data associated with the implementation of the FARS and with the reduction in driving associated with the energy crisis period of approximately 1974.

Drivers aged twenty when involved in a fatal accident showed a significant increase coincident with the lowering of the legal drinking age. Their HBD rate increased from 28.8% to 40.9%. This represents a 42% increase in the HBD rate for this age.

Drivers in the age range of 18 to 20 all showed an increase in the average HBD rate which coincided with the change in the law lowering the legal drinking age to 18. Only one of the ages showed any other significant changes coinciding with the partitions defined in Table 9. The 19- year olds showed an additional increase two years after the law change. Thus, all the groups most directly affected by the law showed an increase in the HBD rate in fatal accidents coincident with the time of the law change. Furthermore, these increases were not of short duration—they have maintained through 1976. Indeed, some have increased further in recent years.

It is important to investigate what changes, if any, other ages experienced in their HBD rates during the period from 1968 to 1976. If all ages showed an increase in the HBD rate in 1972, then that would presumably be due to some external cause and not to the change in the law. Only three ages older than 20 showed any significant partitions. The drivers aged 21 showed an increase in their HBD rate when comparing 1972 and 1973 with 1974 through 1976. The average HBD rate increased from 33.0% to 53.7% in this comparison. This higher HBD rate coincides with the period when the FARS has been operating. Also, the first year of the higher rate was the energy crisis year. For drivers aged 26, there was a significant increase in HBD rate from 23.6% to 49.3% from 1972 to 1973. No reason for this increase is known. Drivers aged 27 showed a significant increase in their HBD rate from 36.3% to 62.8% from 1975 to 1976. The reason for this change was discussed earlier.

Thus, none of the ages or groups of ages older than 21 showed significant increases in HBD rates among fatal accidents at the time of the lowering of the legal drinking age. The only increases in HBD rates which occurred at that time occurred for drivers under age 21.

The experience of drivers of ages 16 and 17 has been of recent concern. Drivers aged 17 also showed a significant increase in their HBD rate coincident with the change in the law. Their HBD rate increased from 16.2% to 25.0%. Thus there may be some "spill-over" to this age group. That is, the legal availability of alcoholic beverages to 18-year olds may have made it easier for 17-year olds to obtain alcoholic beverages (illegally). There appears to be some evidence of increased HBD rates among 17-year-old drivers in fatal accidents at any rate.

Drivers aged 16 did not show a significant increase at the time of the lowering of the legal drinking age. However, they did show a significant increase in their HBD rate from 1972 and 1973 to 1974 through 1976. The rate increased from 13.1% to 25.6%. There are probably several contributing factors to this increase. One is almost certainly the reduction of missing data in the HBD variable which occurred at the same time due to the introduction of the FARS. Another may be the reduced driving during the period. Finally, the change in the law may also influence this increase. It seems reasonable that a longer period would occur before the 16 -year olds changed their drinking-driving behavior. Also, the availability of alcohol from friends may be less for 16-year olds than for 17-year olds. However, the increase in HBD rate among 16-year olds is alarming and needs to be monitored.

When drivers were grouped into three-year age groups, similar changes in the HBD rates were observed. The age group 15-17 shows a significant increase (from 15.0% to 22.4%) coincident with the lower legal drinking age change, and also a significant increase (from 17.2% to 26.2%) coincident with the FARS. Drivers aged 18-20 showed significant increases in their HBD rates at the same two times. The former increase was from 26.9% to 41.3% (law change) and the latter was from 34.8% to 45.6%. Drivers aged 21-23 showed no significant increase at the time of the law change, but did show a significant increase (from 35.9% to 49.6%) at time of the introduction of the FARS. None of the other ages groups showed any significant changes in

their HBD rates according to the set of partitions used.[1]

In summary, the pattern of changes in HBD rates among drivers in fatal accidents is consistent with what would be expected if the lowering of the legal drinking age caused alcohol-related crashes to increase among young drivers. Drivers under age 21 showed large increases in their HBD rates coincident with the change in law. Drivers 21 and older showed no significant changes in HBD rates at the time of the law change. There was some evidence that the reduction of the missing-data rate on the HBD variable which occurred in 1974 with the introduction of the FARS also resulted in an increase in the HBD rates. This increase was not specific to the young (under 21) ages.

### 3.3 Cohort HBD rates

With data on individual ages of drivers for the nine-year period, it is possible to investigate changes in the HBD rates of a cohort of drivers over time. A cohort refers to those drivers who were 18 in 1968, 19 in 1969, and so on, finally being 26 in 1976. Each such cohort can be defined by the drivers' age in 1968, the first year of the period. Some cohorts have less than the full nine years' data. For example, those who were 16 in 1970 could only drive (legally) for the seven years 1970 through 1976. Since data for single ages of driver were only used for ages 16 through 34, there is also an upper limit on the beginning age of the cohorts which can be followed for the full nine years.

Partitioning of the overall chi-square statistic into its single degrees of freedom was also used with the data on cohorts. A different set of partitions was appropriate in some of the cohorts. The first partition for each cohort divided the time period into the time before and after that cohort could drink legally. The second partition was made at the change in the legal drinking age law (in cases where that did not coincide with the first). The third partition was at the time of the introduction of the FARS--that is, at 1974. When possible an additional partition was made between 1970 and 1971, since that coincided with a change in the form. Of

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[1] The age group 45-49 showed a significant chi-square overall, but none of the partitions was significant.

course cohorts which were aged 21 or older in 1968 did not have a partition coinciding with their enfranchisement as legal drinkers.

Table 12 summarizes the results of the cohort partitioning. In the table the years in each part of the partition are given since this varies among the cohorts. The changes in the average HBD rate for each partition are also presented. Only two types of partitions were found to be significant: those which coincided with the enfranchisement of the cohort as legal drinkers, and those which coincided with the FARS. Almost all groups showed a significant increase in their HBD rate when they first could drink legally. For four of the cohorts (those who turned 18, 19, 20, or 21 in 1972) this coincided with the change in the legal drinking age. The cohort who were 19 in 1968 showed an increase in their HBD rate coincident with their becoming legal drinkers which was marginally statistically significant. Those who were 20 in 1968 did not show a significant increase when they turned 21--the rate increased from 31.3% to 40.9%, but it was not statistically significant.

Several groups showed a significant increase in their HBD rates coincident with the introduction of the FARS: those who became 16 in 1968, 1969, or 1970, and those who became 19 in 1968. (Those who turned 16 in 1972 also showed an increase in their HBD rate at the time of the introduction of the FARS, but this was also the time at which they first were legally able to drink.)

Two other significant changes were detected. The cohort who were 21 in 1968 showed a significant decrease in their HBD rate from the period 1968-70 to 1971. The change was from 44.7% to 28.9%. Also those who were 22 in 1968 showed a significant decrease in their average HBD rate coincident with the change in the legal drinking age law. Their average HBD rate decreased from 43.1% to 30.7% from the 1968-71 period to the 1972-76 period. These decreases, particularly the latter one, are probably reflecting a trend for the HBD rate to decrease with the age of the driver. A fairly slow but steady decrease with age after age 22 over the nine years could show up as a significant decrease coincident with the partition which divides the period into the first four years and the last five.

None of the older cohorts showed any significant changes in their rates with the set of partitions used. In fact, all of the overall chi-square

Table 12

Summary of Significant Chi-square Partitions for Cohorts

| Cohort | Par-tition | Partitioned Years | | | Chi-square | Change in HBD |
|---|---|---|---|---|---|---|
| 16 in 1974 | 1 | (74-75) | vs | (76) | 14.04 | 24.9%-to-44.7% |
| 16 in 1973 | 1 | (73-74) | vs | (75-76) | 34.71 | 21.9%-to-49.2% |
| 16 in 1972 | 1 | (72-73) | vs | (74-76) | 42.5 | 17.5%-to-45.5% |
| 16 in 1971 | 1 | (71-72) | vs | (73-76) | 22.8 | 21.9%-to-41.9% |
| | 2 | (73) | vs | (74-76) | 7.46 | 31.7%-to-45.7% |
| 16 in 1970 | 1 | (70-71) | vs | (72-76) | 35.6 | 16.0%-to-44.2% |
| | 2 | (72-73) | vs | (74-76) | 15.97 | 35.6%-to-52.0% |
| 16 in 1969 | 1 | (69-71) | vs | (72-76) | 36.3 | 21.0%-to-43.0% |
| | 2 | (72-73) | vs | (74-76) | 9.6 | 36.5%-to-49.0% |
| 16 in 1968 | 1 | (68-71) | vs | (72-76) | 34.2 | 19.2%-to-37.9% |
| 17 in 1968 | 1 | (68-71) | vs | (72-76) | 26.2 | 24.9%-to-41.1% |
| 18 in 1968 | 1 | (68-70) | vs | (71-76) | 14.99 | 25.4%-to-39.2% |
| 19 in 1968 | 1 | (68-69) | vs | (70-76) | 6.71 | 31.3%-to-41.8% |
| | 2 | (72-73) | vs | (74-76) | 11.04 | 33.3%-to-50.5% |
| 20 in 1968 | - | | none | | - | 31.3%-to-40.9% |
| 21 in 1968 | - | (68-70) | vs | (71) | 7.53 | 44.7%-to-28.9% |
| 22 in 1968 | - | (68-71) | vs | (72-76) | 9.16 | 43.1%-to-30.7% |

Older ages had no significant partitions.

statistics for the older groups (20 or older in 1968) were not significant, indicating that there were no changes in the HBD rates over the nine years in excess of what could reasonably be ascribed to chance fluctuations.

