DOCUMENT RESUME

ED 073 228 VT 018 422

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TITLE Characteristics of Youthful Bicycle Riders in an Urban Community and Events Accruing to Operation of Their Vehicles.
INSTITUTION North Carolina Univ., Chapel Hill. Highway Safety Research Center.
PUB DATE Jun 71
NOTE 109p.

EDRS PRICE MF-$0.65 HC-$6.58
DESCRIPTORS Accident Prevention; Educational Needs; Elementary School Students; Junior High School Students; *Participant Characteristics; Physical Design Needs; *Traffic Accidents; Traffic Safety; Transportation; *Urban Areas; *Urban Youth; Vehicular Traffic
IDENTIFIERS *Bicycle Riders

ABSTRACT

A 6-month study of elementary and junior high school bicycle riders and events accruing to everyday use of their vehicles was conducted in Raleigh, North Carolina. Of the 2,369 mail questionnaires that recorded demographic and bicycle description data and information which permitted calculation of bicycle ownership rates by sex, 495 useable responses were obtained. Accident data were accumulated from hospital emergency rooms, police records, and a monthly report form that received 397 useable responses. Mileage data was calculated through use of cyclometers on the subjects' bicycles. Younger riders tend to sustain the more serious accidents, while the older rider is more often involved in a police-reported situation. Riders with less than two years experience tend to sustain more accidents. Only the time of the day (three to six P.M.) and the month of the year (May and June) were positively associated with bicycle accidents. Accident rate differences according to the type of bicycle, its age, condition, or passenger carrying status are statistically insignificant. The findings of this study substantiate other studies that cite rider disaccommodation to the bicycle as a factor in development of the accident situation. Bicycle riding instructions might be organized according to the experience and sex of the rider. (Author/AG)

Highway Safety Research Center

a study of youthful bicycle riders in an urban community

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june, 1971

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER
CHAPEL HILL, NORTH CAROLINA

CHARACTERISTICS OF YOUTHFUL BICYCLE RIDERS IN AN URBAN COMMUNITY AND EVENTS ACCRUING TO OPERATION OF THEIR VEHICLES

by

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June, 1971

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ACKNOWLEDGEMENTS

This study of bicycle accidents was possible only by virtue of faithful cooperation by Raleigh elementary and junior high school students, their teachers, and supervisory officials of the Raleigh Public Schools.

Similarly, only the cooperation of Raleigh police officers, physicians, and hospital administrators made it possible for UNC to obtain injury data.

The Raleigh Optimists Clubs gave valuable assistance in the planning phases of the study and in mounting mileage meters on hundreds of bikes.

A special word of appreciation is sincerely extended to the entire HSRC technical and clerical staff, especially Verneta Clark for programming, Barry Blackburn for data management, and the secretaries who provided the typed copy.

Finally, a generous, unrestricted financial gift from the Bicycle Institute of America made the whole effort possible.

Grateful thanks are tendered to all of these.

ABSTRACT

A study of youthful bicycle riders and events accruing to everyday use of their vehicles was conducted in a Southern U.S. city from May to October of 1970. The subjects, ranging in age from 6-19 years, were chosen in a random manner from selected elementary and junior high schools included in the Raleigh, N.C., City School System. Initial contact with the subjects was accomplished by a questionnaire that recorded demographic and bicycle description data and information which permitted calculation of bicycle ownership rates by sex. Of the 2,369 questionnaires sent to originally chosen subjects, 495 or 21% were completed and returned. Accident data were accumulated through three levels of reporting: hospital emergency rooms, police records and a monthly report form that was sent to subjects who agreed to participate in the data collection phase of the study.

An estimate of exposure was calculated through use of a cyclometer (mileage meter) attached to the front wheel of each subject's bicycle. Five hundred and twenty-three cyclometers were applied to subject's bicycles, with 397 subjects eventually supplying mileage data of acceptable quality. It was determined that the three types of bicycles identified in the study (highrise, lightweight and standard) experienced accidents at rates which did not attain statistical significance. Observed rates for accident occurrence for males, as compared to females, and by age groups was also not statistically different. It was found that highrise bicycles outnumbered the other styles, with standard and lightweight types following in decreasing order of ownership.

It was observed that younger riders will be likely to sustain the more serious accidents, while the older rider will more often be involved in a police-reported situation. Accidents examined by riding experience of the subject involved suggest that the less-than-one-year to two-year-experience groups sustain accidents at greater than expected values by a statistically significant margin. It was proposed that bicycle riding instructions might be organized by experience of the rider as well as by male/female specific instruction.

Of the conditions associated with bicycle accidents, only time of the day (3-6 p.m.) and month of the year (May and June) appeared to have relevance for safety-oriented programs. Bicycle age, condition and passenger carrying status were not found to be significantly associated with accident occurrence.

Other studies (Vilardo and Anderson 1969 and The Ontario Department of Transportation 1970) cited rider disaccomodation to the bicycle as a factor in development of the accident situation. Findings of this study would tend to substantiate their observations.

INTRODUCTION

An historical documentation of man's existence on earth would be notably incomplete without proper reference to transportation and the vehicles specifically designed for the movement of passengers and goods. Progressing from foot travel through domesticated beasts, to jet and rocket craft, men have searched for ways to implement their mobility and reduce travel time between any two points in space. As vehicles have become more sophisticated, and energy sources more efficient, muscle power has steadily lost favor as the motive source of choice.

Among the consistent adherents of motion-through-exertion were the more youthful segments of human populations who seized whatever devices were available to them. Generally, these devices were two-wheeled vehicles, popularly called bicycles or "bikes," which have become indispensible companions to youngsters over many decades of close association.

During the last decade the "bike" changed remarkably in configuration. At that point manufacturers began developing and marketing models that reflected the influence of individually customized bikes, which could be seen in increasing numbers in Southern California. These newer models, eventually termed the "Highrise" (or spyder) style, apparently satisfied the requirements of large numbers of potential customers, as they eventually accounted for over half of all yearly bicycle sales in this country.

The distinctive proportions of the new style render it immediately recognizable even to the most casual observer. Predominant features include: exceptional loft and spread of the handlebars; an elongated seat, which is occasionally fitted with bars projecting vertically from the rear of the saddle; small wheels, usually not exceeding 24" in diameter and generally 20" with smaller sizes being observed occasionally; a standard frame (of 16"-24" size) giving the impression of massiveness and strength; and, finally, any number of accessories and gearing combinations, limited only by the imagination and resources of the owner.

The resulting high visibility of the vehicle attracted attention to the design features and led some observers to theorize as to the inherent riding safety of the mechanism relative to the variant configurations. From there, it was but a short step to expansion of the question to include riding experience for all bicycle types.

To attack the problem of relative safety, a population survey employing a random method for selection of the subjects was developed. As primary interest lay within the 6-17 year age groups, elementary and junior high school student bodies were designated as the target population. The process for the selection of the subjects in the main study is discussed more fully in the Study Design and Objectives section.

Selection of the general area to serve as the location of the study was given first consideration. After consultation with co-workers at the Highway Safety Research Center, it was decided that an urban area would offer more in the way of practical advantages than either suburban or rural locations. There would be a larger population in a more restricted geographical territory, and its composition would tend to be more varied in socio-economic characteristics. As the United States had now become principally an urban country, results of the study would thereby be generally referable to a larger proportion of the total U. S. population.

It was proposed that the city of Raleigh, North Carolina, might most effectively serve both the interests of the study and tactical execution of the general plan. Raleigh, with a population of some 117,000 (1970 census), may be considered as broadly representative of a sector of the U. S. population. It is perhaps reasonable to assume that population centers of between 75,000 and 150,000 inhabitants share many important demographic characteristics. If this assumption is admissible, then a summation of the populations residing in cities falling within that range might be some indication of the representativeness of a city with approximately 100,000 population.

Inspection of the 1970 Commercial Atlas and Marketing Guide (Appendix 2, page 102) produced a list of some 145 cities with populations within the indicated limits. Summing the totals of the cities produces a combined population of 14,575,500 inhabitants residing within the 145 cities. Further application of simple arithmetic discloses that the mean population is calculated to be 100,521. A standard deviation of 20,720 indicates the Raleigh population (''7,000) is within one standard deviation of the mean (100,521) of this selected segment of the total U. S. population. It was decided, on the basis of the factors discussed, that the city of Raleigh would be an acceptable population base for a study of this nature.

To test the instruments designed for data collection, a pilot study was initiated. For this evaluative phase, two schools in the Raleigh school system (Sherwood-Bates Elementary School and Josephus Daniels Junior High School) were contacted through the office of the Superintendent of Schools, and permission to enlist the student body was granted by the principals of the two institutions. For this test of the system, all of the students in the fourth and sixth grades of Sherwood-Bates and the seventh and ninth grades of Josephus Daniels were sent explanatory letters and questionnaires. It was requested that all of the questionnaires be returned whether or not participation in the study was elected. This provision permitted calculation of ownership rates from which projections into the Raleigh and total U. S. populations were made. The pilot study was not further processed, as attention shifted to implementation and organization of the Main Study data collection.

In bicycle studies previously recorded in the literature, exposure data necessary for the estimation of accident rates were not available. The Raleigh, N. C., study, described herein, employed a mechanical counter known as a "cyclometer," which records distance traveled (from 0.0 to 9,999.9 miles) when properly affixed to the front wheel of the bicycle. There were 523 of the devices attached to subjects' vehicles with 397 eventually reporting exposure data that satisfied the reporting standards of the study from which accident rates were calculated.

Bicycle accidents occurring in the Raleigh area were accumulated through three separate reporting media. A surveillance of the three hospitals in Raleigh provided emergency room data on medically treated injuries. All such accidents were recorded and data were accumulated through a telephone interview, which was performed according to a standard format (Appendix 1, p. 76). Permission to examine police records was granted and data accruing to this source were similarly processed. The participating school-aged study subjects formed the third reporting medium. Their bicycling experiences were documented regularly on a monthly mileage report form (Appendix 1, p. 87). This report form (self-addressed and stamped) was sent every month to each subject with spaces provided for information on mileage, broken cyclometers, and accidents. Accidents were then processed by the same procedure as described for Hospital and Police accidents.

An investigation of this nature would appear to be most appropriate at this time. considering the increased interest in bicycling over the past few years. The U. S. Dept. of the Interior (1967) projects a 32% growth in bicycling from 1965 through 1980 and concludes that this activity has shown the greatest increase of all outdoor sports since 1965.

In summation, the current investigation has attempted to identify certain characteristics of bicycle usage as these relate to exposure and the occurrence of accidents. Successful implementation of the design allows estimation of accident rates by bicycle type. sex and age, corrected for exposure in terms of mileage.

LITERATURE REVIEW

In contradiction to the lengthy experience of the bicycle in the U. S. stands the paucity of technical and empirical data relating engineering and design features to its use in the service of the bicycling public. The existing studies having relevance to the current investigation are recorded herein.

A limited recent study of bicycle design and performance features by Rice (1971) suggested a difference between highrise and other bicycles in handling characteristics that affected balance and maneuverability to a marked degree. The author found variations in dynamic balance that suggested the highrise is less stable in the lower speed ranges (under 10 mph) than other bicycle types. His conclusions included suggestions that the highrise is better suited for enjoyment than transportation and that information on proper braking technique should be provided at the time the bicycle is purchased.

One of the earliest attempts to gather descriptive data was initiated by the National Safety Council (NSC). In 1958, each of the forty-eight states was polled in an attempt to gain information on bicycle fatalities which had occurred in 1957. Forty-two of the states responded by supplying information on 82 percent of the fatal accidents. NSC, after analyzing these data, derived the following conclusions:

1. 84% of the fatalities were under 16 years of age;
2. 86% of the fatalities were males;
3. 70% of the fatalities occurred from April to Septemb
4. 70% of the fatalities ensued during the daylight hours:
5. Highest frequency of observed fatalities was on Saturday, the lowest on Sunday;
6. 80% of the fatalities took place when the bicyclist was "violating a rule of the road."

These findings were generally supported by later investigations (Vilardo, Nicol and Heath, 1968; Kohler, 1962; and the Ontario Department of Transportation, 1970). The studies surveyed rider practices and revealed evidence of rider "violation of rules of the road." Violations involving bicycles must be considered in respect to the highly subjective manner in which judgment is reached. Unlike motor vehicle operation, there is no nationally recognized code that regulates the operation of a bicycle.

The National Safety Council (Vilardo and Anderson, 1969) sampled six geographic areas of the country and found males over-represented in bicycle-motor vehicle accidents with fewer but more severe accidents occurring after dark. They also advanced three other findings of note: accident frequency is not differentiated by bicycle type, the "accommodation" of the child to the bike may be critical, and the 10-14 year age group experienced the highest accident frequency.

Waller and Reinfurt (1969), in an analysis of bicycle-motor vehicle accidents occurring in a three-year period in North Carolina, concluded that a typical accident happens in clear, dry weather, in daylight, and involves an auto driven by a male 25-45 years of age. The cyclist, a male (10-15 years of age), appears unexpectedly from a driveway, alley or intersection. While it was found that younger riders experience higher accident frequency, fatalities are associated with the older rider. This last finding may be explained in part by the accident experience of the areas where most of the riding time is accumulated. Accidents incurred on the open highway experience a greater case-fatality ratio.

Increasing interest in the relative safety of consumer items may be reflected in the emphasis of the most recent bicycle studies. Waller (1970) and the Ontario Department of Transportation (1970) each applied their scrutiny to differences in accident experience by bicycle type. Each study found no difference by bicycle type, but the Ontario report qualifies its findings by citing limitations of the study design. Differences in rates of accident occurrence by bicycle type in the Raleigh, N. C., study, described herein, are developed through incidence values (i.e., estimated from known numbers of events ensuing within a known population over a given period of time).