Thus the general pattern in the HBD rates for the cohorts is that each cohort has experienced a large and statistically significant increase in its HBD rate when it first became able to drink legally. For the earlier years, this increase coincided with becoming 21, while for the later years the

increase has occurred when the cohort reaches age 18. Cohorts who were in between these ages when the law took effect in 1972 showed increases at their age in 1972. Thus it appears that a traditional pattern of a large increase in the HBD rate among drivers in fatal accidents coincident with the age of enfranchisement at age 21 has been shifted to a large increase in the HBD rate coincident with the new age of enfranchisement at age 18.

### 3.4 A Linear Models Approach to the Changes in HBD Rates

The chi-square partitioning technique used in sections 3.2 and 3.3 isolates changes over time within a single age group (or cohort) of drivers. The changes which are observed are then compared among different age groups to determine what similarities exist. A modeling approach may be used to incorporate changes across ages into the same analysis as changes across time within ages. That is, the linear modeling approach includes terms in the model which reflect any population wide changes or trends, then investigates the significance of within age changes over and above any population wide changes.

To investigate the relationship between the HBD rate and the age groups over and above the year-to-year variation, a linear model was fit to the data. The method of estimating the parameters of the model was by weighted least squares (equivalent to the modified minimum chi-square approach). The calculations were accomplished by the GENCAT program available on the Michigan Terminal System. A detailed discussion of the approach and the program can be found in Landis et al. [5].

The model which was judged to be the best was

$$EP_{ij} = u+a_i+b_i+y_j$$

where u is an overall average HBD rate, $a_i$ are the effects of being in age group i before the lower legal drinking age went into effect, $b_i$ are the effects of being in age group i after the lower legal drinking age went into effect, and $y_j$ are the year-to-year effects. Here i runs from 1 to 4 and j runs from 1 to 9. The $E(p_{ij})$ is the expected HBD rate for age group i and year j.

The parameters $a_i$ measure the differences among the four age groups 15-17, 18-20, 21-23, and 24-26 before the law change. The $b_i$ measure the

differences among the four age groups after the law changed, and the $y_i$ measured the differences among the nine years 1968-1976. Differences ($a_i - b_i$) measure the change in the HBD rate for age group i which occurred at the same time as the lower drinking age.

It should be noted that it was necessary to group the ages in order to comply with size restrictions of the program. It is also reasonable since the grouped rates would be subject to smaller random fluctuations. However, a result of the fact that only the ages up to 26 were included is that this model cannot estimate changes which occurred in the older age groups. In addition, if large changes occurred at a particular time in most of the four groups, it is possible that these would be estimated as the year-to-year effects rather than being isolated as relating primarily to one or two of the age groups.

The model was fit to the data on drivers in fatal accidents in Michigan. The general conclusions were similar to those from partitioning. There were significant differences among the age groups both before and after the law change. There was a significant, although smaller, amount of year-to-year variation, with generally the later years—particularly 1975-1976—having higher HBD rates. The 15-17 age group had an HBD rate that was generally lower than the other groups. The 18-20 age group's HBD rate was somewhat lower than average before the law change and higher after the law change. The 21-23 age group had the highest HBD rate, both before and after the law change, but the difference for the average was smaller in the latter period. Finally, the 24-26 age group had an HBD rate above average in both periods, but much closer to average in the latter period.

The numerical values for the parameters are presented in Table 13. The model explained more than 95% of the variability in the HBD rate among the age groups and years. (The actual value was 95.4%.)

The test of lack of fit for the model was not significant. In combination with the fact that the model explained 95.4% of the variability in the HBD rates, this indicates that it is unlikely that any important sources of variation are not included. In Table 13 parameters with a negative sign indicate that they represent an effect which reduces the HBD rate on the average. For example, the parameters for the years 1968 to 1973 are all negative, indicating that the HBD rate was generally lower in those

Table 13

Parameters and Tests for the Linear Model

The model $E(P_{ij})=u+a_i+b_i+y_j$ has the tabulated estimates for its parameters:
The $R^2$ (corrected for the mean) is 0.9535.

| Age Effects | | |
|---|---|---|
| Age Group | Before | After |
| (15-17) | $a_1=-0.1245$ | $b_1=-0.1267$ |
| (18-20) | $a_2=-0.0287$ | $b_2=+0.0405$ |
| (21-23) | $a_3=+0.0842$ | $b_3=+0.0595$ |
| (24-26) | $a_4=+0.0690$ | $b_4=+0.0268$ |
| Year Effects | | |
| $y_1=-0.0771$ | $y_4=-0.0431$ | $y_7=0.0822$ |
| $y_2=-0.0481$ | $y_5=-0.0400$ | $y_8=0.1081$ |
| $y_3=-0.0679$ | $y_6=-0.0130$ | $y_9=0.0988$ |

u=0.3014

| Effect | $X^2$ | df | P (Sig.) |
|---|---|---|---|
| Lack of fit . . . . . | 25.16 | 21 | NS(P=.24) |
| Age groups before ($a_i=0$) . | 191.67 | 3 | *** |
| Age groups after ($b_i=0$) . . | 142.27 | 3 | *** |
| Years ($y_j=0$) . . . . . | 237.73 | 8 | *** |
| Change in (15-17) ($a_1-b_1=0$) | 0.02 | 1 | NS(p=.89) |
| Change in (18-20) ($a_2-b_2=0$) | 25.71 | 1 | *** |
| Change in (21-23) ($a_3-b_3=0$) | 2.75 | 1 | (P=0.097) |
| Change in (24-26) ($a_4-b_4=0$) | 6.51 | 1 | (P=0.01) |

***=P<0.0001

$a_1-b_1=+0.0023$ A nonsignificant, very slight decrease.
$a_2-b_2=-0.0692$ A large, significant increase.
$a_3-b_3=+0.0247$ A moderate decrease of questionable significance.
$a_4-b_4=+0.0422$ A large, significant decrease.

years. On the other hand, the years 1974 through 1976 all have positive parameters, indicating that the HBD rate was somewhat higher in those years. This change in the year-to-year parameter effects coincides with the introduction of the FARS in January of 1974. In addition, this coincides approximately with the occurrence of the energy crisis.

The effect of the FARS was to reduce the missing data on the HBD variable in the fatal file. It appears that the "true" rate of HBD among the missing data was somewhat higher than among the cases of non-missing data. Consequently a reduction in the missing data would have a tendency to increase the HBD rate observed. The effect of the energy crisis is somewhat less certain. It did affect driving habits and patterns and apparently reduced driving somewhat. There was a reduction in the total number of fatal accidents coincident with the energy crisis—larger than the generally downward trend in fatalities. (All accidents also appear to have been reduced.) This had the effect of reducing the denominator in the HBD rate. It appears that the numerators—that is the number of fatal accidents in which the driver had been drinking—did not show a reduction for these age groups. As a result, the numerator stayed about the same or increased somewhat while the denominator decreased, resulting in an average increase in the HBD rate.

The age group 15-17 averaged an HBD rate that was 12.5% below the average in the before-law period and that was 12.7% below the average in the post-law period. There was a very small change in this age group's HBD rate (after the year-to-year effects were removed), and this change was not significant.

The 18-20 age group averaged 2.9% below average in the HBD rate prior to the law change and averaged 4.1% above the average after the law change. As a consequence this group averaged an increase of 6.9% in their HBD rate coincident with the law change and above general year-to-year changes. This increase in HBD rate was highly significant. ($X^2$= 25.1 with 1 degree of freedom). An additional point to note is that after the law change, the 18-20 group had an HBD rate (drivers in fatal accidents) which was 1.9% below that of the 21- to 23-year- old drivers and 1.4% above that of the 24- to 26-year-old drivers. Before the law change there were three rather different HBD rates among these four age groups (the 21-23 and 24-26 groups

being about the same) while after the law change the 15-17 ages remained low, while the 18-20, 21-23, and 24-26 groups all had essentially the same HBD rates.

The 21-23 age group showed a moderate decrease in its HBD rate coincident with the law change. The change was a decrease of 2.5 percentage points. This was of questionable statistical significance ($p=0.097$), so could be due to chance. The 24-26 group also showed a decrease in its HBD rate which amounted to a change of 4.2%. Again this was of some statistical significance ($p = 0.0107$), but could also be due to random fluctuations.

The results from the linear model may appear to differ somewhat from the results from the chi-square partitioning. For example, the partitioning technique showed significant increases in HBD rate with the introduction of FARS for several age groups. In addition, age group 15-17 showed a significant increase coincident with the lower legal age law change. The linear model incorporates any year-to-year changes in the average HBD rates across all groups (from 15 to 26) into the year effects. Thus, the age group parameters isolate changes particular to that age group which did not occur in the aggregate. Thus, the effect of FARS and the energy crisis shows up as a common effect to all these age groups and appears as the change in sign from negative to positive in the year effects beginning with $y_7$, which corresponds to 1974.

The average effect across the four years prior to the law change is estimated as -0.0591, while that averaged across the five years after the law change is +0.04772. Thus, all four age groups are estimated to have experienced this average increase. The parameters $a_i$ and $b_i$ measure how much a particular age group differed in its increase from the average.

The year effects may also be separated into the three time periods to point out the estimated effect of the FARS/energy-crisis period. The average effect in the 1968 to 1971 period is again -0.0591. For the two years immediately post-law, 1972 and 1973, the estimate is -0.0265, while for the years from 1974 to 1976 the estimated effect on the HBD rate is +0.0964.

Thus, the linear model analysis agrees with the analysis by partitioning. Table 14 shows the average HBD rates predicted by the model

for the different age groups and time periods. The essential difference is that the increase in HBD rate beginning in 1974 is common to all four age groups, while an increase beginning in 1972 also occurred, but was of different size for the four groups. The model is more specific in isolating age effects which are not common to the four groups than is the partitioning. If more age groups had been used in the model it is possible that, since the older groups did not show increases in 1972, the year-to-year average effects would not reflect this increase. In that case, the youngest age groups (15-17) effects might be significant. That is, with more older drivers in the data set, the increases in 1972 might be ascribed to the young age groups rather than to year-to-year variation. The increase coincident with the FARS in 1974, however, is general and would probably remain a common effect across the ages.

Table 14

Average HBD Rates Estimated From the Model by Age and Year

| Age | Period | | | |
|---|---|---|---|---|
| | 68-71 | 72-73 | 74-76 | 72-76 |
| 15-17 | 11.8% | 14.8% | 27.1% | 22.2% |
| 18-20 | 21.4% | 31.5% | 43.8% | 39.0% |
| 21-23 | 32.7% | 33.4% | 45.7% | 40.9% |
| 24-26 | 31.1% | 30.2% | 42.5% | 37.6% |

## 3.5 HBD and Driver Sex

To more clearly delineate the HBD problem we included driver sex as a variable in the current study. Analysis was performed by driver sex on the HBD variable using the chi-square partitioning program previously described. Male drivers represent an overwhelming proportion (80%-85%) of the drivers in the file and an even larger proportion of the drinking drivers (96%-98%) in the file. Thus it is not surprising that the results of the chi-square

analysis of males is almost identical to the chi-square analysis of all drivers. This being the case, the following section reports on the findings for female drivers in the fatal file while the previous sections (pertaining to all drivers in the file) are applicable to male drivers.

## Proportion of Females in the Fatal File

Female drivers have historically represented a small proportion of the accident population, and Table 15 shows that this is true of female drivers in the Michigan fatal file also. Female drivers in general represented between 16% and 20% of the fatal-accident-involved drivers over the nine-year study period, and the 18- to 20-year-old female drivers represented a similar proportion of all drivers in their age group. Table 16 shows the proportion of had-been-drinking drivers who are female for the same two age groups. The proportion of had-been-drinking drivers who are female is only 2-3.5% of all drivers who had been drinking. This exemplifies the minimal involvement of females in the overall HBD experience in the Michigan fatal files.

One should note in Table 16 that, even though the proportion of HBD drivers who are female is low, the last two years (1975-1976) indicate a slightly increasing proportion of female drivers.

Table 15

Proportion of Drivers Who are Female in the Michigan Fatal Files from 1968-1976 for 18- to 20-year olds and All Ages.

| Age | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| 18-20 | .163 | .179 | .189 | .203 | .175 | .184 | .142 | .169 | .189 |
| All Ages | .168 | .182 | .193 | .181 | .176 | .196 | .171 | .185 | .191 |

The mean proportion of HBD drivers that are female is 2.3% for the years 1968-1974 and 3.3% for 1975-76. This represents an increase of 43.5%

Table 16

Proportion of HBD Drivers Who are Female in the Michigan Fatal Files from 1968-1976 for 18-20 Year Olds and All Ages

| Age | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| 18-20 | .007 | .018 | .027 | .013 | .031 | .029 | .023 | .034 | .046 |
| All Ages | .021 | .024 | .027 | .020 | .022 | .026 | .023 | .034 | .032 |

in female HBD drivers during '75-'76 as compared to the previous six years. The increase in the proportion of 18- to 20-year-old HBD female drivers is 90.5%, with a 1968-74 mean of 2.1% and a 1975-76 mean of 4.0%. While it is admittedly true that 4% is a small proportion of drivers, an increase of 90% is certainly noteworthy.

An important point should be made with respect to inferences such as the previous and those that follow. The number of drivers in the fatal file who were female is obviously relatively small, Table 17. When this number is filtered into age groups and HBD/HNBD cells the frequencies quickly become small. Small cell sizes must be taken into account when drawing inferences from the data as they may change rather drastically from year to year as the result of small frequency shifts. This is not to say that, for example, the above mentioned trend of an increasing proportion of female, HBD drivers does not exist in reality but rather that such a trend could change rather suddenly.

## HBD Rates for Females in the Fatal File

In the previous section it was shown that female drivers represent only 1-5% of the HBD drivers in the fatal file. Table 18 shows the rate of HBD female drivers among females of all ages, 18- to 20-, and 21- to 23-year old drivers. The previous discussion of small frequencies of individual age/year combinations is again pertinent. As a result of the low HBD frequencies for female in the fatal file chi-square partitioning analysis was performed on grouped data only.

Table 17

Frequencies of Total and HBD Female Drivers in the Michigan Fatal Files for 18-20, 21-23, and All Ages.

| Age | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| **Female HBD Drivers** | | | | | | | | | |
| 18-20 | 2 | 6 | 8 | 4 | 12 | 11 | 9 | 12 | 19 |
| 21-23 | 4 | 7 | 7 | 6 | 2 | 5 | 7 | 13 | 14 |
| All Ages | 45 | 58 | 58 | 48 | 57 | 66 | 54 | 75 | 78 |
| **Total Female Drivers** | | | | | | | | | |
| 18-20 | 64 | 76 | 68 | 73 | 78 | 79 | 55 | 61 | 81 |
| 21-23 | 64 | 60 | 60 | 44 | 43 | 50 | 39 | 35 | 48 |
| All Ages | 505 | 584 | 529 | 490 | 506 | 557 | 401 | 416 | 480 |

Table 18

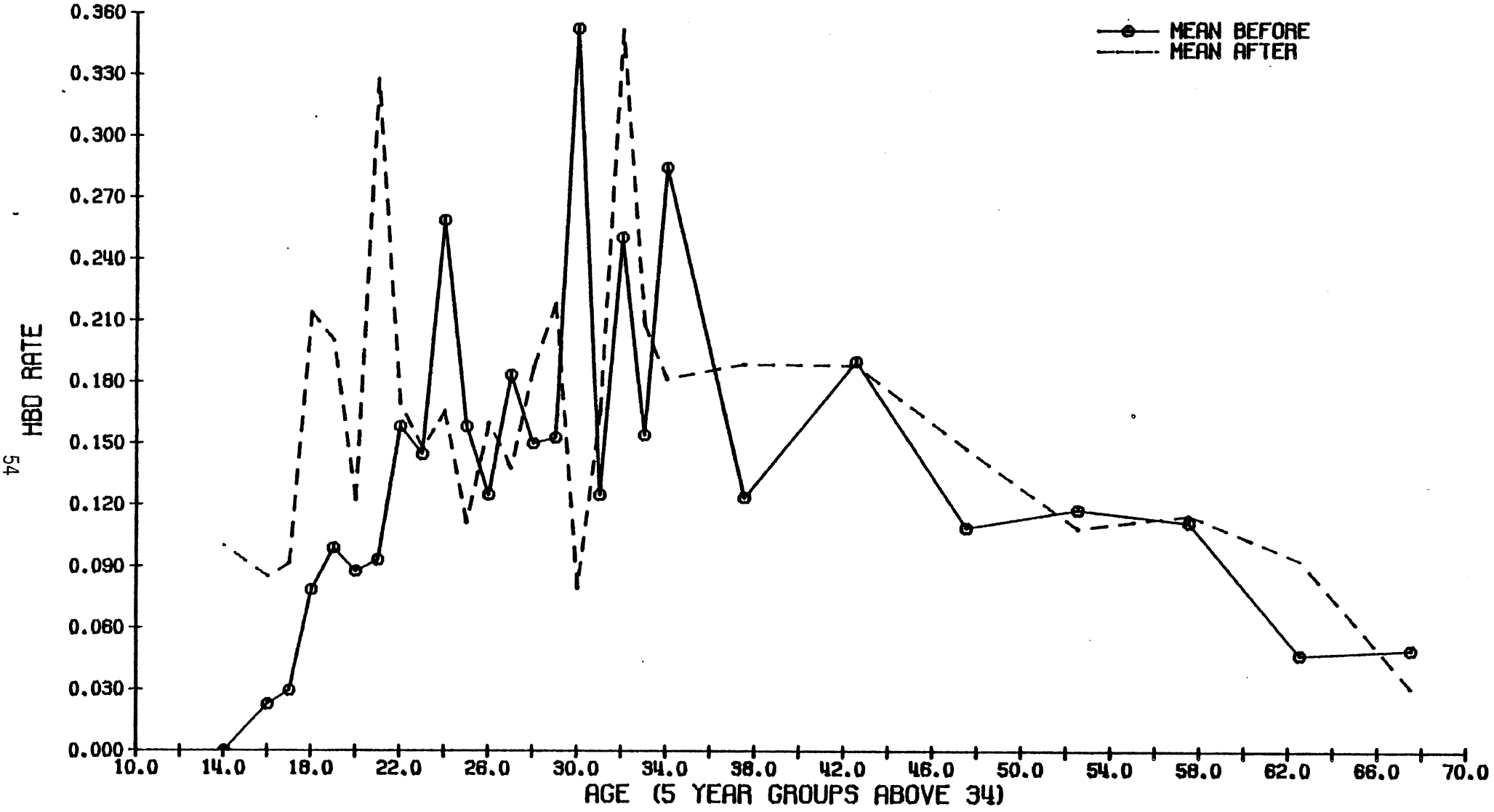
Rate of HBD among Fatal Accident-Involved Female Drivers for 18-20, 21-23, and All Ages

| Age | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
| 18-20 | .044 | .090 | .146 | .069 | .167 | .162 | .164 | .197 | .241 |
| 21-23 | .078 | .149 | .146 | .143 | .053 | .111 | .180 | .371 | .298 |
| All Ages | .116 | .123 | .137 | .108 | .123 | .131 | .135 | .183 | .167 |

The overall chi-square test for nine years was statistically

significant ($X^2$=17.34, $p<.05$) for female HBD drivers of all ages but was not significant for any particular partition. The test showed a significant increase over the nine years in the HBD rate for females of all ages. For 18- to 20-year old female drivers there was a significant ($X^2$=11.9, $p<.05$) increase in the HBD rate coinciding with the lowering of the drinking age. The partition corresponding to the introduction of FARS and the energy crisis was significant for the 21- to 23-year old drivers ($X^2$=13.8, $p<.05$). The overall chi-square for both the 18- to 20- and 21- to 23-year olds were also significant and showed that the increases in the HBD rates over the nine-year period are statistically significant for both groups. No other age group of female drivers had any significant partitions or overall chi-square values which were significant.