Six thousand five-to-twelve-year-old children were studied by Waller (1970) for patterns of ownership and bicycle riding experience. Additionally, 104 medically treated accident victims were paired with matched controls selected from the neighborhood to compare bicycle style and riding background. His data contain similarities to findings obtained in the Ontario study. In his study population, 80 percent learned to ride by age 7; highrise bikes produced higher injury rates, which were not significantly different from other bicycles; children at the time apparently preferred highrise to all other styles; and parents generally exercised good judgment in initiating riding practices. He recommended improved handle bar mounting and a guard to prevent injury from intrusion of a body member into the wheel spokes.

The Ontario Department of Transportation (1970) analyzed 275 police-reported bicycle collisions and compared the bicyclist to a control group of 1,082 male riders. This study, as well as The National Safety Council (1969) report, cited "disaccommodation" as a factor which may be considered to influence risk of accident inception. This factor seems to be well documented and should be given consideration by parents seeking to purchase a bicycle for their youngster, particularly so if it is the first bicycle to serve as a "learning" vehicle for the neophyte rider.

STUDY DESIGN AND OBJECTIVES

The elements of the question posed to the researchers (viz., accident rates and characteristics of use by population sub-groups) operationally defined the procedures, elaborated upon in the research design. It is necessary to generate exposure data, in a comparatively reliable manner, on a selected sample of the target population. This is the essence of sampling—to extract a small group from a much larger group while attempting to retain the characteristics of the large group in similar proportions.

Selection of the Sample

To attack the problem, the range considered most vulnerable to accidents was selected (6-17 years—Accident Facts, 1970). As random selection was indicated, a method was devised to sample from grade school and junior high school students in a manner that would assure reasonable impartiality in the identification of the subjects. Sampling was to be conducted in the environment where the subjects could most easily be enumerated—the schools. A list of all Raleigh city school children (grades 2 through 9) was obtained from the Office of the Superintendent. The list was organized by school, grade, homeroom and homeroom teacher, with each pupil to be accorded an identification number. Because there were fewer of them, all of the junior high schools were used for sampling, while a systematic selection process was devised for the elementary schools.

Twenty-eight elementary schools were grouped by total pupil enrollment for grades two through six. There were five large schools (enrollment range 526-602), eleven medium schools (enrollment range 336-486), and twelve small schools (enrollment range 108-294). Complicating the selection was the desire to reduce the number of participating schools to a minimum (to decrease the number of cyclometer installation sites) and yet to obtain a representative sample with adequate numbers and approximately equal probability of selection for all pupils within the school system. It had been previously determined to invite 2,000 to 2,600 pupils on the assumption that approximately 20-30 percent would return the questionnaires. Guided by this reasoning, the research team selected all of the larger schools along with six of the eleven medium and six of the twelve small schools. A random selection process identified the small and medium size schools. This resulted in the following list of schools selected to participate in the study (also see map Appendix I, p. 78).

Junior High Schools	Elementary Schools (large)
Aycock	Lacy
Carnage	Washington
Carroll	Brooks
Martin	Douglas
	Green

Elementary Schools (medium)	Elementary Schools (small)
Conn	Thompson
Mt. Vernon-Goodwin	Phillips
Hunter	Underwood
Root	Olds
Bugg	Boylan Heights
York	Wiley

With the selection of the schools, a random process was used for the identification of individual students. Names of homeroom teachers were alphabetized and given numbers according to their alphabetical position within a particular grade. Within each grade and school half of the classes were chosen. If there were an odd number of classes in a particular grade, the numbers of classes to be chosen were raised to the next highest integer. To transfer as exactly as possible the proportions existing within the school population to our sample (i.e., equal probability of selection for each student), about one-quarter of the students in each class in the large schools was to receive questionnaires while one-half of the students in each class in the medium and small schools was to be included on the mailing list.

When the list of classes was compiled, the students were chosen in the following manner: The names of the students, last name first, were ordered alphabetically within each class and given a corresponding number. The number of students in each class was recorded, and the students were individually collected by the following convention. If the number was:

≤ 16 , the students were arranged in eight groups of two each;

> 16 to ≤ 24, the students were arranged in eight groups of three each;

> 24 to ≤ 32, the students were arranged in eight groups of four each;

> 32 to ≤ 40, the students were arranged in eight groups of five each.

In each case, therefore, there were eight groups.

When one-quarter of the students in a grade was needed, two of the groups were used; for one-half of the students, four of the eight groups were selected. In the event that the number of students was not exactly 16, 24, 32, or 40, some groups were partially or totally unpopulated. If these unpopulated groups were selected for a particular grade, an additional group or portion thereof was appropriated to fill or replace them. In this case the proportion selected exceeded the indicated one-quarter or one-half. For example, if there were 27 students and we wanted at least one-quarter of them (i.e., a large school), then in fact eight were chosen. Let us assume that groups one through eight were printed in the following order: 8, 7, 6, 1, 2, 5, 4, 3. Since the eighth group of four has no people (numbers 29 through 32) we go to the next number which is 7. Since the seventh group consists of numbers 25 through 28 and there are only 27 students, the seventh group consists of three people. The random number following number 7 is used only to complete that group of four (i.e., the first person in group 6 number 21 is picked). To get our second group of four we use the next random number which is 1. Hence, all of the first group (numbers one through four) were chosen. As a result, where the required proportion was one-quarter of the students in a class (i.e., the large schools) and the number of students in the class was:

≤ 16 , four students were chosen;

> 16 to ≤ 24, six students were chosen;

> 24 to ≤ 32, eight students were chosen;

> 32 to ≤ 40, ten students were chosen.

Where a medium or small school was being processed, four groups were picked by the same procedure outlined above, yielding twice the number of students from each class.

As indicated earlier, all of the junior high schools were retained with one-quarter of the students selected. This proportion would produce a probability for selection approximately equivalent for the entire school population.

Of the 2,369 questionnaires (p. 12, and appendix 1, p. 81) sent to the original selected subjects, 495 questionnaires were eventually returned. The 495 questionnaires received thus produced three classes of respondents who returned the questionnaires: (1) original subjects, (2) siblings of original subjects, and (3) the "no bicycle" group. Obviously, combinations of the above groups (e.g., original subjects and siblings, original subjects and "no bike," etc.) were possible and were indeed encountered. For purposes of identification and processing, the respondents were grouped in the manner illustrated in the flow chart titled "Disposition of All Subjects" (Figures No. 1 and No. 2). The All Subjects group (subjects identified with the study at any time whether or not they supplied data) is separated (reading from left or right) in Non-Participating, Hospital and Police, and Participating Groups. There were three means by which an individual might become a participating subject. First, selection in the random sample (original subjects); second, siblings of original subjects (non-original subjects); and third, individuals who appeared at cyclometer mounting sites and completed the necessary forms (they were also non-original subjects). The rationale that explains this method of selection presumes that the sampling process is essentially identifying households of individuals all of whom are acceptable for the purposes of the study. Individuals who presented themselves at the cyclometer sites were most likely acquaintances of those originally selected and other interested individuals. While there is self-selection in this portion of the sample, there was no reason to assume that there would be disproportionate representation by bicycle type.

Figure No. 1 illustrates the breakdown of the various groups by class of participation. From left to right in the diagram the partitions include non-participants, hospital and police cases, and participants. Inspection of the group sizes reveals that over half (237 vs. 207) of the original subjects participated in the study. Of the non-original subjects, slightly less than half (286 vs. 292) eventually provided data during the study period, and some information was obtained for each of the 1,204 subjects.

Figure No. 2 identifies the composition of the 1,073 youths who are termed Main Study Subjects. These individuals are differentiated from the Hospital and Police Accidents who are essentially case history subjects, having entered the study by means of experiencing an accident. Reading down the diagram to the fourth row reveals that there were 286 participating non-original and 237 participating original subjects. Of these 523 subjects who received cyclometers, 496 (94.8%) supplied data of some nature to the study, and 397 provided acceptable exposure (mileage) information.

Study groups will be referred to by abbreviations according to their composition. The following list identifies all of the groups designated in this manner:

Main Study Participants (MSP), N=523

- Original; subjects who were sent questionnaires and who elected to participate in study, N=237
- Non-Original; siblings of original subjects plus volunteers who requested entry into the study, N=286

Figure 1

DISPOSITION OF ALL SUBJECTS BY CLASS OF PARTICIPATION

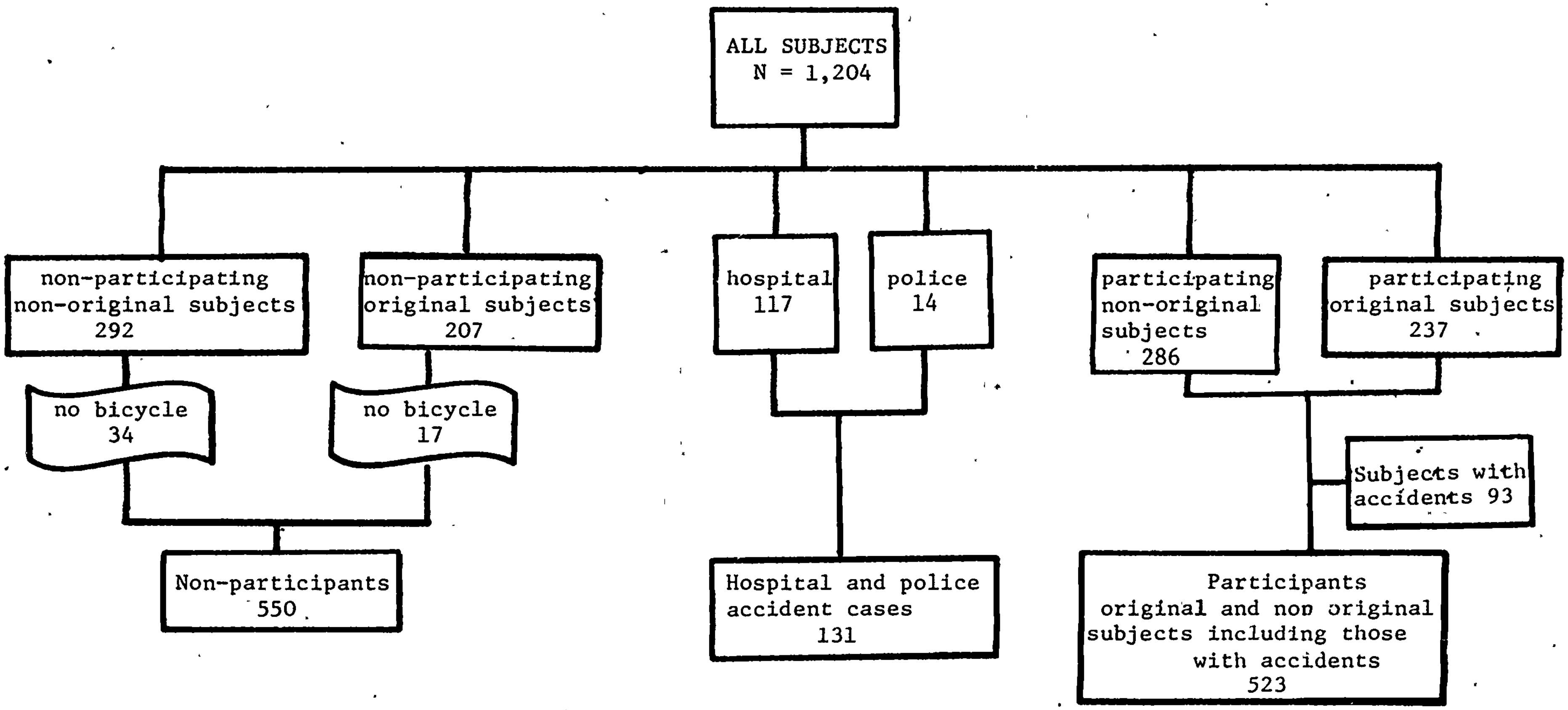
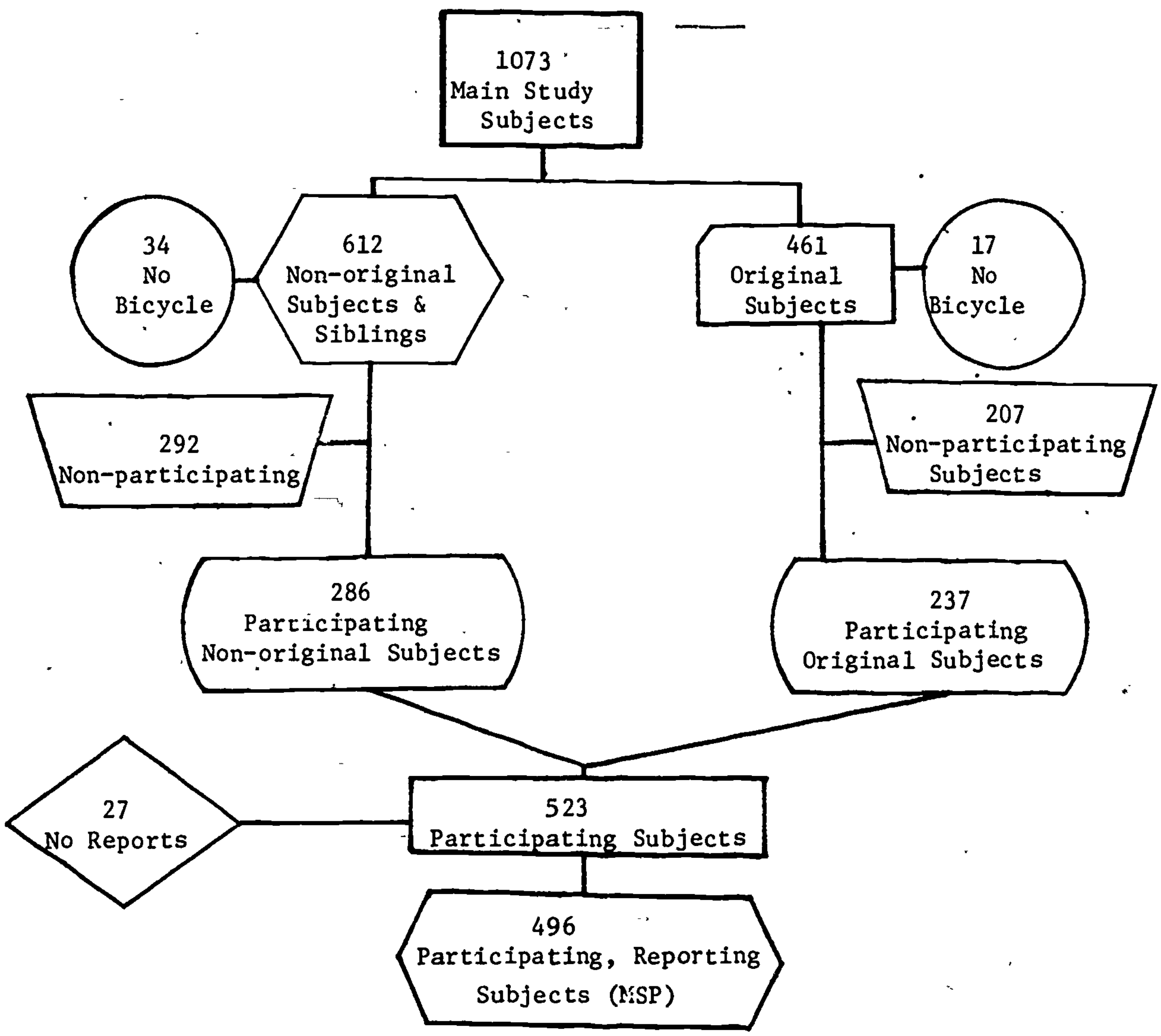