Figure 11 shows the mean HBD rates for females before and after the law change (1972) by age. The younger ages show mean increases after 1972 while older age groups show seemingly random fluctuations which are probably due to the previously mentioned small frequencies. Note that the chi-square analysis showed none of these fluctuations in the older age groups as statistically significant, possibly because of the small frequencies of the cells involved.




HBD RATE (NO M.D.) BY AGE
MEAN RATE BEFORE AND AFTER LAW CHANGE
5 YEAR GROUPS ABOVE 34 PLOTTED AT MIDPOINT

FIGURE 11

## REFERENCES


[1] Douglass, R.L., L.D. Filkins, and F.A. Clark, The Effect of Lower Legal Drinking Ages on Youth Crash Involvement, Report UM-HSRI-AL-74-1-2, Highway Safety Research Institute, The University of Michigan, Ann Arbor, June 1974. DOT HS-801 213.

[2] Office of Highway Safety Planning, Michigan's Eighteen-Year-Old Legal Drinking Age: Its Impact on Youth Crash Involvement, Michigan Department of State Police, Lansing, February 1977.

[3] Douglass, R.L. and J.A. Freedman, Alcohol-Related Casualties and Alcohol Beverage Market Response to Beverage Alcohol Availability Policies in Michigan: Volume 1, Report UM-HSRI-77-37, Highway Safety Research Institute, The University of Michigan, August 1977.

[4] Whitehead, P.C., Alcohol and Young Drivers: Impact and Implications of Lowering the Drinking Age, Monograph Series No. 1, Department of National Health and Welfare, Canada, November 1977.

[5] Maxwell, A.E., Analysing Qualitative Data, Methuen & Co., Ltd., London, 1961 Chapter 3.

[6] Landis, J.R., W.M. Stanish, and G.G. Koch, A Computer Program for the Generalized Chi-Square Analysis of Categorical Data Using Weighted Least Squares to Compute Wald Statistics, Biostatistics Technical Report No. 8, Department of Biostatistics, The University of Michigan, Ann Arbor, Michigan, Department of Biostatistics, The University of North Carolina, Chapel Hill, North Carolina, February 1976.

# Appendix A

## Partitioning Chi-square Into Its Degrees of Freedom

## PARTITIONING $X^2$ INTO ITS DEGREES OF FREEDOM

A Chi-square ($X^2$) statistic may be used to test whether a set of rates or proportions are significantly different, or whether they vary only as much as could be due to chance—random fluctuations. When several proportions are being compared, it is frequently the case that some groups of these are of interest as well as the overall test. To this end, the overall $X^2$ may be partitioned into its individual degrees of freedom, each of which may be compared to the tabulated values for a $X^2$ with one degree of freedom, to assess the statistical significance of each component.

As an example, consider the proportion of drivers who had been drinking (among all drivers of the same age) prior to being involved in a fatal traffic accident. During the period 1968 to 1976 several events occurred which may affect this rate. The partitioning technique will be used to determine whether the proportion before and after these events are significantly different. Note that this will not imply causality—merely that the rate did or did not change significantly at the time of the event.

The following events are of interest:

1) Change in the age of legal drinking January 1, 1972.

2) Introduction of FARS (Fall, 1973) and concurrently the Energy crisis - January, 1974.

3) A change in accident reporting form-January, 1971.

4) Increasing number of reporting jurisdictions during 1968-1970.

These suggest that the 8 degrees of freedom for the nine years be partitioned as shown in Table A1.

Table A1

Definition of Partitions

| Partition Number | Dates | | | Interpretation |
|---|---|---|---|---|
| 1 | 1968-71 | vs | 1972-76 | Before and after the change in legal drinking age. |
| 2 | 1972-73 | vs | 1974-76 | After the change in legal drinking age, before and after the introduction of FARS: also coincides with the energy crisis. |
| 3 | 1972 | vs | 1973 | Compares the first two years after the change in the legal drinking age. |
| 4 | 1974 | vs | 1975-6 | Compares the year of maximum impact of the energy crisis with the two most recent years |
| 5 | 1975 | vs | 1976 | Compares the two most recent years. |
| 6 | 1968-70 | vs | 1971 | Compares the years immediately prior to the first year with a new data form--all before the law change |
| 7 | 1968 | vs | 1969 | No external criteria. |
| 8 | 1968-9 | vs | 1970 | No external criteria. |

The data in Table A2 below give the HBD rates for 18-year-old drivers. These will be used to demonstrate the method.

The following notation is used:

N = the total for the entire table

$n_{\cdot}$ = the total HBD for the table

$n_{1j}$ = the number of HBD in the j-th year

$N_{.j}$ = the total (HBD and HNBD) for the j-th year

$n_{2.}$ = the total HNBD for the entire table

$\sum$ means to sum over the indicated groups or cells.

1) Define the partitions. These are indicated by horizontal lines of varying lengths on Table A2.

2) Sum the HBD and total frequency within each partition. The comparisons involving single years are available directly from the table. Rates may be calculated at this step if desired.

3) Calculate the total $X^2$ for the table. This is given by the formula

$$X^2 = \frac{N^2}{n_{1.}\, n_{2.}} \left[ \sum_{\text{all 9 groups.}} \frac{n_{1j}^2}{N_{.j}} - \frac{n_{1.}^2}{N} \right]$$

4) Calculate each component of the $X^2$ by applying the following formula

$$X^2 \text{ component} = \frac{N^2}{n_{1.}\, n_{2.}} \left[ \sum_{\substack{\text{2 groups} \\ \text{in comparison}}} \frac{n_{1j}^2}{N_{.j}} - \frac{\left(\sum n_{1j}\right)^2}{\sum N_{.j}} \right]$$

5) As a check, the sum of the individual $X^2$ should add to the total.

As an example the calculations for partition 1 are;

$$X^2 = \frac{1154^2}{(381)(773)} \left[ \frac{112^2}{469} + \frac{269^2}{685} - \frac{381^2}{1154} \right] = 29.813$$

For partition 2;

$$X^2 = \frac{1154^2}{(381)(773)} \left[ \frac{85^2}{254} + \frac{184^2}{431} - \frac{269^2}{685} \right] = 6.152$$

The total may be obtained by summing all 8 chi-squares or it my be calculated directly.

The total $x^2$ is 41.915 with 8 degrees of freedom, which is highly significant.

In the example the comparison of the before and after the law change is by far the most significant. That is, the proportion of HBD prior to 1972 was 23.88% while after the law changed the HBD rate for 18-year-olds was

39.27%. This is a statistically significant increase. ($X^2$ = 29.813 with 1 d.f.) All of the other comparisons are not significant except for the comparison #2, coincident with the energy crisis and the introduction of FARS. For 1972-1973, the proportion of 18-year-old HBD is 33.46%; in 1974-1976 it is 42.69%. This difference is significant ($X^2$ = 6.1522 with 1 d.f.).

## DOCUMENTATION FOR CHIPART

A program that will partition the overall chi-square statistic in a 2 x k contingency table has been developed at HSRI. This program partitions the chi-square value for the entire table into k-1 single degrees of freedom according to a set of partitions specified by the user. A check that the partition is valid—i.e., that the chi-square can be partitioned additively in the manner specified—is also performed by the program.

The program provides the following outputs: the total chi-square; the proportions for each cell of the table; the sample size for each cell and the total sample size; and the proportions, sample sizes, and chi-squares for each specified partition. The program calculates single degrees of freedom. However, if only a few single degrees of freedom are of interest, these may be calculated and the remaining chi-squares (with more than one degree of freedom) obtained by subtraction.

To run the program , use

```
$RUN SH3Y:CHIPART
```

The program responds: "enter table dimension" "enter FORMAT for set 1."

Here a format is specified for the entry of data to the program into the first row of the first table. One may specify any format sufficiently large, e.g. "20I5," and then enter the data on the terminal separated by and concluded by commas, as 2,3,5,6, .

The program continues "enter Format for set 2."

The user specifies the format for the second row of data, followed by the data.

The program asks: "enter cells for group 1."

Here the cells for one group of a partition are specified. The program asks "enter cells for group 2." The table cells or columns are numbered consecutively from the left. Thus, entering the cells for group 1 as 1,2 and those for group 2 as 3 would result in a chi-square for the pooled columns 1 and 2 compared with 3.