Figure 2

DISPOSITION OF MAIN STUDY SUBJECTS



Main Study Participants Without Accidents (MSPWA)

Original plus non-original who had no accidents, N=430

Main Study Participants With Accidents (MSPAC)

Original and non-original MSP who experienced accidents during the study, N=93

Hospital Accident Cases (HAC)

All accident cases recorded through emergency room treatment records, February through November, 1970, N=117

Police Accident Cases (PAC)

All accident cases investigated and recorded by Raleigh City Police Department during 1970, N=14

Hospital and Police Accident Cases (HPAC)

HAC + PAC = HPAC, N=131

Main Study Accident Cases (MSAC)

MSPAC + HAC + PAC = MSAC, N=224

Main Study Non-Participants (MSN-P), N=550

Original, sent questionnaires and declined to participate in study, N=207

Non-original, siblings who declined to participate plus volunteers who acquired cyclometers without subsequently providing data, N=292

All Subjects No Bicycle (ASNB); Original, N=17; Non-original, N=34

All Subjects (AS), N=1,204

MSP + HAC + PAC + MSN-P = AS

The Questionnaire

In constructing the questionnaire (Appendix 1, p. 81), emphasis was placed upon a requirement of a high degree of utility in each query included. The instrument had to be productive yet uncomplex, comprehensive yet brief, and exhaustive yet intelligible. Organization of the questionnaire was accomplished in two parts. Part I was biographical and bicycle ownership data, and Part II was principally oriented towards bicycle description by type. It was noted with pleasure that misinterpretation of a question or the directions appeared to be extremely rare finding and could not be considered as a major source of data error. This was due, in part, to experience gained from a pilot study previously performed on a small sub-group of the study population.

The questionnaire was assembled to provide necessary data without being intrusive or objectionable to the respondent. It is conceded that other questions would have been pertinent to the study requirements. Many were formulated, considered and discarded to reduce the risk of alienating the respondent with excessive complexity and overinquisitiveness. Perhaps a valid indicator of success is that 94.8% of the participants who elected to join the study reported acceptable data of some nature.

Recording Exposure Data

Exposure and accident data for main study participants were recorded monthly on the mileage report form. This self-addressed and stamped instrument (Appendix 1, page 87) was developed to attempt to provide maximum data without exceeding the capabilities and resources of the youngest respondents. Even so, the mileage data from the youngsters required the most deliberate interpretation. Numerous erroneous configurations were encountered. Occasionally a decimal would be misplaced, numbers would be inverted or recorded in the wrong sequence. Each entry was given individual consideration and examined in light of previous mileage reports from the same subject. Other variations required more involved interpretation: occasionally it was necessary to call the subject on the telephone to request a re-reading either by himself or by his parent. By this process the attempt was made to reduce mileage misstatements to a minimum. Whenever an accident was noted, the subject was contacted by phone and systematically queried on certain aspects of the event. To reduce biased reporting a prepared format was employed in the interview (Appendix 1, page 76).

Inclusion of a stick figure for anatomical location of injury appeared to be an effective device, especially for more youthful populations(Appendix 1, p. 87). Injuries were described by three modes of identification: first, Degree of Injury (medical identification); second, Type of Injury (extent of physical damage); and third, Area of Body Injured (anatomical location). Assessment of the injury in this systematic manner allowed for the estimation of injuries for Raleigh (results and discussion section, page 17; Appendix 2, page 101) and for the total United States bicycling population. The resulting values could then be compared, superficially, with nationally published figures of bicycle injuries, as compiled by the United States Public Health Service in recent years. Direct in-depth comparison of the two sets of data, however, is not advised, as two differing methods were employed for their respective estimations.

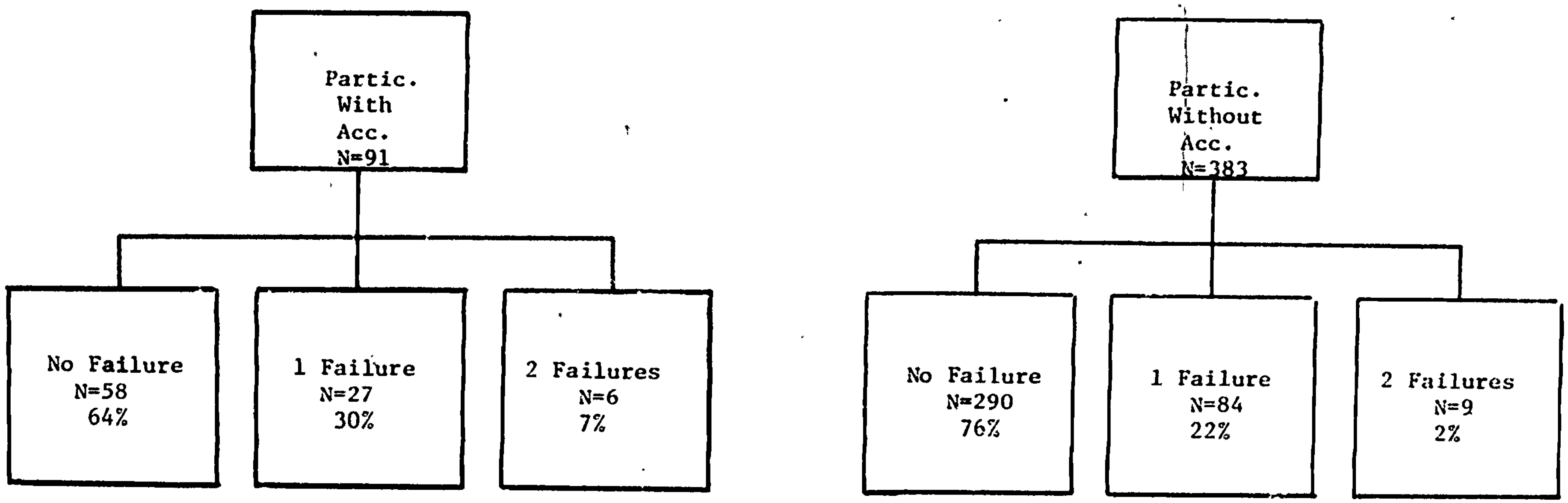
The Cyclometer

One entry included in the monthly report form was designed to do double duty. A question relating to the current mechanical status of the cyclometer provided a means for the replacement of inoperative mechanisms and served to measure the reliability (in this case the durability) of the instrument itself (See Figure No. 3).

Participants with accidents experienced a higher rate of cycometer failure (37% vs. 24%) than participants without accidents. The two distributions were tested by a X^2 and found to be significant (X^2=7.49, 2df, $.02 < p < .05$). Some of the failures in the accident group may be the result of accident-incurred damage, but this was not determined. Perhaps a more reliable estimate of the failure rate is the overall or combined rate of 26.6% or approximately one-quarter of all instruments applied to the subjects' vehicles.

Figure 3

Frequency of Cyclometer Failure For Main Study Participants By Accident Experience



Before the particular cyclometer model was chosen for general distribution, it was tested on several bicycles owned by members of the Highway Safety Research Center Staff and by others willing to provide assistance. The precision of the instrument was assessed over a measured one-half mile course. The course was located on a straight stretch of secondary blacktop road and was measured with steel tape. Four instruments were obtained from a box containing several hundred and applied to two bicycles.

The bicycle was ridden in constant motion to the half-mile mark. The front wheel was stopped on the mark, the rider picked the bicycle up vertically, turned it around and rode back. This process was continued for several traverses whereupon the known distance was compared the the cyclometer reading. Accumulated mileages appearing on the dial were recorded. It was known that some backlash (i.e., slack, play, looseness, or tolerance) existed in the gearset and would account for some small initial error. Over the accumulation of several miles this discrepancy was not observable. The instruments, therefore, were adjudged suitable for the anticipated task.

When the instrument was reported by the subject to be inoperative, a replacement was mailed, no later than the following day, for the subject to install. The replacement unit. which included a full set of instructions, was complete and ready for installation. The cyclometer was also used as a medium for renewal of association with the subjects during a period halfway through the study when it was presumed interest might have lagged. It had been determined (over a course of several months) that the original plastic washer tended to allow some rotation of the cyclometer mounting bracket about the front axle. In order to prevent displacement and subsequent dysfunction of the cyclometers, a quantity of steel washers was obtained as replacements for the original plastic parts. A covering instruction letter (Appendix 1, p. 91) was written and, with washers included, sent to all of the study participants. It was felt that this measure necessitated the inspection of the bicycle by the subject and/or his parent and provided an opportunity for any adjustment or repair which might thereby be discovered.

Report Forms

Collected data were recorded on individual report forms covering every contingency of the study. The forms used, which consisted of the Subject Data Report, Medical Form and Accident Report Form (Appendix 1, pages 93, 95, 97), contained all of the information collected on a given subject. From these forms the data were transferred to IBM punch cards. When, at the conclusion of the study, all of the data were finally accumulated and verified, the IBM cards were transferred directly to magnetic tape, then scrutinized until their reliability was considered satisfactory in preparation for computer processing.

Data Analysis

Data analysis followed the system whereby examination progressed from the general to the specific. Every comparison for which adequate data were available was made where interpretation bore prime relevance to the objectives of the study. Fundamentally, the method was a cross-comparison of the variables and, where feasible, means and standard deviations were calculated with ranges being occasionally included. Mileage data were reduced to the levels of sub-groups to permit comparisons of accident rates for specific areas of interest. Tests of significance for these data were performed with the Chi-square (X^2) and with other appropriate statistics where they were indicated.

In demonstration of the representativeness of the sample, indices were selected which referred to general demographic characteristics as well as entities specific to this particular investigation. Accordingly, age, sex, occupation, bike ownership by type, riding experience, accident experience and exposure (both by mileage and subjective estimation) were accumulated and recorded in an appropriate manner.

RESULTS AND DISCUSSION

Interpretation of data may be implemented and reinforced when some knowledge of the representativeness of the sample has been acquired. Similarly, factors which are known to influence almost all data sets must be identified and "controlled." The total number of subjects assembled for the study, for which we have qualitative or quantitative data, are termed All Subjects (AS) (Figure 1, page 9 and page 10). Certain characteristics were recorded for all individuals regardless of their means of entry into the study and without consideration of their final disposition. The All Subjects (AS) group serves as a useful standard for comparison against which to compare the MSP group for representativeness.

Age

The first of the factors to be so examined was age (Graph 1). The distributions for the Main Study Participants (the MSP group comprises original and non-original subjects who are participants) who supplied acceptable data to the study are compared with the AS Group by two-year age intervals. Inspection reveals that the age 7-12 year range is over-represented in the MSP group (however, the two distributions are similar in shape), which tends to provide us with more data of the type in which we have interest. When the two distributions were compared statistically, the difference was found to be significant: $X^2=31.84$, $p < 0.005$ (Appendix 2, page 104).

Overall, the age distribution reflects the age groups that more readily respond to the inducements offered by the study and, fortunately, provides good numbers for age groups that produce critical data. From these viewpoints, the MSP group appears to have the qualifications to generate acceptable data. As a means of characterizing the group we did not "capture," the age variable is displayed (Graph 2) for Main Study Non-participants (the MSN-P group comprises original and non-original subjects who are not participants) in age ranges similar to the graph for the AS and MSP groups. Direct comparison becomes noticeable in the 9-10 age interval and continues through 15-16 years. For the 9-12 year interval the MSN-P proportions are lower than for similar AS and MSP values, while for the 13-16 year interval, the MSN-P group has greater representation.

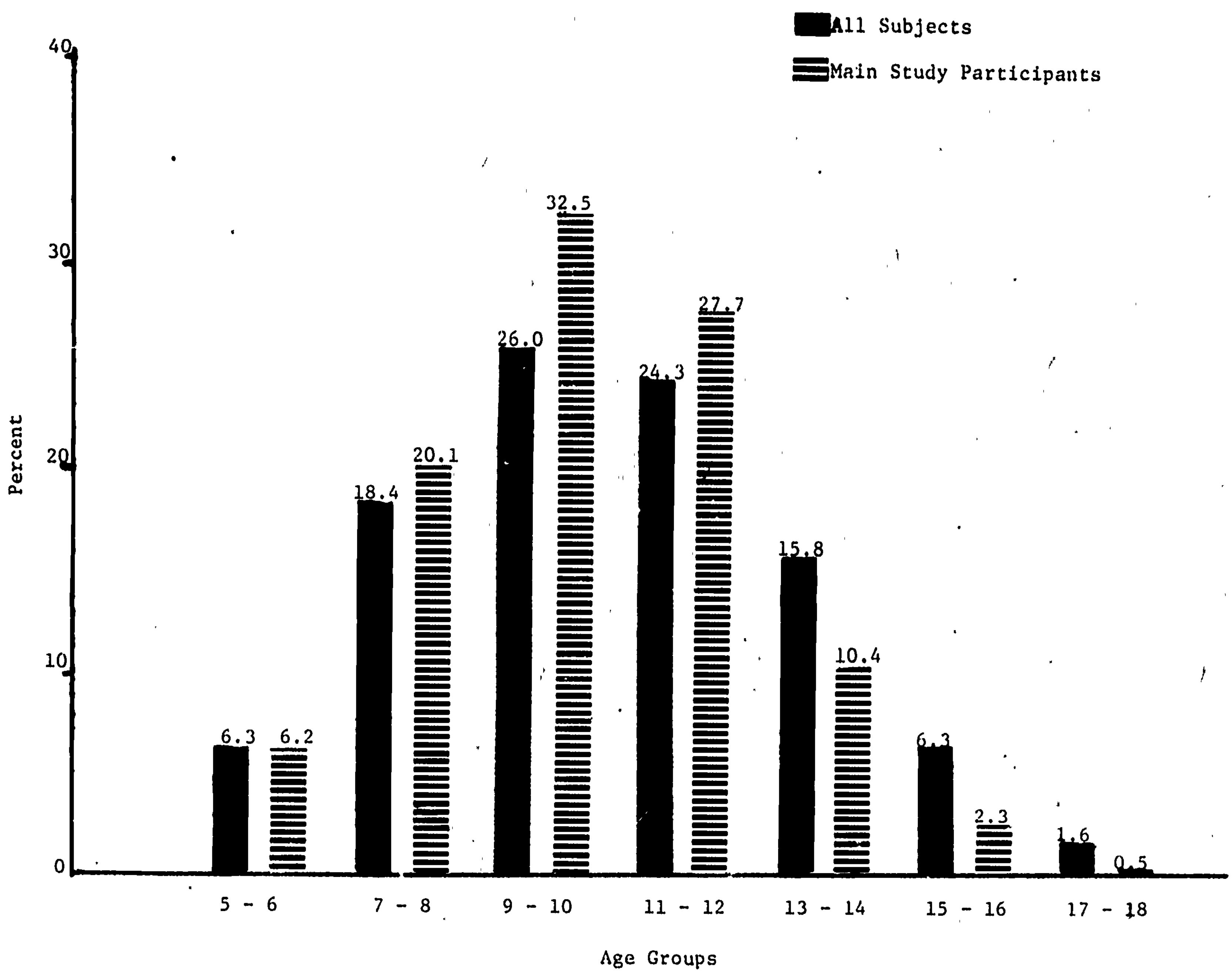
As for the observed differences, multiple factors probably influence the deviation. It would seem likely in this instance that the 9-12 year group represents the age where maximum numbers of individuals desire, and have the qualifications, to become involved in an undertaking of this nature. Under this age they are too young; over this age competition arising from factors of maturation sharply deplete the numbers willing to participate.

Graph No. 3 illustrates mean ages for AS and permits comparison with sub-groups of that population. Average age for the entire study group (for whom age is available) stands at 10.26 years, while for Main Study Participants Without Accidents (MSPWA) and Main Study Participants with Accidents (MSPAC) the average age is less. The remarkable feature in this comparison is the pronounced difference in mean age between the MSPAC and the AS. Obviously, it is the younger child who has the accident, as there is approximately a five-month mean difference between the two groups in age.

Continuing, the next column to the left, Hospital Accedent Cases (HAC) show a further decrease in Average Age (8.7 yrs). This finding documents the increased danger to

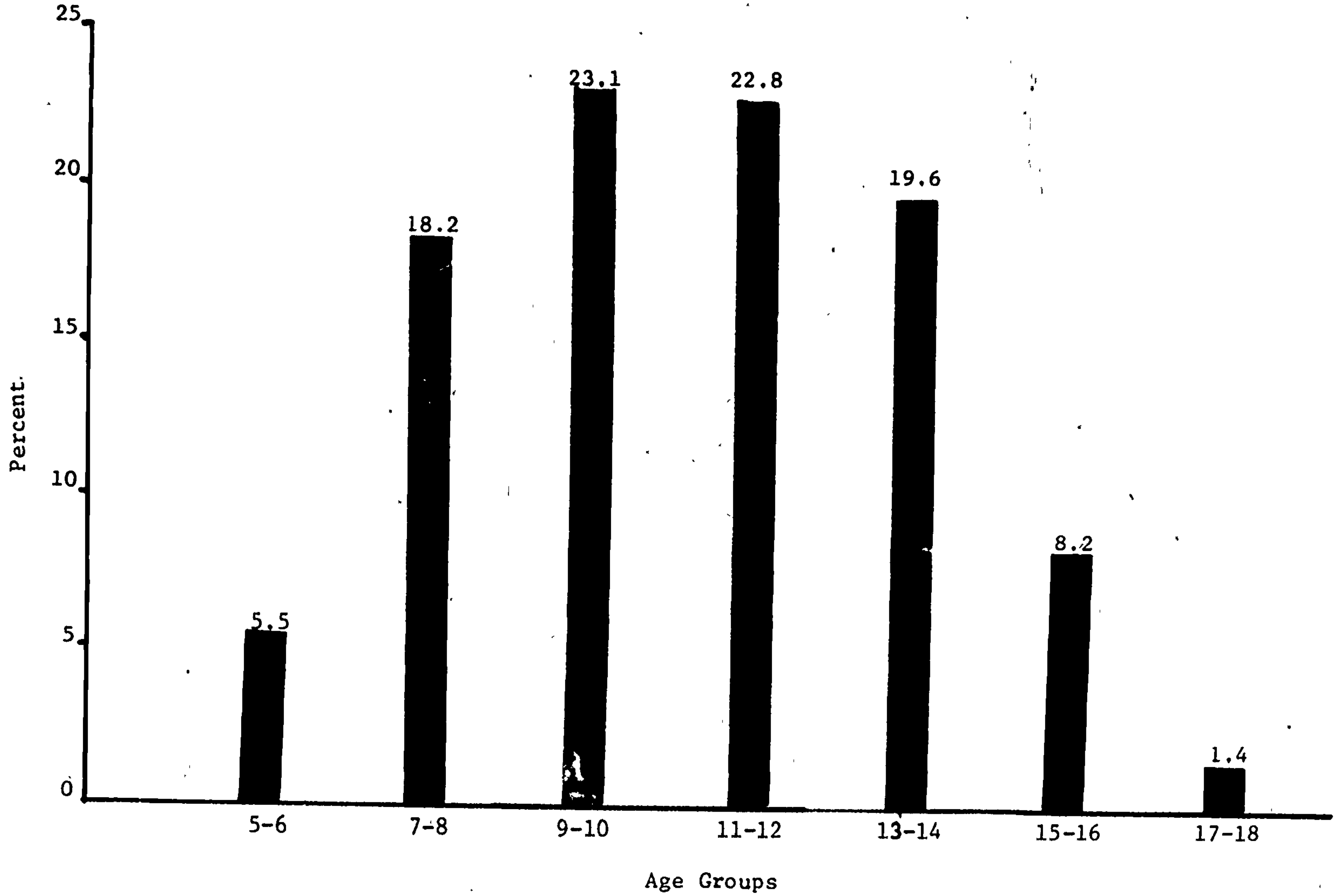
Graph 1

AGE DISTRIBUTION



Graph 2

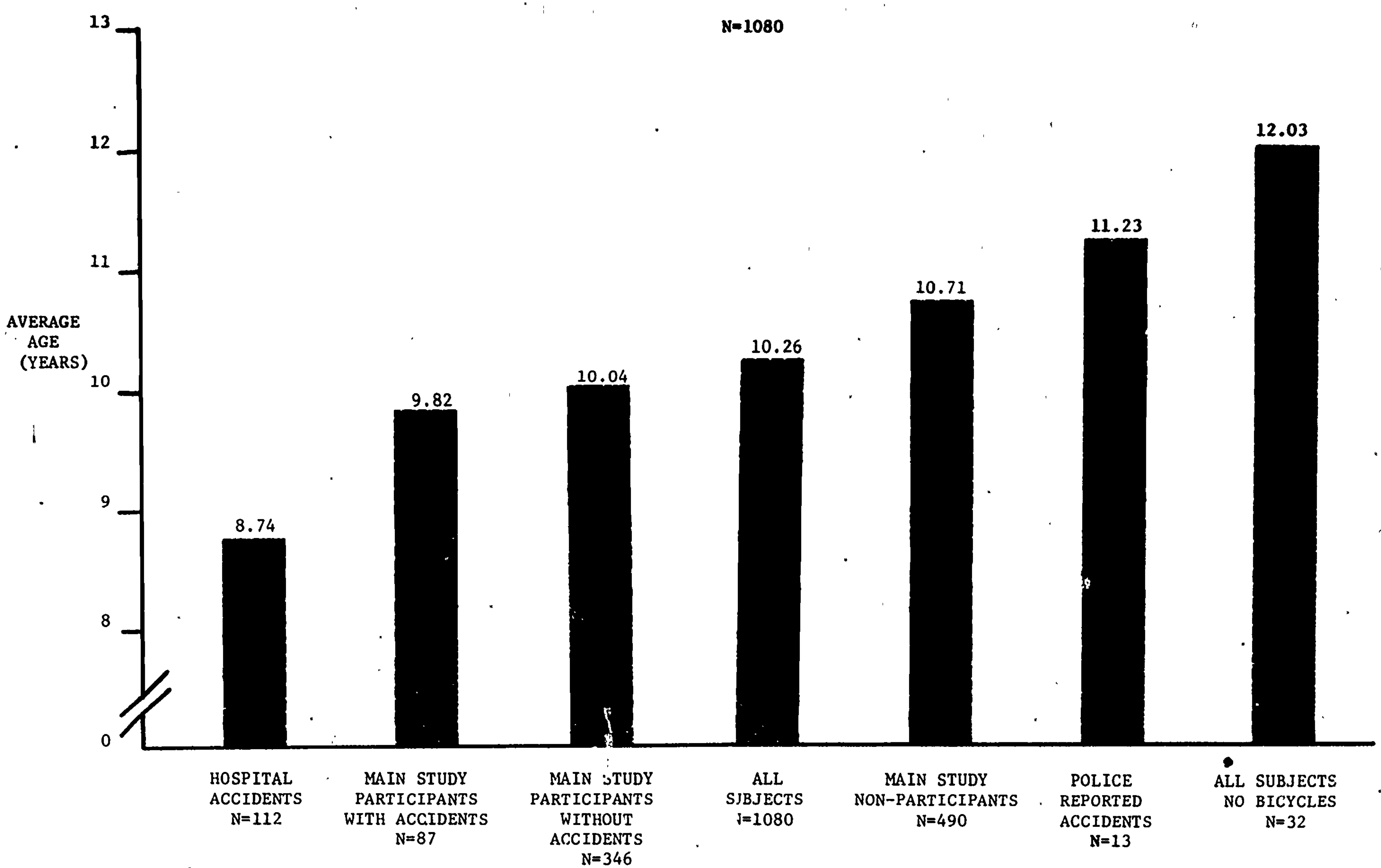
AGE DISTRIBUTION FOR MAIN STUDY NON-PARTICIPANTS



Graph 3

AVERAGE AGE FOR ALL SUBJECTS AND SELECTED SUB-GROUPS

N=1080



the youngest and most inexperienced group of riders. A highly vulnerable individual may be produced by the combination of riding inexperience, ignorance of motor vehicle traffic patterns, and unawareness of a maneuver that is potentially accident-provoking.

Police Accident Cases (PAC) average out to 11.23 years of age and stand out in direct contrast to the Hospital Accident Cases. That is, this accident group is characterized by older riders. The increased age and riding experience suggest that the police accident case may occur farther from home where the parents are not available to administer to the situation. MSN-P average age is 10.71 years. This places these individuals on the next step past the AS and just below the PAC. They were not motivated to join the study, and they occupy a niche midway between the AS and PAC in mean years. Assuming this particular placement is not artifactual in nature, this may be a meaningful point of bifurcation in the chronological development of adolescent youth. Just what direction these diverse groups proceed to and what immediate goals they attain is beyond the scope of this investigation, but it might provide stimulating interpretational material were it known.