The program then calculates the part of the chi-square associated with the two groups specified, the proportions and sample sizes, and then it prints them. It then asks for the cells for groups 1 and 2 of the next partition. After k-1 partitions have been computed, the program will check that the sum of the chi-square values equals the total, prints a message to the effect that this is the end of a given partition, and asks if a different partition is desired or if a new table is to be analyzed. A sample run using the data for the 18-year-old drivers follows. The first part of the output, Table A2, gives the HBD, HNBD, and total frequencies for each year, followed by the HBD rate. The horizontal lines indicate the partitions. Table A3 gives the proportion and totals for each group in each partition and the chi-square for that partition.

```
 $RUN SH3Y:CHIPART

EXECUTION BEGINS

ENTER TABLE DIMENSIONS

9,

ENTER FORMAT FOR SET 1

(9I10)

ENTER FORMAT FOR SET 2

(9I10)

ENTER DATA FOR SET 1

26,36,20,30,47,38,58,59,67,

ENTER DATA FOR SET 2

93,94,96,74,87,82,89,75,83,
```

Table A2

```
THERE ARE  8 INDEPENDENT PARTITIONS
 TOTAL CHI-SQUARE=   41.91490
 INPUT DATA & PROPORTIONS

       SET 1  SET 2  TOTAL   PROP

    1     26     93    119  .2185
_____________________________________ 7
    2     36     94    130  .2769
_____________________________________ 8
    3     20     96    116  .1724
_____________________________________ 6
    4     30     74    104  .2885
_____________________________________ 1
    5     47     87    134  .3507
_____________________________________ 3
    6     38     82    120  .3167
_____________________________________ 2
    7     58     89    147  .3946
_____________________________________ 4
    8     59     75    134  .4403
_____________________________________ 5
    9     67     83    150  .4467

ENTER CELLS FOR GROUP 1
1-4
ENTER CELLS FOR GROUP 2
5-9
```

```
ENTER CELLS FOR GROUP 1
5-6
ENTER CELLS FOR GROUP 2
7-9
ENTER CELLS FOR GROUP 1
5
ENTER CELLS FOR GROUP 2
6
ENTER CELLS FOR GROUP 1
7
ENTER CELLS FOR GROUP 2
8-9
ENTER CELLS FOR GROUP 1
8
ENTER CELLS FOR GROUP 2
9
ENTER CELLS FOR GROUP 1
1-3
ENTER CELLS FOR GROUP 2
4
ENTER CELLS FOR GROUP 1
1
ENTER CELLS FOR GROUP 2
2
ENTER CELLS FOR GROUP 1
1-2
ENTER CELLS FOR GROUP 2
3
```

Table A3

GROUP TOTALS, PROPORTIONS AND CHI-SQUARE BY PARTITION

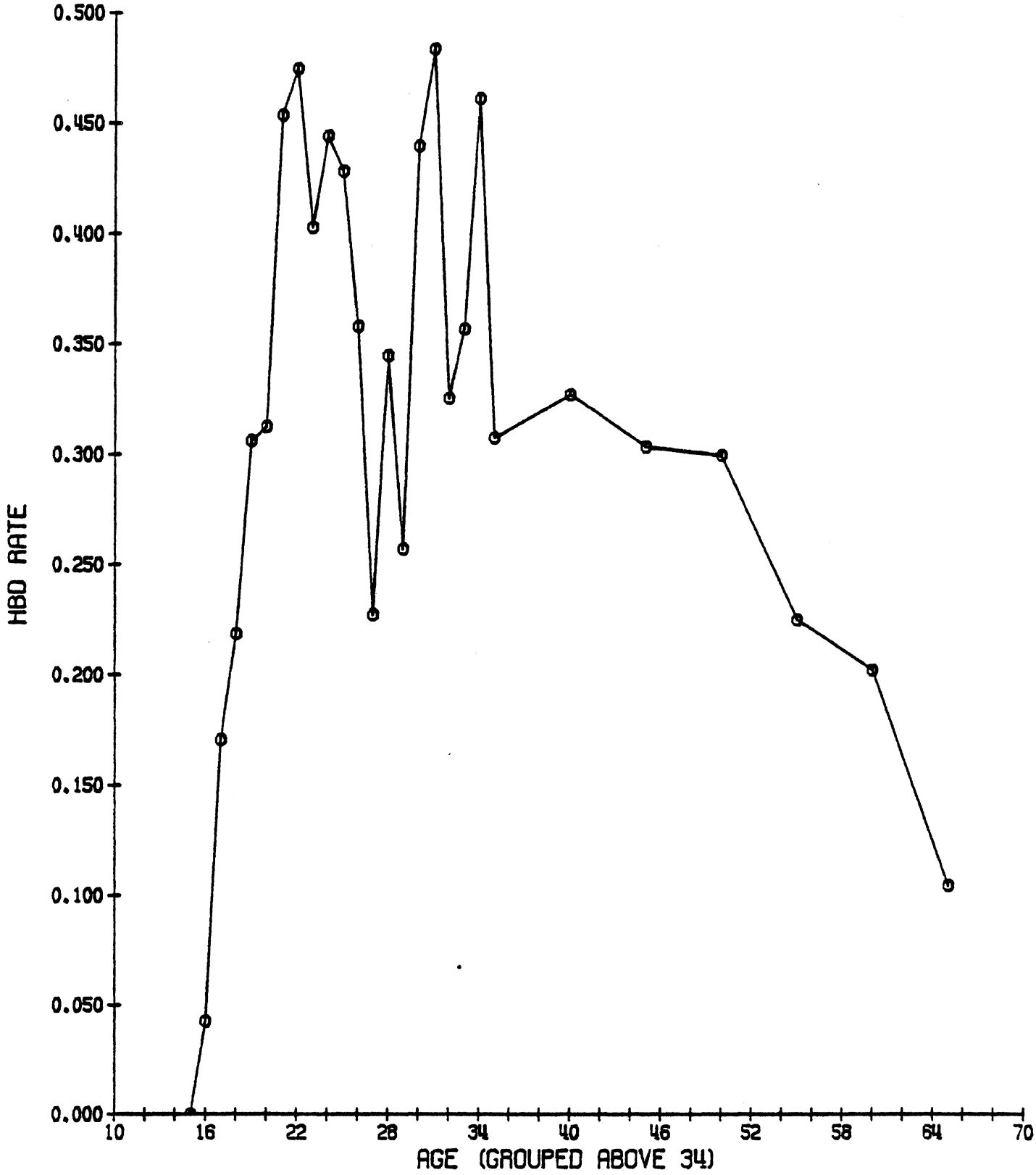
| PART NUM | GROUP 1 TOTAL | GROUP 1 PROP | GROUP 2 TOTAL | GROUP 2 PROP | PARTITION CHI-SQUARE | CUMULATIVE CHI-SQUARE |
|---|---|---|---|---|---|---|
| 1 | 469 | .2388 | 685 | .3927 | 29.81346 | 29.81346 |
| 2 | 254 | .3346 | 431 | .4269 | 6.15221 | 35.96567 |
| 3 | 134 | .3507 | 120 | .3167 | 0.33242 | 36.29808 |
| 4 | 147 | .3946 | 284 | .4437 | 1.05606 | 37.35413 |
| 5 | 134 | .4403 | 150 | .4467 | 0.01297 | 37.36710 |
| 6 | 365 | .2247 | 104 | .2885 | 1.48984 | 38.85693 |
| 7 | 119 | .2185 | 130 | .2769 | 0.95930 | 39.81622 |
| 8 | 249 | .2490 | 116 | .1724 | 2.09860 | 41.91481 |

THIS COMPLETES A SET OF PARTITIONS

```
DO YOU WANT ADDITIONAL PARTITIONS OF THE SAME TABLE (Y=YES)

no

DO YOU WANT TO ENTER A NEW TABLE (Y=YES)

no

EXECUTION TERMINATED
```

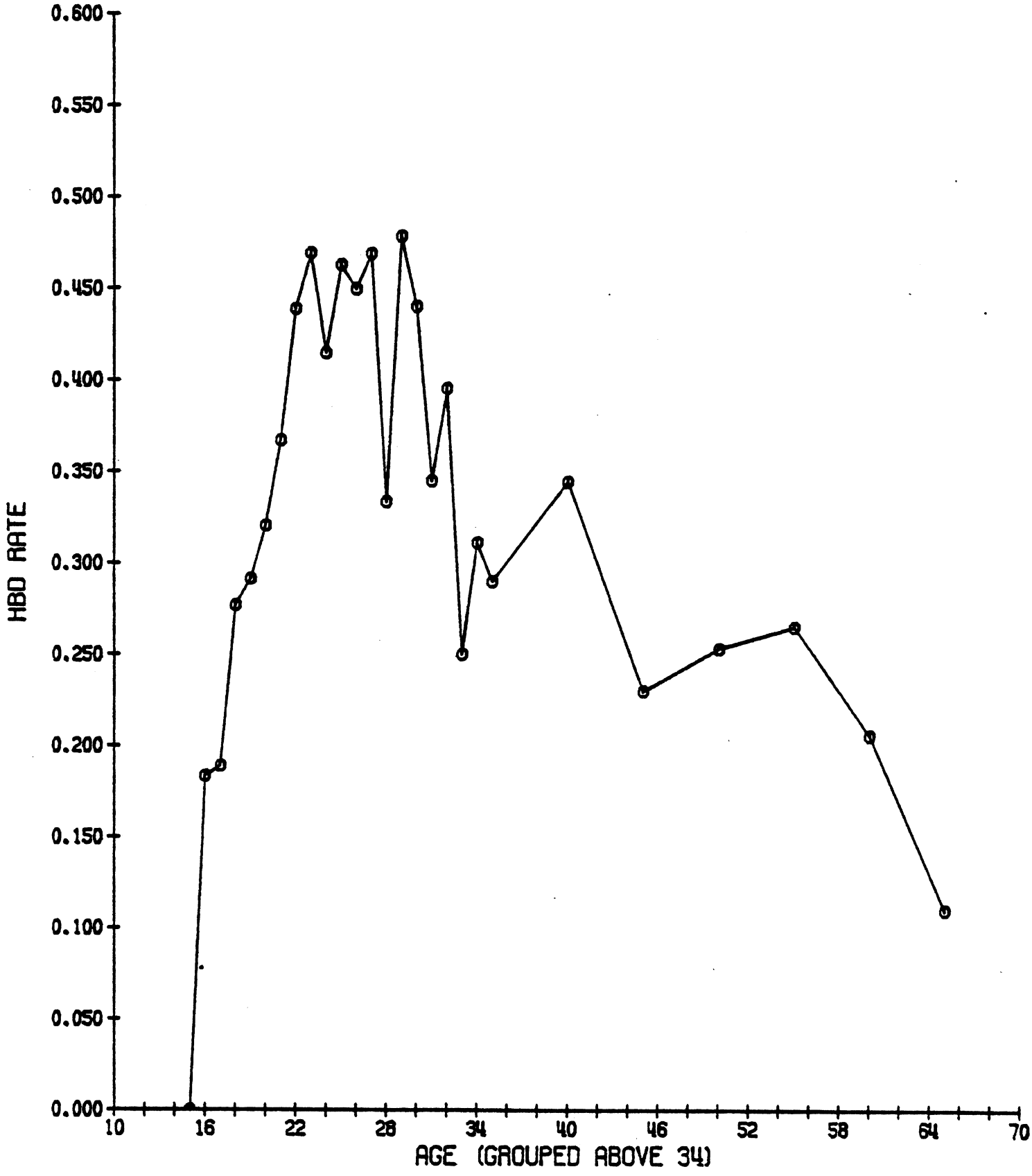
Appendix B

Plots of HBD Rates by Age



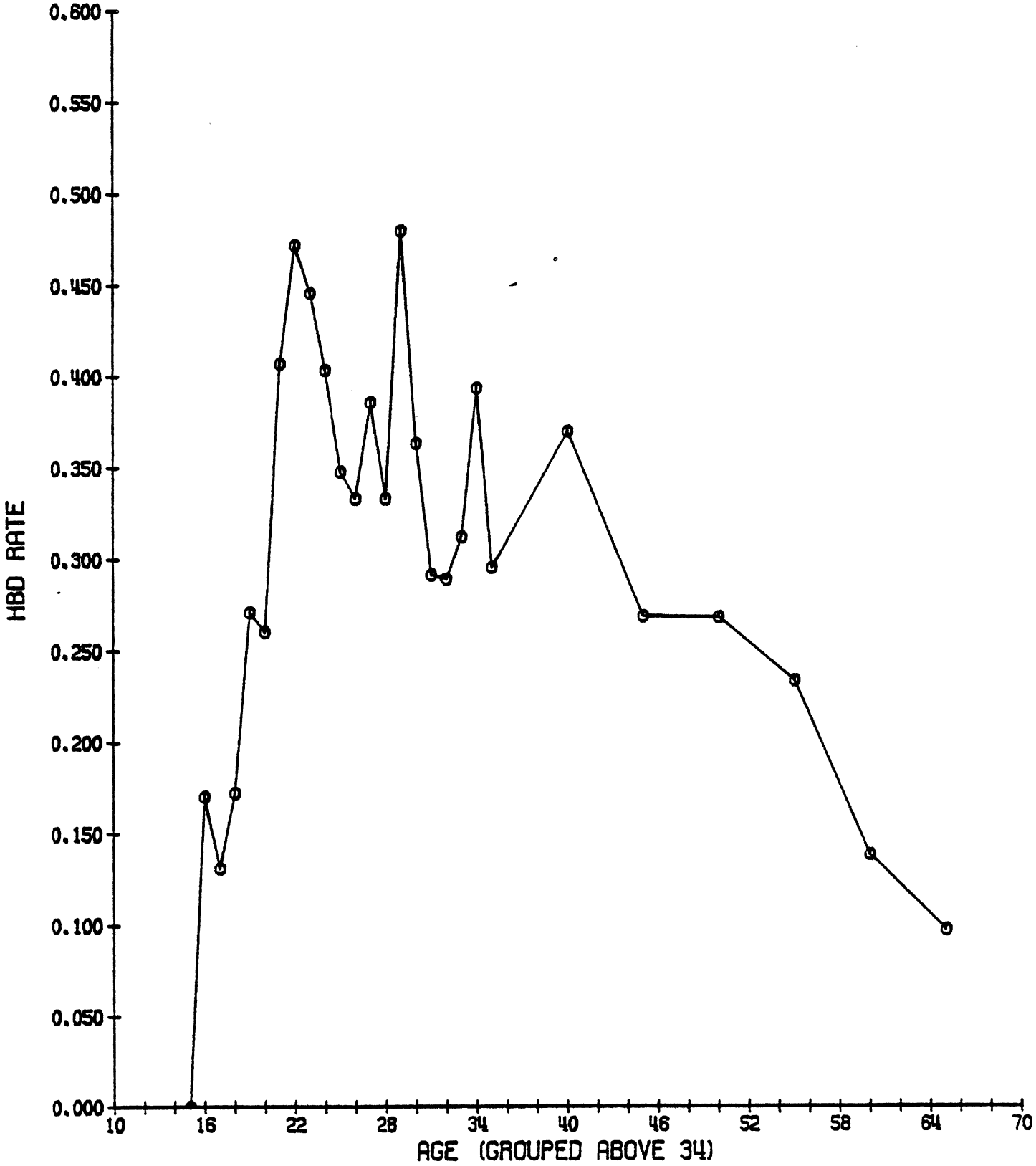

HBD RATE (NO M.D.) BY AGE
5 YR GROUPS ABOVE 34 (PLOTTED AT FIRST YEAR OF GROUP, 35 REPRESENTS 35-39)
1968 FATAL FILE

FIGURE B1




HBD RATE (NO M.D.) BY AGE
5 YEAR GROUPS ABOVE 34
1969 FATAL FILE

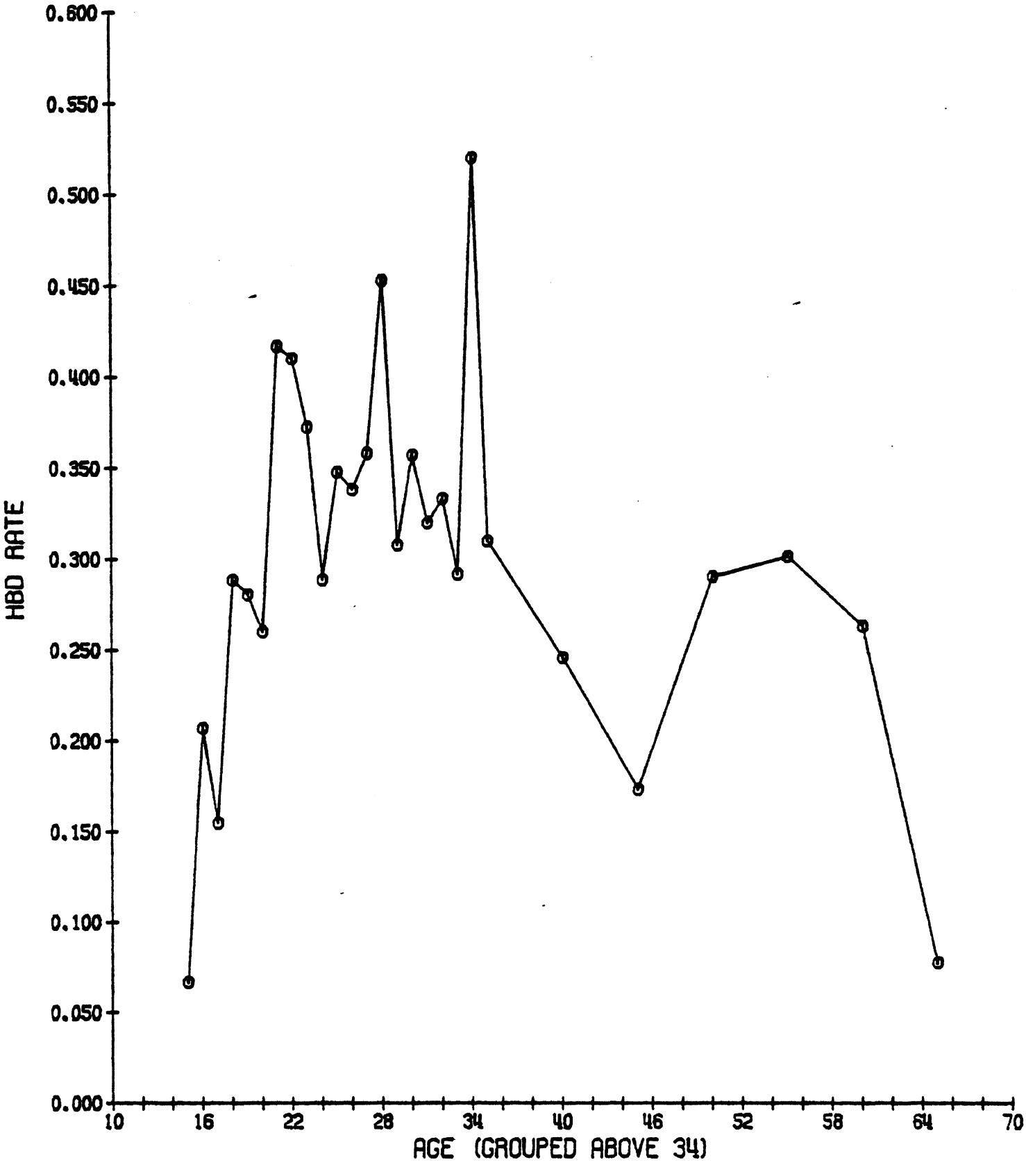
FIGURE B2