Of the seven principal groups the oldest mean age is found in the All Subjects No Bike (ASNB) category, 12.03 years. With 32 subjects it is one of the smaller groups and may represent former bike owners who have gone on to other pursuits. Perhaps some of them have their licenses and drive cars or motor bikes, while others may never have owned bicycles or at an early age branched off into other activity areas. These presumptions are drawn in part from the statistics of the distribution. Specifically, the mean, median and mode are 12.031, 11.833 and 15.0 years respectively. The range is 7.0-18.0 years and the standard deviation 3.053 years, with ten subjects being 15 years old and older.

Graph No. 4, which displays curves for Main Study Participant Accident Cases (MSPAC) and Hospital and Police Accident Cases (HPAC), clearly identifies the location of the discrepancy in ages, as more broadly inferred from Graph No. 3. Age ranges 5-6 and 7-8 are heavily over-represented in the HPAC, while for age intervals 9-10 and 11-12 the HPAC are similarly under-represented, with the remaining intervals being considered equivalent. Examination of this graph reveals how differences in interpretation can result from examination of fragmentary data. HPAC data would suggest that accidents rise very sharply and peak at 7-8 years, declining steadily thereafter. When the MSPAC curve is considered, the ascent is more gradual and peaks at 9-10 years. The descent is similar in character and the two distributions overall are alike, with the exception of the modal interval: A difference of two years separates the two arrays.

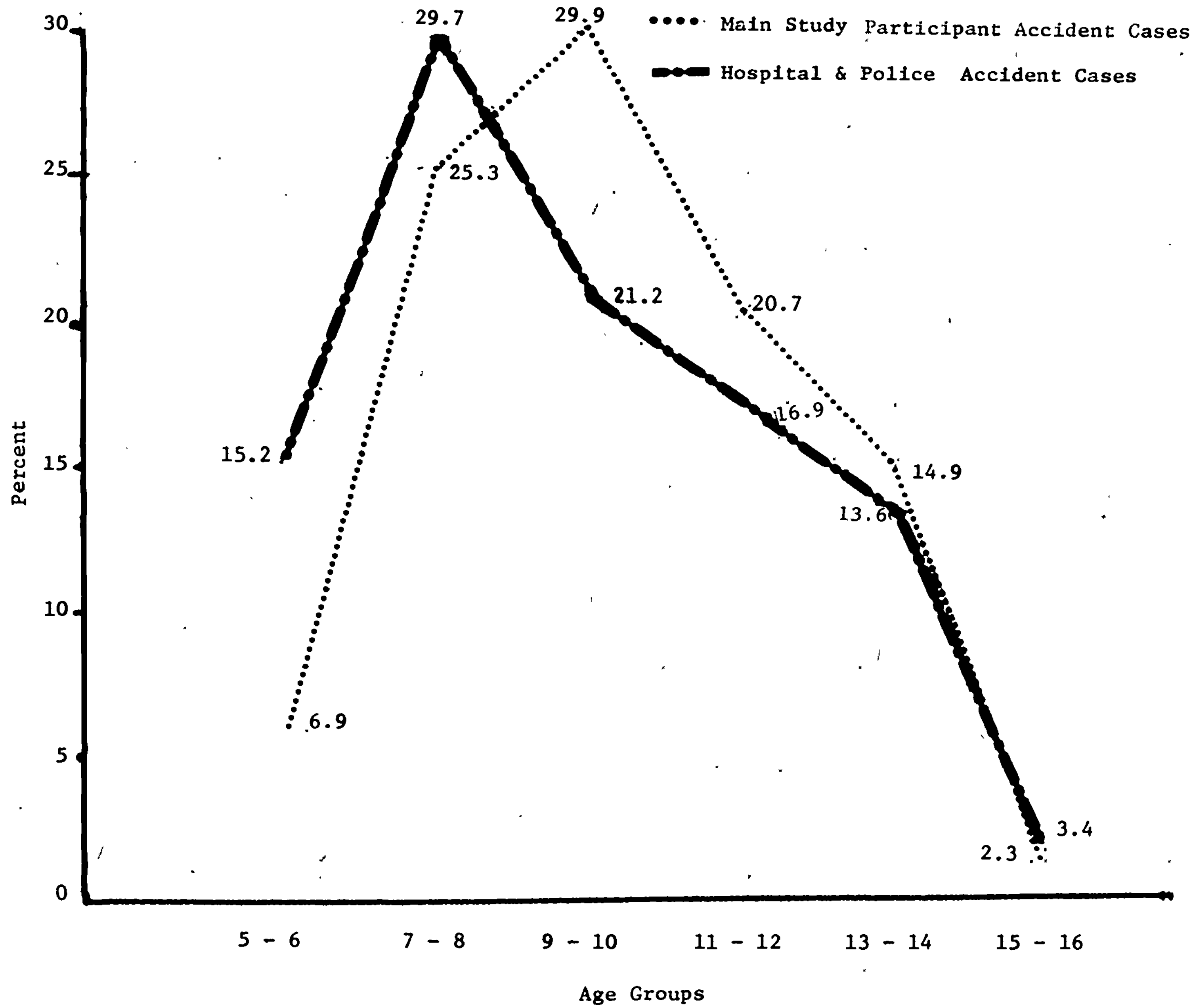
Taken together, the accident experience may be said to rise sharply from ages 5-6 to 7-8, then to plateau for the next two years and then to decline. Clearly the age range from 5 to 14 years demands the most attention. This finding agrees with nationally published accident figures (Accident Facts, 1970, p. 61). Examination of subsequently presented data may provide more insight referable to the high-risk groups within this age range.

Male - Female Distribution

Proportion of the sample by sex (Graph No. 5) suggests that males differ somewhat from females in willingness to accept an invitation to participate in an organized activity of this nature. Proportions of males in the MSP group are approximately 3.4% greater than for the AS. While this difference is not desirable, adequate numbers of each sex (Males 311, Females 212) for the MSP may tend to minimize misrepresentations that might arise from an excessively large differential in Male-Female proportions.

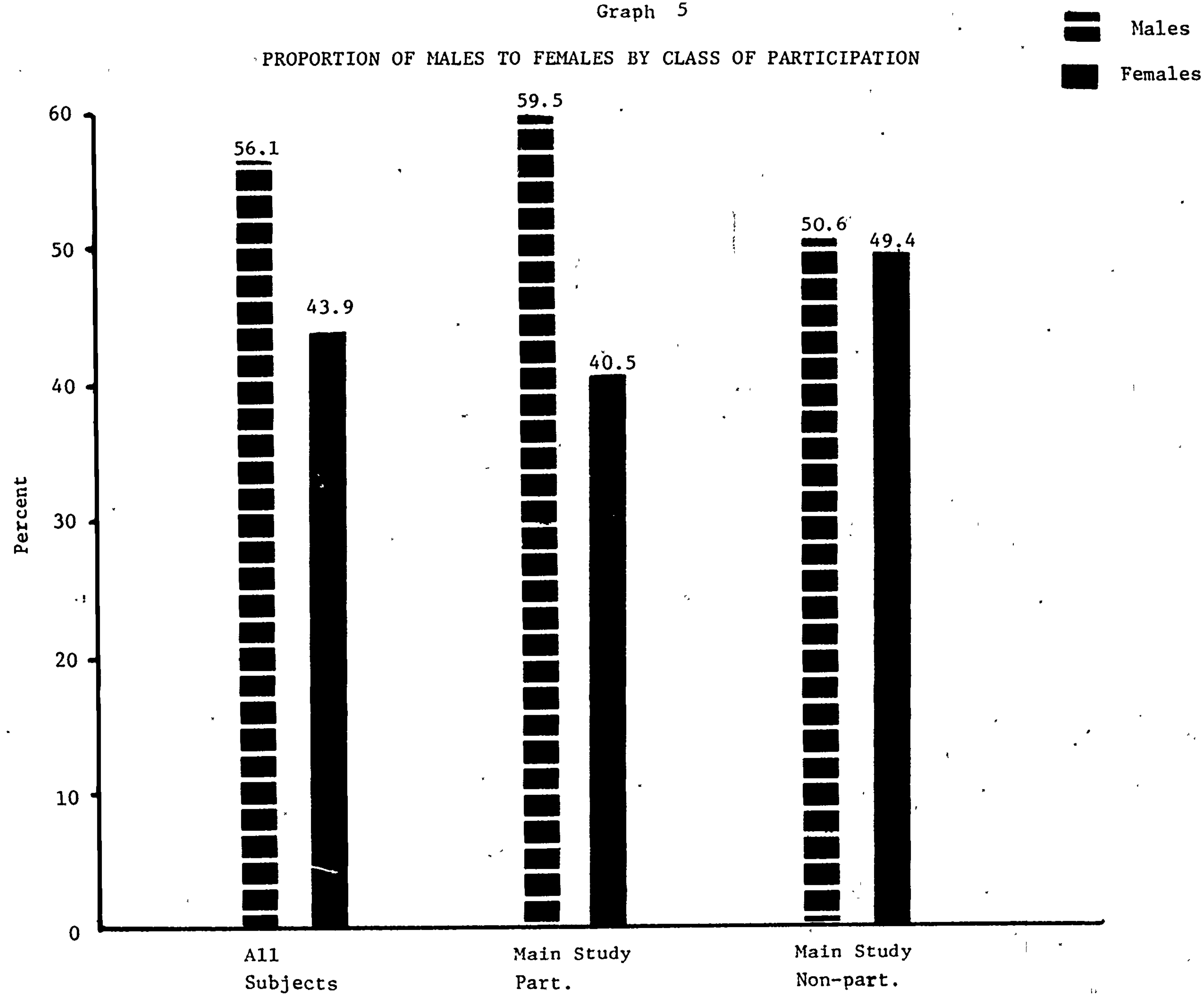
Graph 4

AGE DISTRIBUTION



Graph 5

PROPORTION OF MALES TO FEMALES BY CLASS OF PARTICIPATION



It is notable that the MSN-P has a different ratio of essentially 1:1. This is explained in part by the over-response of the males to the study to a degree that nearly equalized the two sex groups in size. Accident cases (Graph No. 6) grouped separately as Main Study Participants with Accidents (MSPAC) and Hospital and Police Accident Cases (HPAC) have a distribution that is readily identifiable. In this array the divergence for proportion of males vs. proportion of females is greater than for the previous distributions (Graph No. 4).

Of the Main Study Accident Cases (MSAC) the males show a 31% preponderance (65.6% vs. 34.4%) over the females, while in Hospital and Police Accident Cases a difference of some 37% (68.5% vs. 31.5%) is seen. Speculation as to the cause of this large majority of males centers principally on the class of accidents experienced by each sex. Boys, accumulating more mileage per unit of time (Table 1, page 26) will experience higher accident frequency (number of accidents per subject or group) and may be predisposed to wander farther from home. Accidents occurring out of the subjects' immediate neighborhood may be more likely to attract police attention than those happening near home where a parent can attend to the situation. Boys, then, will appear to be over-represented when exposure is ignored and be more likely to appear on police records. Also, it may well be that males tend to experience accidents of greater severity levels, prompting witnesses to summon qualified assistance without further delay.

Accumulated Mileage

Reference to Table 1, page 26, supports opinions derived in a somewhat more informal manner. Highrise bicycles appear to travel farther than standard types for a given unit of time. This amounts to 57.0 miles farther in a six-month period or about 9.5 miles per month. By bicycle type the lightweight logs the greatest average miles traveled in the six-month period by some five miles over the highrise.

When this is examined in detail, it is noted that the 5-9 and 15-19 age groups record very large average mileages. While the numbers of subjects in these cells are small (3 and 5 respectively), they should not be discounted. The three individuals in the 5-9 year cell may represent some special use of the bicycles, which made the lightweight the logical choice at this rather young age. In the 15-19 year cell the high mileages may suggest regular or long distance use of the bicycles (as to school) or special events such as bike hikes or summer vacation trips.

Overall conclusions from the mileage table, by main effects, lend support to previous implications that males ride more than females, lightweights log the most miles (they may form a special use group), followed by highrise and then standard. Worthy of special note is the age effect by bicycle type. In the highrise there is negative association, which is to say that as age increases mileage decreases. Lightweight bicycle mileage patterns form two peaks, one at each end of the curve, while the standard shows a regular increase in a positive manner (viz. as age increases, mileage also increases). During the six-month period the average distance traveled by all MSP was estimated at 199.9 miles.

Physical Characteristics of Bicycle Owners

Table 1A records the mean height, weight and age of the various sub-groups by sex and bicycle type. It is apparent that the male and female highrise owners were the youngest

Graph 6

PROPORTION OF MALES AND FEMALES
BY ACCIDENT EXPERIENCE

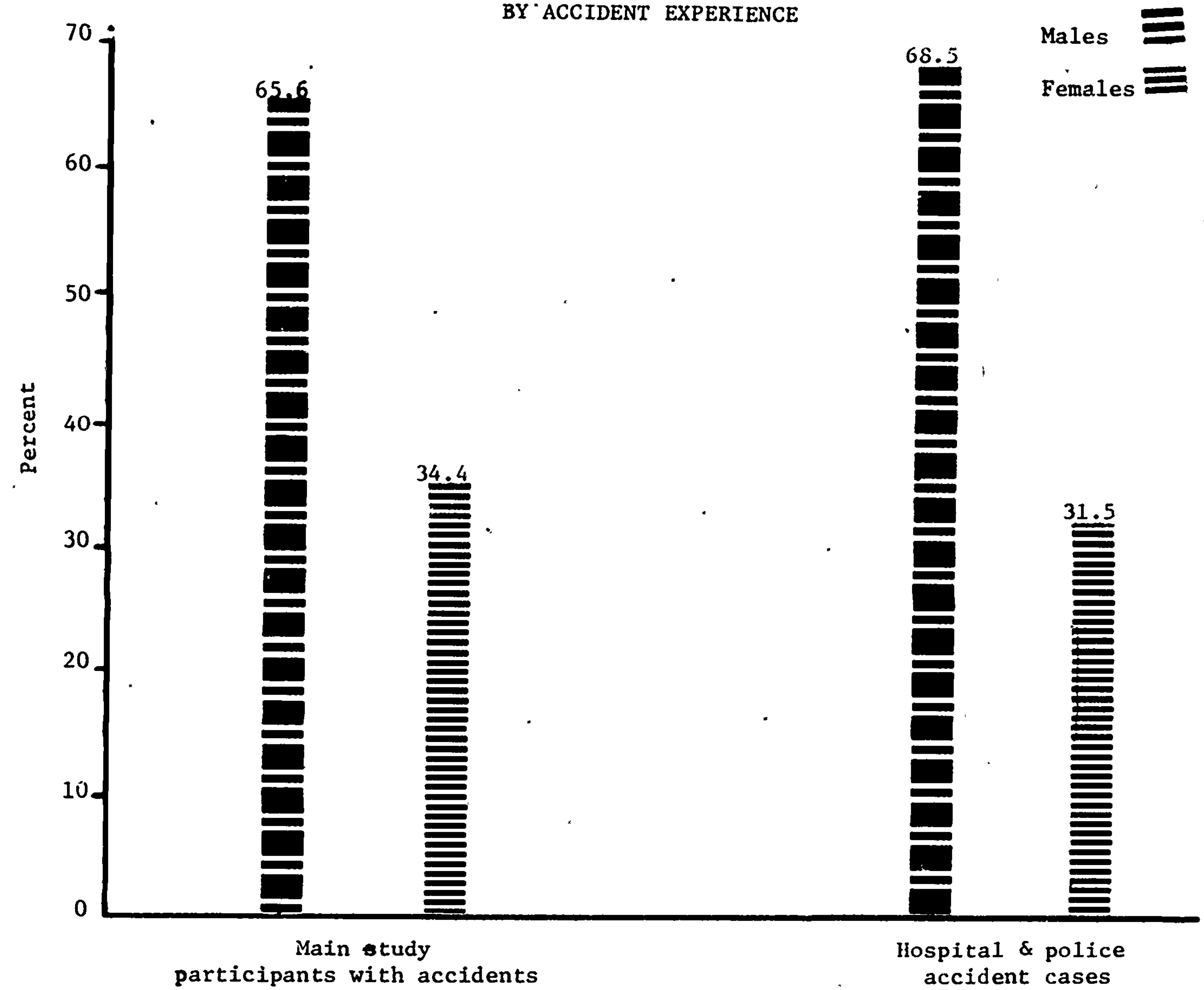


Table 1

Estimated Average Miles Traveled In Six Month Period By Bicycle Type, Age and Sex For Main Study Participants

	Highrise	N	Ltw	N	Std	N	Total	N
Male	251.2	129	272.8	41	235.0	60	250.8	230
Female	150.9	62	104.9	16	115.4	89	127.6	167
5-9	227.2	95	335.3	3+	154.7	74	197.9	172
10-14	212.6	94	206.4	49	171.0	71	197.4	214
15-19	93.5	2	349.0	5	193.4	4	246.0	11
Total	220.6	191	225.7	57	163.6	149	199.9	397

+All male

Table 1A

Mean Height, Weight and Age By Bicycle Type and Sex For Main Study Participants

	Males			Females		
Bicycle Type	Height (Inches)	Weight (Pounds)	Age (Years)	Height (Inches)	Weight (Pounds)	Age (Years)
Highrise	55.4	78.1	9.8	54.4	70.9	9.3
Lightweight	60.9	101.0	12.2	60.6	95.7	11.6
Standard	55.4	80.6	10.0	54.7	74.2	9.4
Mean For All Bicycle Types	56.4	82.8	10.3	55.1	74.7	9.6
Overall Mean For All Bicycle Types and Sex	55.9	79.6	10.0	-	-	-

and lightest in weight within their respective groups, below average in height but about equivalent to standard owners in that measurement. For both sexes lightweight owners were older, taller and heavier. One comparison may be noted that lends some degree of confidence to the reliability of the biological measurements recorded for the study. For the lightweight owners (the oldest, tallest group), the females are only three tenths of an inch below the mean male height (60.9" vs. 60.6"), even though the female mean age is about seven months less. This is consistent with known growth and development patterns, illustrating the increased rate of female growth during the early teen periods. Examination, then, by age, height and weight produces no unexpected or contradictory findings regarding demographic characteristics for owners of the three types of vehicles.

Occupation Class

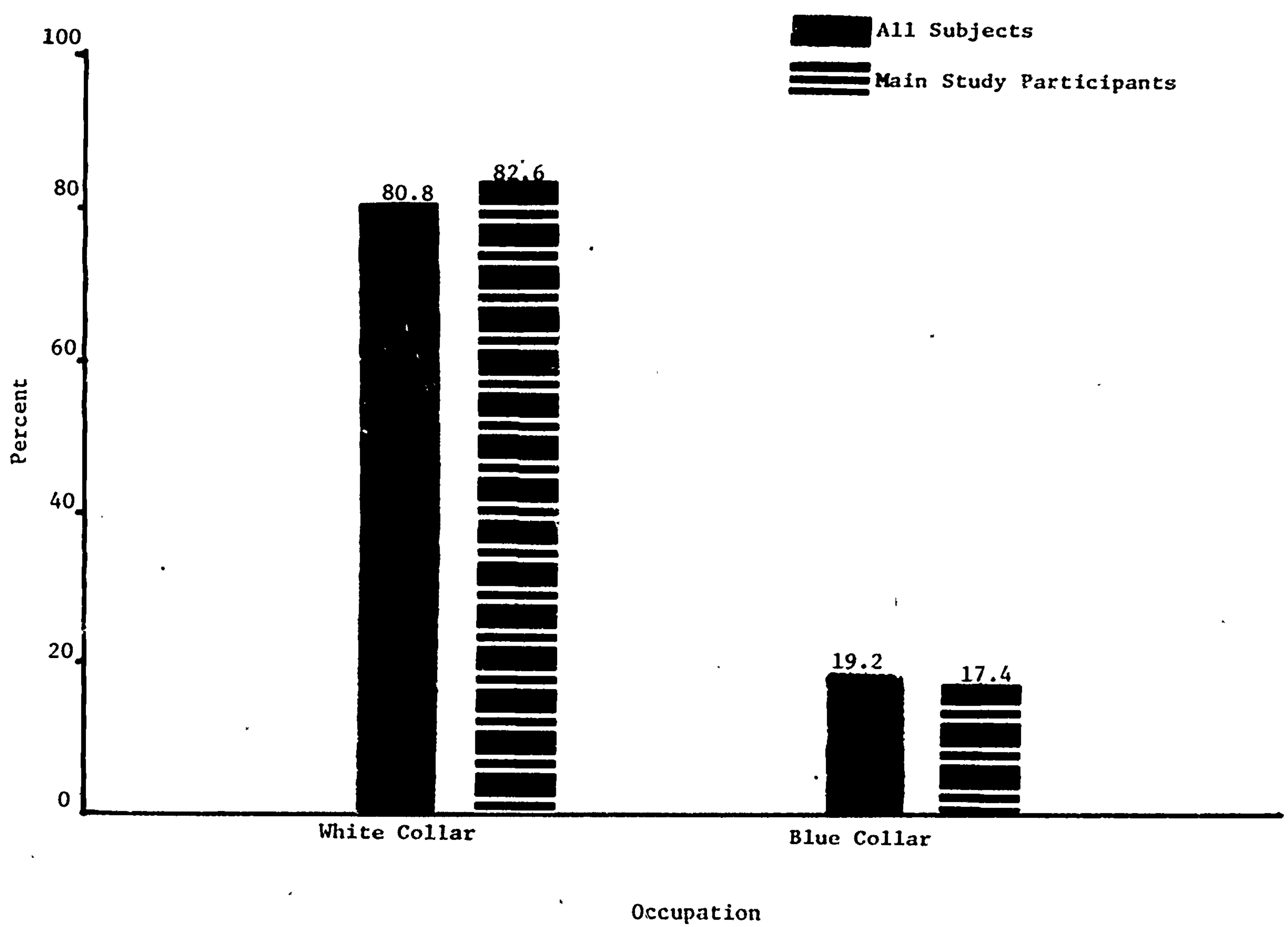
For this study, parent's occupation class was represented by a simple division separating those employed into white and blue collar workers (Adopted from U. S. Bureau of Census, 1960, Classified Index of Occupation and Industries). Graph No. 7 compares white and blue collar workers for AS and MSP. Most noticeable is the fourfold preponderance of white collar workers in the AS group. This ratio is somewhat greater in the MSP group but is not statistically significant ($Z=.947$, $N=431$, $p=0.17$, Appendix 2, p. 104). A reduced level of participation for any organized activity has been a recognized characteristic of groups with less education, lower income and depressed standards of living (this did not appear, however, to change the accident experience for the two groups; Graph No. 7A shows white collar and blue collar to be similar). With this in mind, certain adjustments were effected before the cyclometers were mounted on the subjects' bicycles. First, the larger schools (which tended to be in the blue collar areas) were all retained in the study, while medium and small schools were randomly selected as outlined in the Study Design and Objectives chapter. This adjustment would tend to insure that subjects in the blue collar areas would receive full opportunity to be invited to participate. Nine of the twelve original sites considered for cyclometer mounting were eventually retained. More than one-third of the nine sites were in the southern, low rent housing area of the city (see Map Appendix 1, p. 78). They were situated in a manner which was intended to reduce to a minimum the need for auto transportation and the distance the youngsters would have to travel on public streets to reach the site.

Bicycle Type

Ownership by type of bicycle is shown in Graph No. 8 for AS and MSP. There is a slightly higher proportion of highrise bicycles in the participant group than is shown for AS, but overall the proportions are not significantly different ($X^2 = 5.9$, $.05 < p < .10$, Appendix 2, p. 104).

Type of bicycle by class of participation for age and sex of owner is shown in graphs No. 9, 10, and 11. Graph No. 9 for MSP delineates the negative association between highrise bicycles and age. In the 5-9 year category, 57.0% of all bicycles are highrise, in the 10-14 year category the percentage is 44.8, while for owners 15-19 years old it is 25.0%. In the same graph the lightweight shows a positive association with age, going from 1.7% to 23.0% and reaching 41.7% in the highest age category. The standard displays its own curve, and in some respects it is similar to the highrise; in the first two age intervals a decline is noted and then the curve levels out.