HBD RATE (NO M.D.) BY AGE

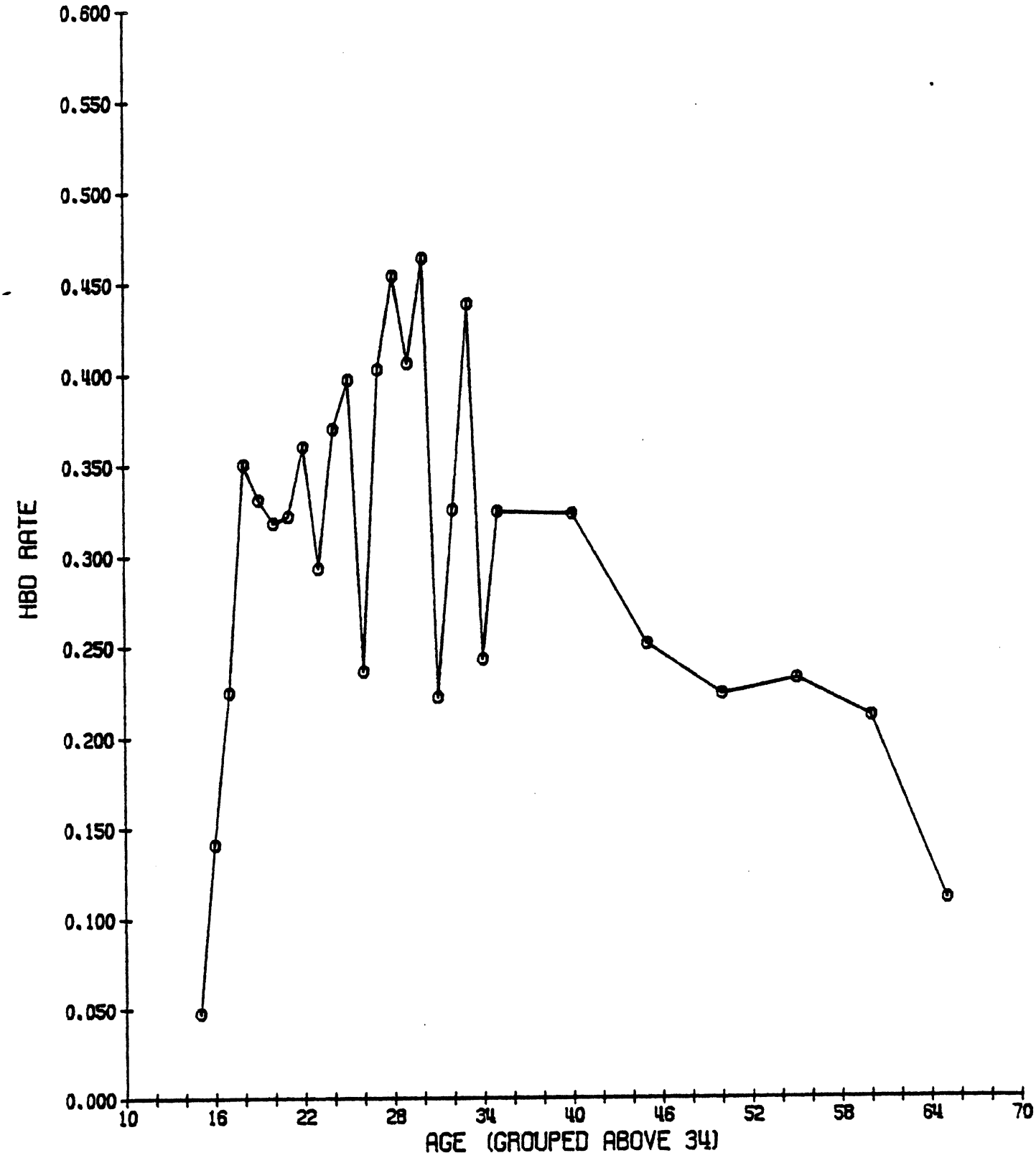
5 YEAR GROUPS ABOVE 34
1970 FATAL FILE

FIGURE B3



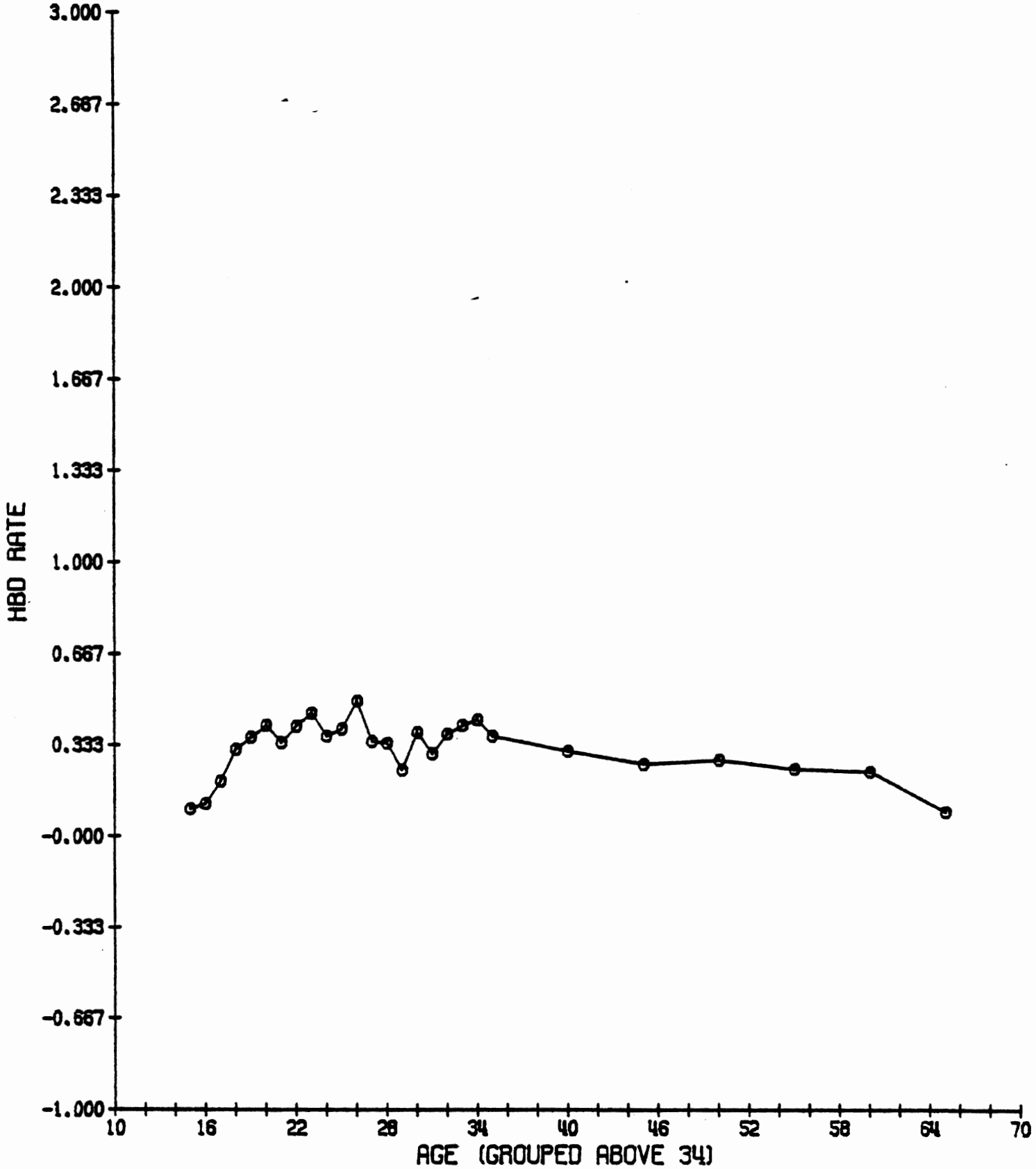

HBD RATE (NO M.D.) BY AGE
5 YEAR GROUPS ABOVE 34
1971 FATAL FILE

FIGURE B4



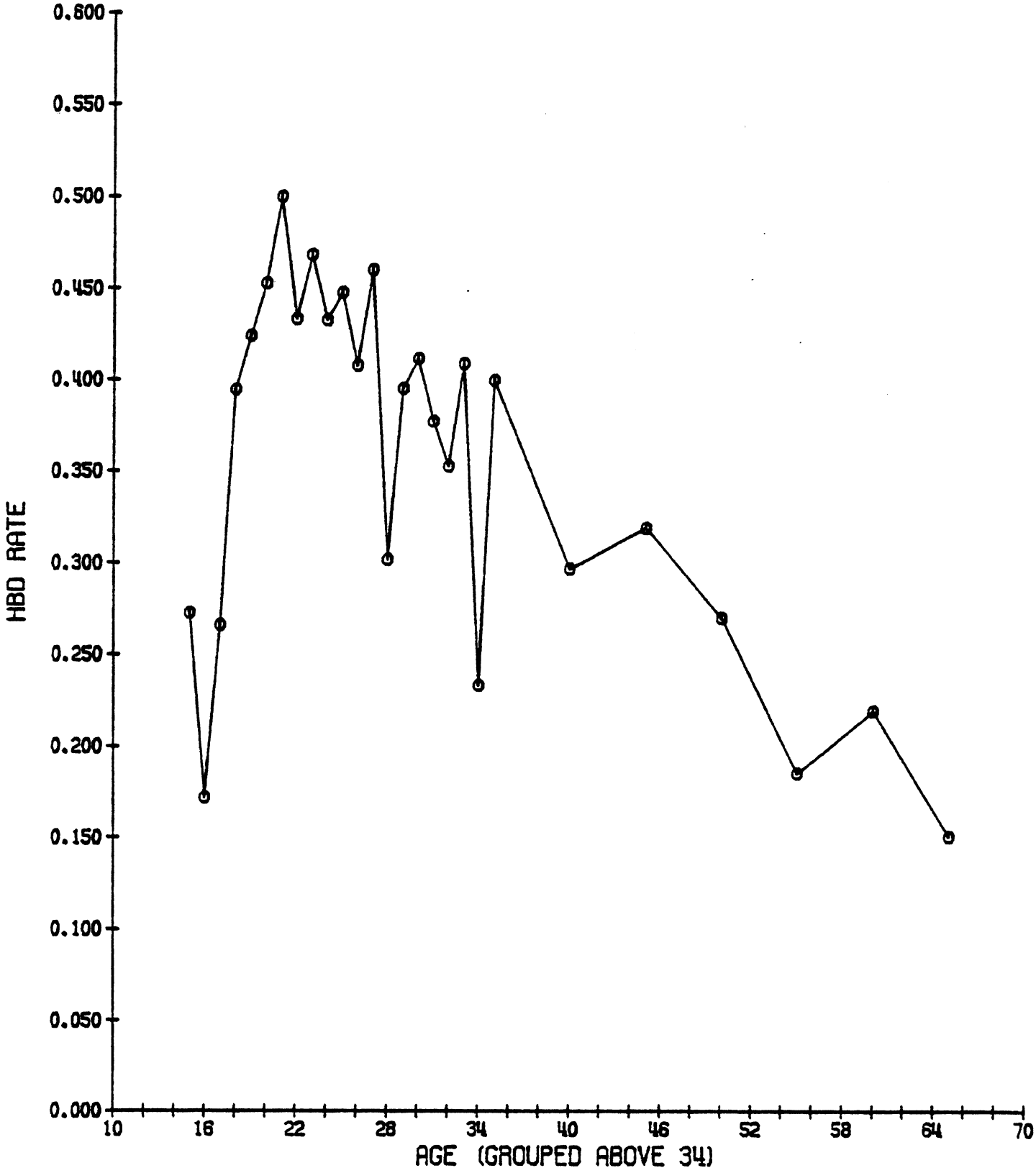

HBD RATE (NO M.D.) BY AGE
5 YEAR GROUPS ABOVE 34
1972 FATAL FILE

FIGURE B5