Graph 7
OCCUPATION LEVEL

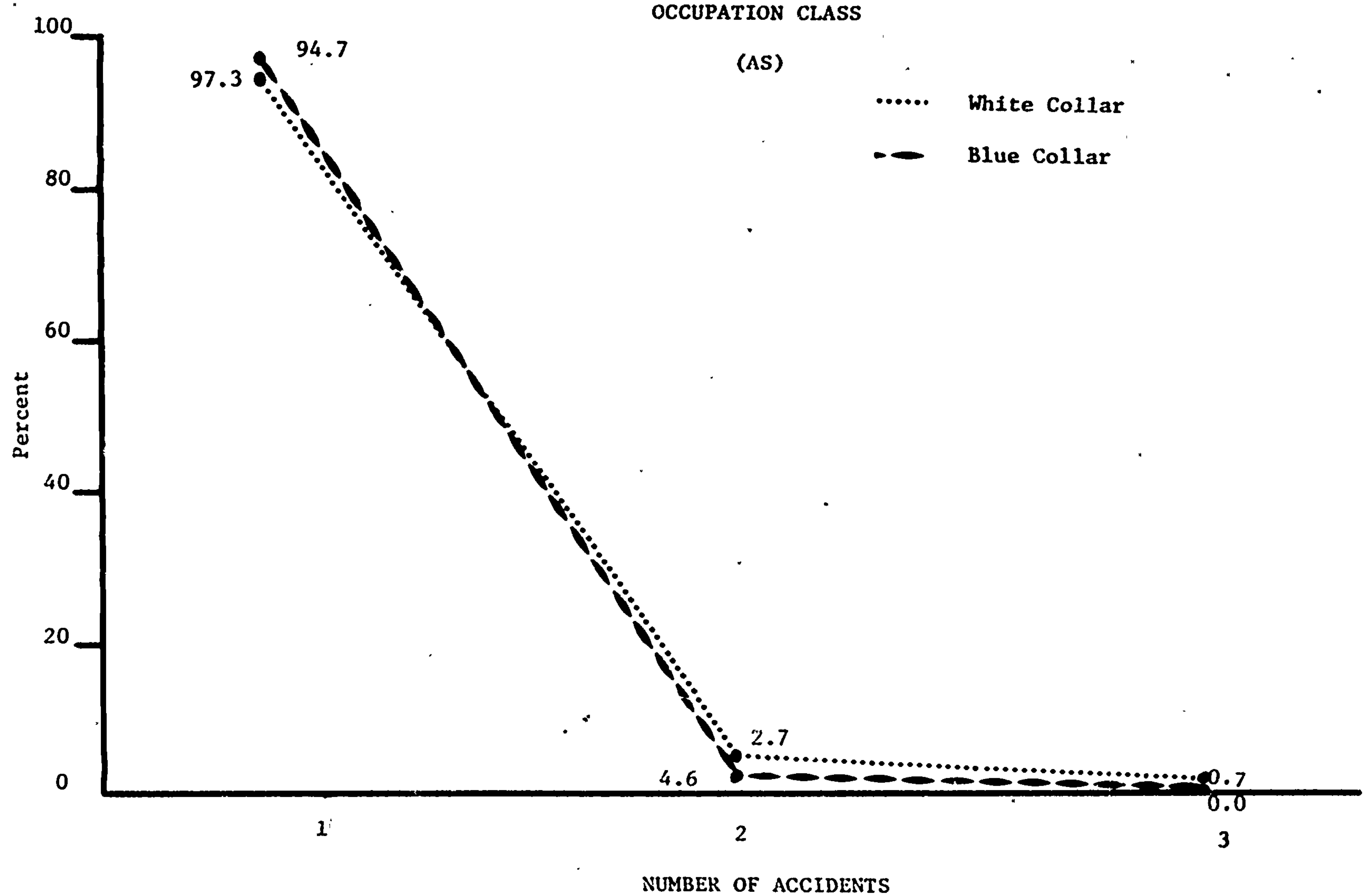


Graph 7A

ACCIDENT FREQUENCY BY

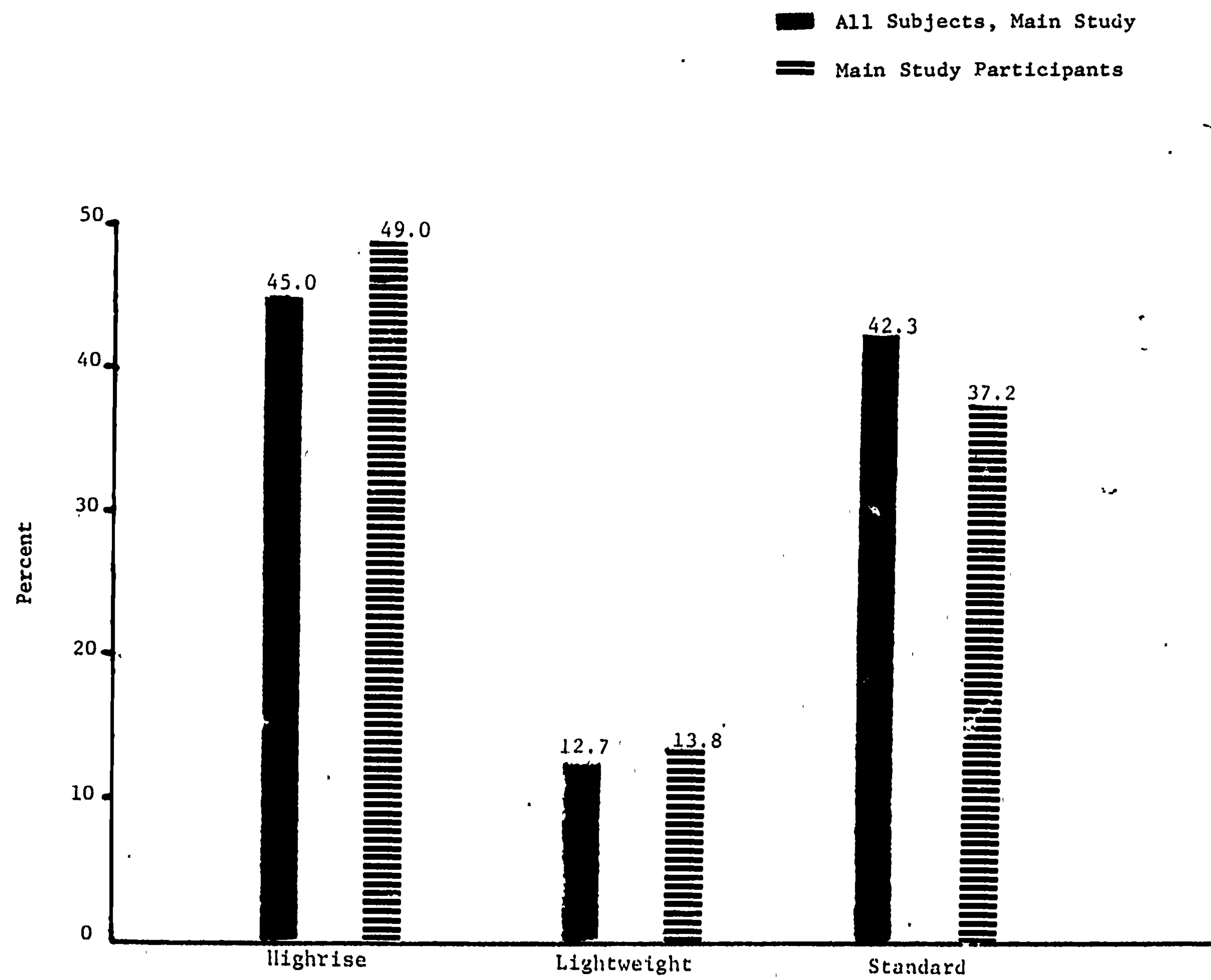
OCCUPATION CLASS

(AS)



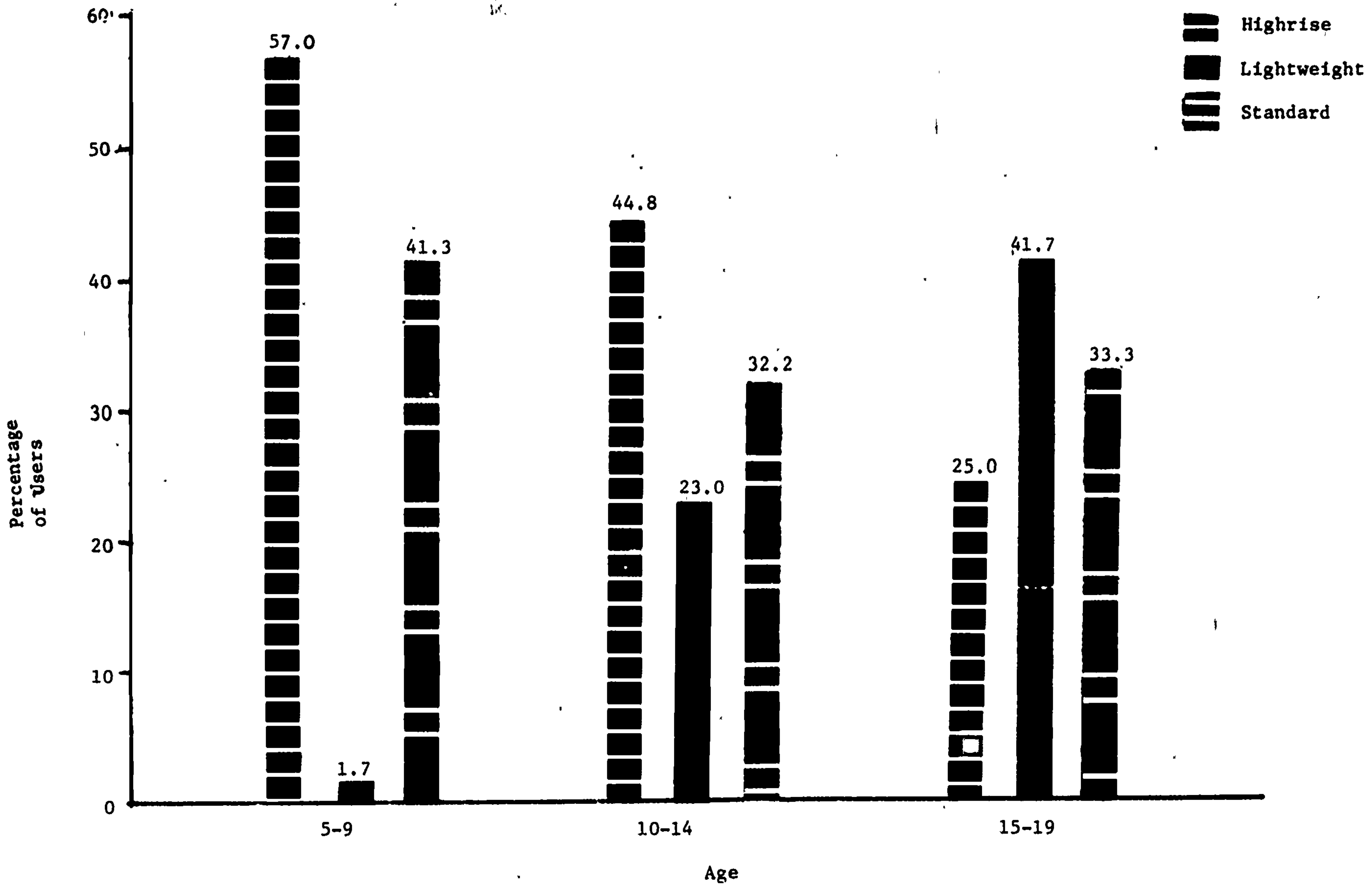
Graph 8

PERCENTAGE OF OWNERSHIP
BY TYPE OF BICYCLE



Graph 9

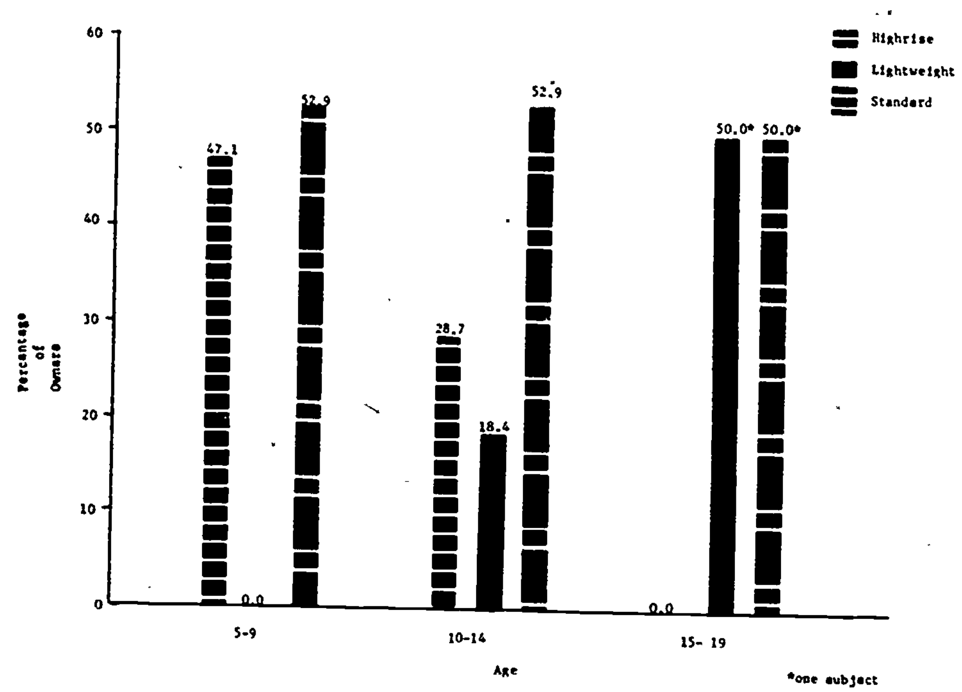
TYPE OF BICYCLE BY AGE OF OWNER
MAIN STUDY PARTICIPANTS



*each age interval totals 100%

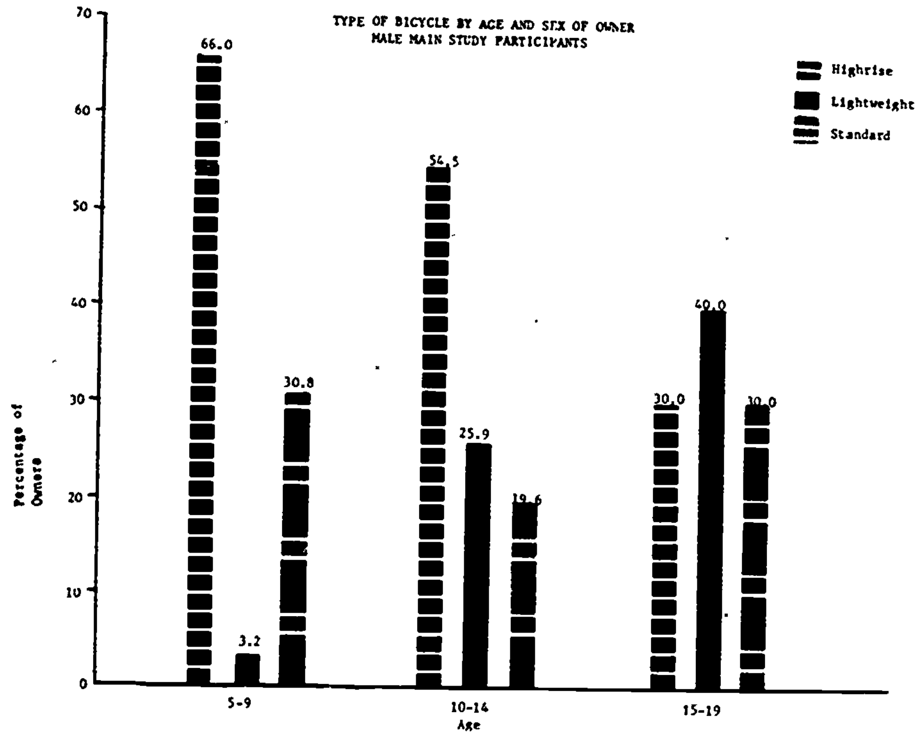
Graph 11

TYPE OF BICYCLE BY AGE AND SEX OF OWNER
FEMALE MAIN STUDY PARTICIPANTS



Graph 10

TYPE OF BICYCLE BY AGE AND SEX OF OWNER
MALE MAIN STUDY PARTICIPANTS



In Graph No. 10, the proportions for the males are similar to MSP with greater proportional representation for the highrise and somewhat greater ownership for the lightweight. The standard bicycle is apparently less attractive to males, as the percentages for this type are lower in every age interval, compared to the MSP group. The females, Graph No. 11, reverse the trend. They own more standard bicycles in the 5-9 and 10-14 year groups and demonstrate equal ownership between standard and lightweight types in the 15-19 group, but this is based on inadequate numbers. As a type, highrise predominates, followed by standard and lightweight in that order. Males own more highrise and lightweights and females more standard and highrise, by order of preference.