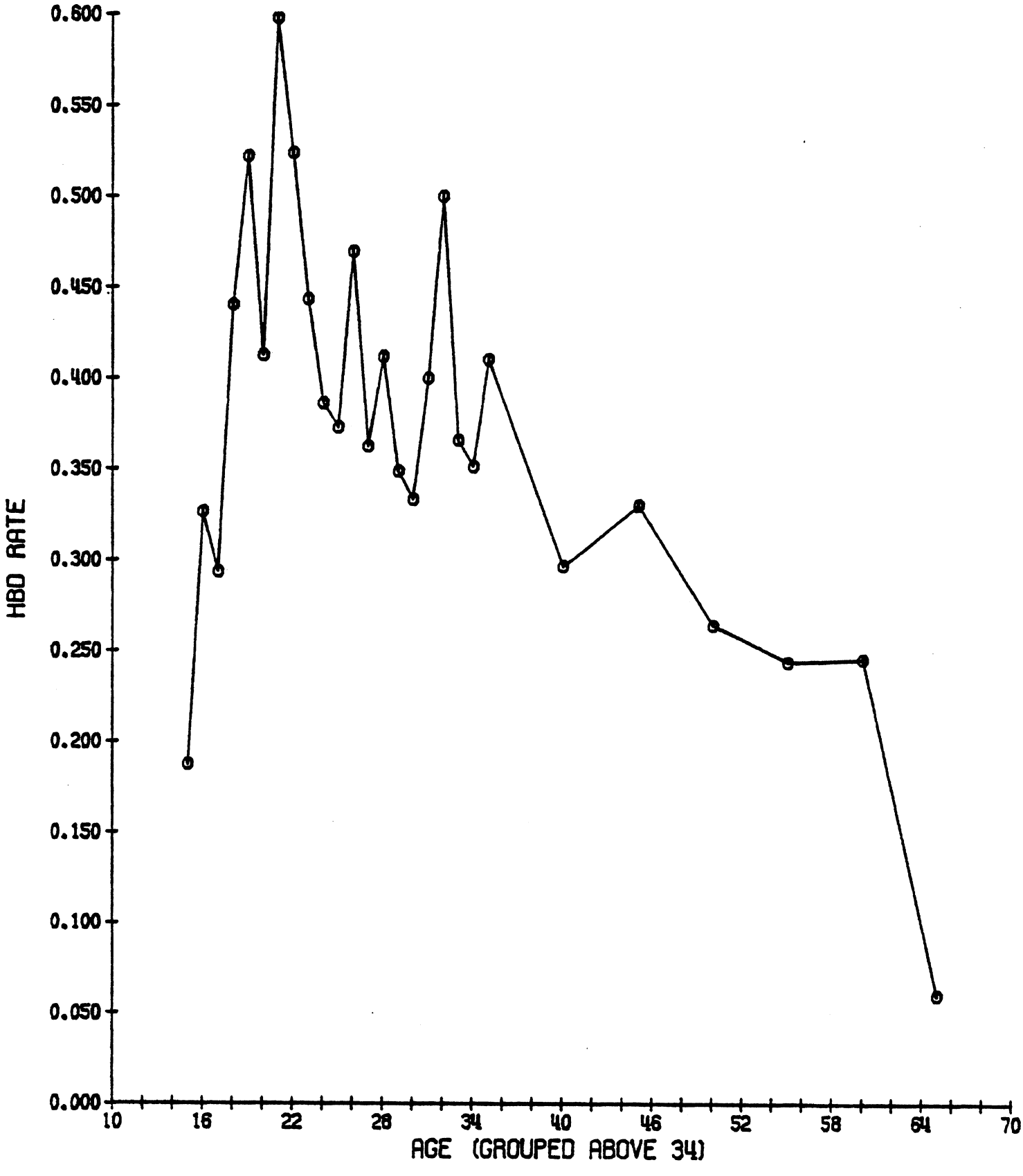

HBD RATE (NO M.D.) BY AGE
5 YEAR GROUPS ABOVE 34
1973 FATAL FILE

FIGURE B6



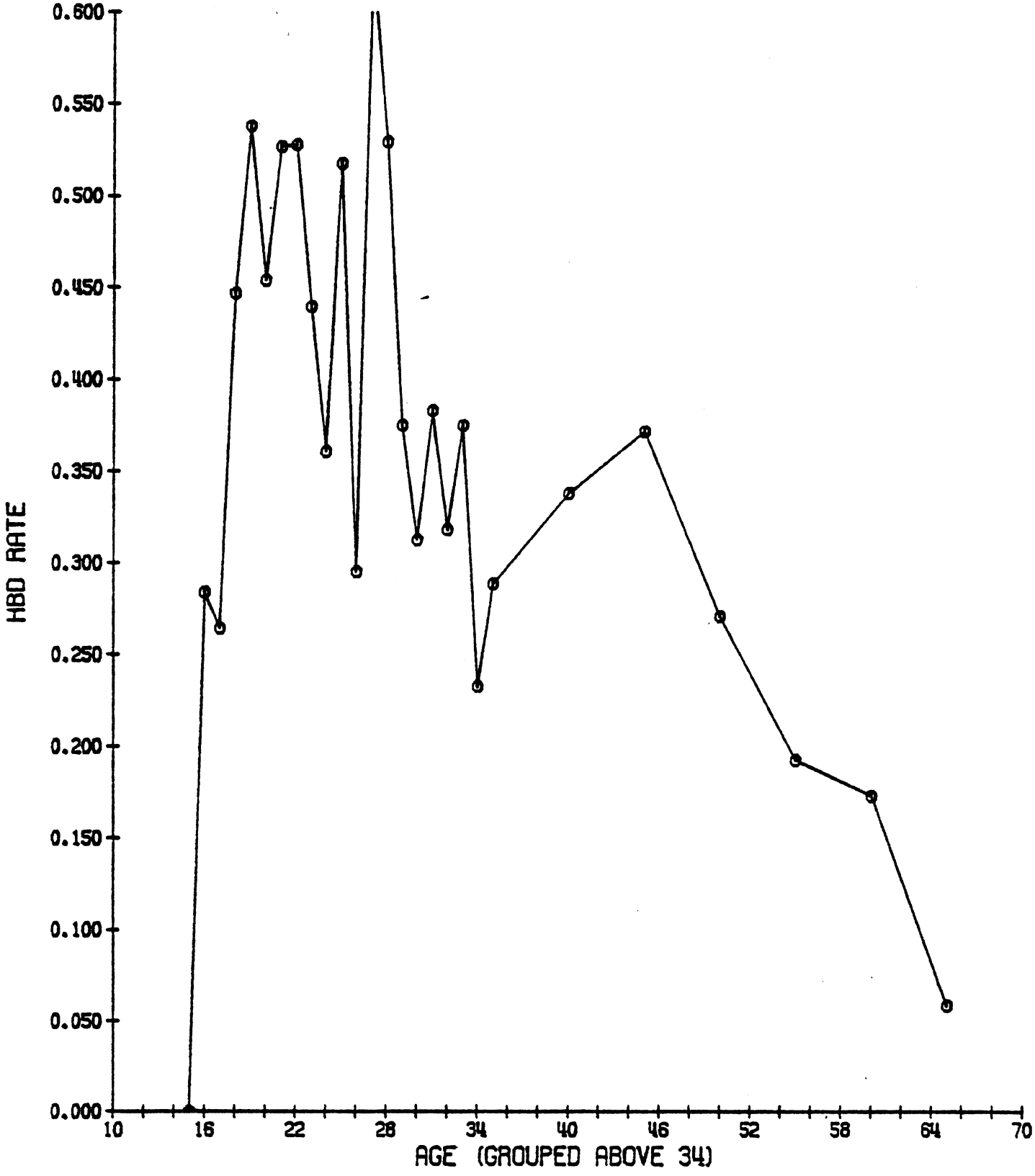

HBD RATE (NO M.D.) BY AGE
5 YEAR GROUPS ABOVE 34
1974 FATAL FILE

FIGURE B7




HBD RATE (NO M.D.) BY AGE
5 YEAR GROUPS ABOVE 34
1975 FATAL FILE

FIGURE B8




HBD RATE (NO M.D.) BY AGE
5 YEAR GROUPS ABOVE 34
1976 FATAL FILE

FIGURE B9