Percentage of ownership by bicycle type for Main Study Participant Accident Cases (MSPAC) and Hospital and Police Accident Cases (HPAC) is displayed in Graph No. 12 p. 35. To assist in the interpretation of this graph, let us assume that accident occurrence for a given bicycle type may be expected to have proportions similar to that of bicycle ownership in the population of which they form a sub-group. Comparisons, then, will be made between MSPAC vs. MSP and HPAC vs. AS. When the two curves are so compared, it would appear that the lightweight is over-represented in the MSPAC data and the highrise over-represented in the HPAC group (the differences, however, for the HPAC data were not found to be significant, $X^2=3.5$, $.50 < p < .70$). For these data, then, the differences in accident occurrence do not appear to be substantially different.

Mean Ages of Accident Groups

Table No. 2, p. 36 permits several comparisons which may be of some consequence in the development of safety programs. In every instance, matched by bicycle type and accident group, the mean age for the females is noticeably less than for the males. This suggests that females may develop willingness to attempt advanced motor skill application before the males, placing them in jeopardy at a younger chronological age.

Mean ages for accident groups are well differentiated, both by sex of subject and type of bike. Males in Table No. 2 display deviations in mean ages ranging from 9.1 years for HAC and 10.0 years for MSPAC to 11.7 years for PAC. For females the corresponding mean ages are 7.9, 9.4, and 6.0 years. Age distributions for males and females were tested for HPAC and MSPAC (Table 2, p. 36). For the HPAC the distributions were found to differ significantly ($X^2=9.74$, 2df, $p<0.01$). For MSPAC data the effect was not significant ($X^2 = 1.58$, 2df, $p>0.30$). Graph No. 13 illustrates the age-sex accident relationship for MSPAC and HPAC. Essentially, the females are exposed to the greatest risk in the 5-9 interval and the males are the high risk group in the 10-14 age band. The graph suggests that in the 15-19 interval, sex diminishes as a factor and the curves tend to converge at that point. In substance, it would appear from these data that males and females demand individualized indoctrination in order to properly and safely acquire bicycle riding skills. Females would seem to require more intensive instruction earlier than males, who, while starting at a later chronological age appear to continue the need for instruction over a longer period of time, and to a more advanced age.

Graph 12

PERCENTAGE OF OWNERSHIP
BY TYPE OF BICYCLE

Table 2

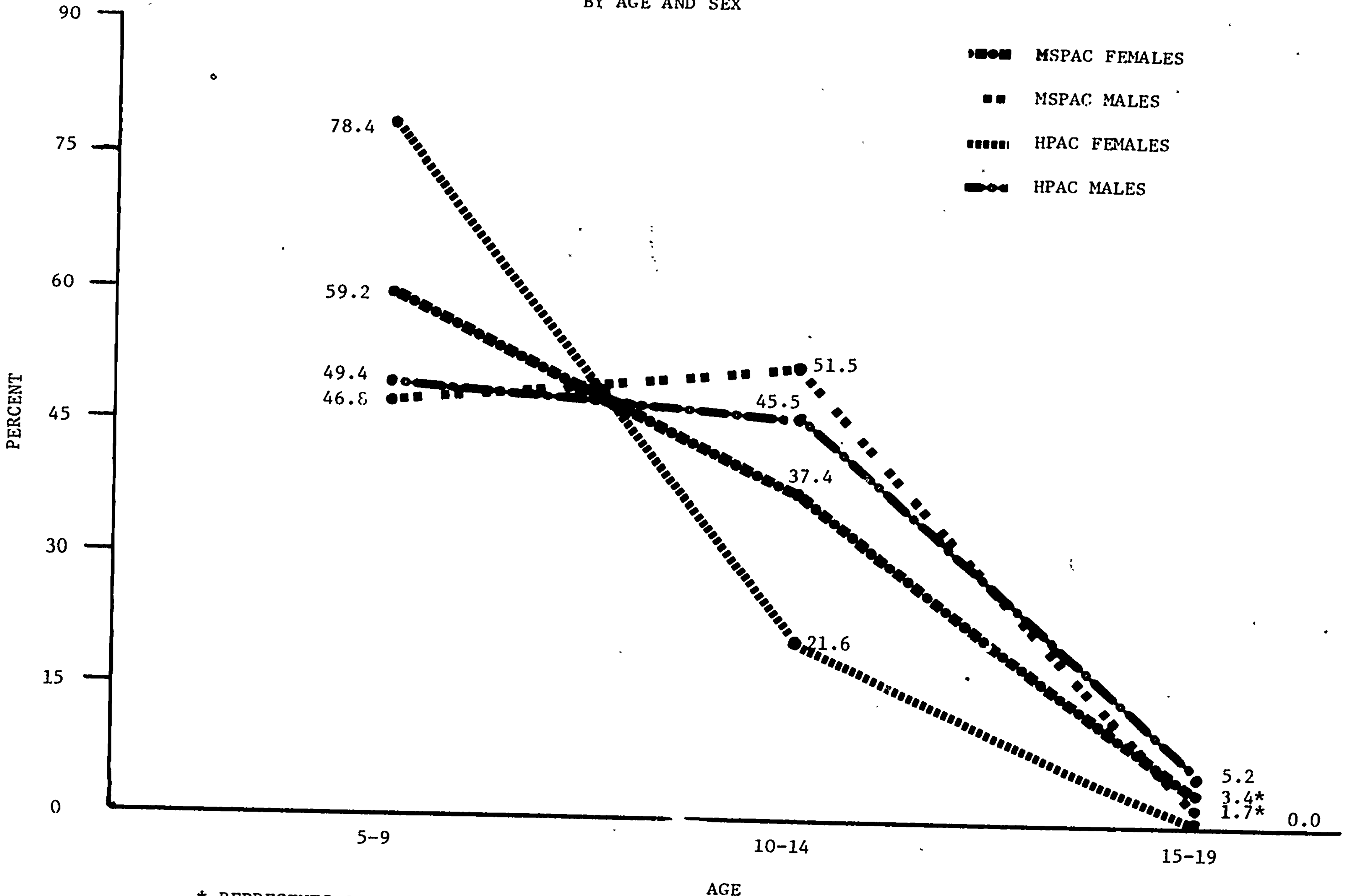
Mean Age of All Main Study Bicycle Owners Who Experienced Accidents, By Bicycle Type and Sex

Accident Group	Males				Females				Mean for both sexes
	Bike Type			Mean	Bike Type			Mean	
	High-rise	Light-weight	Stan-dard		High-rise	Light-weight	Stan-dard		
Main Study Participant Accident Cases	9.2	12.6	9.5	10.0	9.3	11.0	9.1	9.4	9.8
Hospital Accident Cases	9.0	8.0	9.4	9.1	8.0	6.0	8.0	7.9	8.7
Police Accident Cases	10.3	13.8	10.8	11.7	6.0+	*	*	6.0	11.2
Mean	9.1	12.1	9.6	9.7	8.5	9.0	8.4	8.5	
Mean for both sexes	8.9	11.5	9.1					Overall mean=9.3	

*=No observations
+=One observation in this cell

GRAPH 13

DISTRIBUTION OF ACCIDENTS FOR MAIN STUDY PARTICIPANTS (MSPAC)
AND HOSPITAL AND POLICE SUBJECTS (HPAC)
BY AGE AND SEX



* REPRESENTS ONE SUBJECT

Riding Experience

Previous bicycle riding experience for All Subjects (AS) and Main Study Participants (MSP) in Graph No. 14 agrees well with the age distributions as displayed in Graph No. 1. Over-representation of MSP in the 1-2 and 3-4 year experience groups would be expected with the similar over-representation observed in Graph No. 1 from the 7-12 age range in MSP. Obviously, the less-than-1-year-experience group is too young (both by our study criteria and age) to have been selected as an original subject, and the greater-than-four-years-experience group very likely found the study lacked sufficient challenge or reward.

Upon comparing the Main Study Participant Accident Cases (MSPAC) and Hospital and Police Accident Cases (HPAC) in Graph No. 15, it is noticeable that as experience increases the proportions within the two groups approach parity. There is distinct disagreement with the less-than-1-year interval, somewhat less disagreement for each of the succeeding two intervals and practically no disagreement for the last interval. As riding experience increases, accident rates expressed as proportions within the two study groups tend to be the same. Riding experience, then, in association with age, apparently combines to produce similar probabilities of accident occurrence within the two (MSPAC and HPAC) accident groups. If we employ the percentages in each riding experience interval for the AS group in Graph No. 14 as a standard, and compare them with similar values (for MSPAC + HPAC = MSAC) in Graph No. 15, we have essentially "observed and expected" values of accident experience by riding experience.

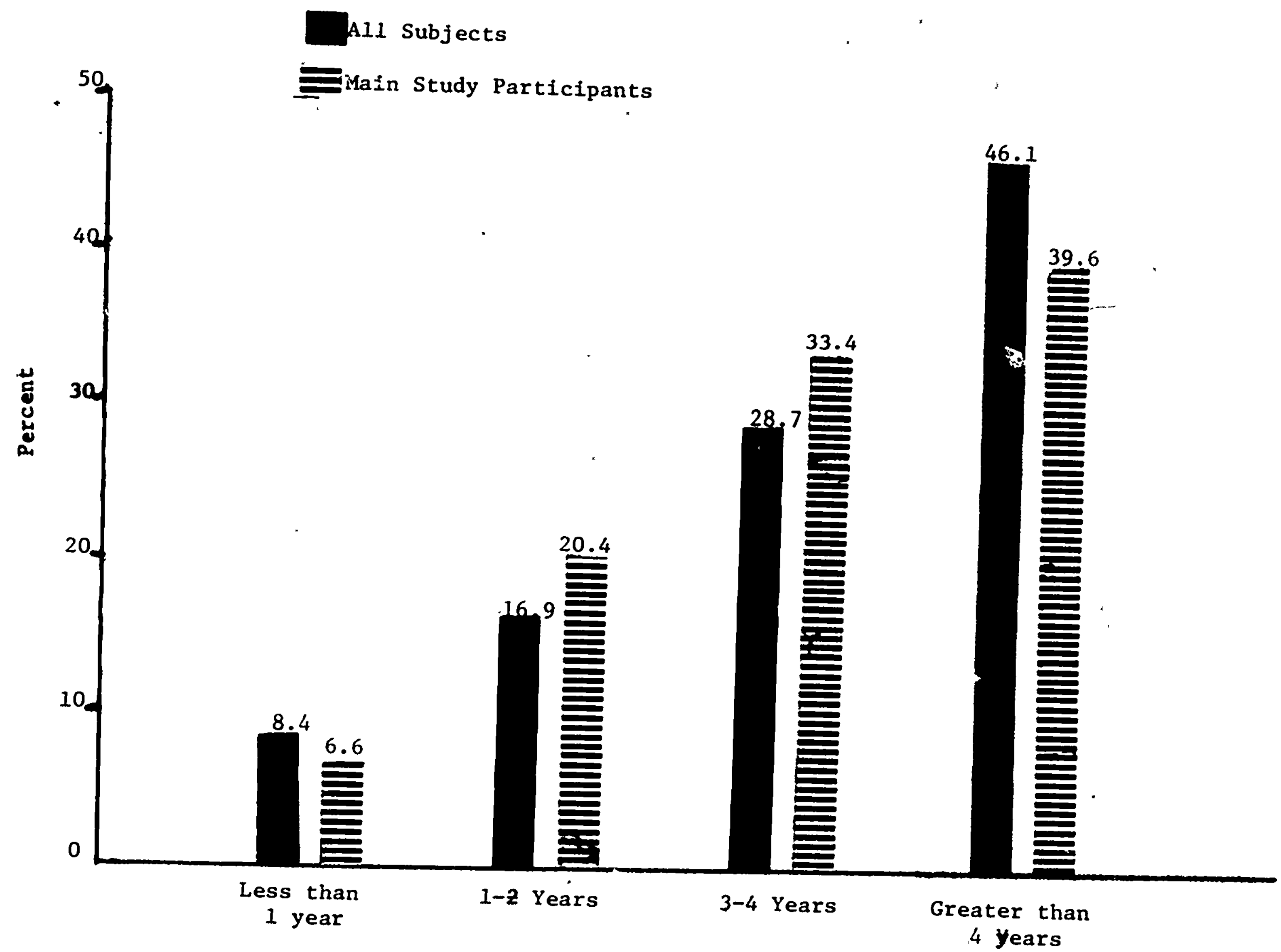
Extracting the values from Graphs No. 14 and No. 15 provides percentages recorded in this manner:

Riding Experience (yrs.)	1	1-2	3-4	> 4
("Expected") AS	8.4	16.9	28.7	46.1
("Observed") MSAC	11.7	21.4	23.8	43.2
Absolute change (from expected)	+3.3	+4.5	-4.9	-2.9
Proportional change (from expected)	+39.3	+21.9	-17.1	-6.3

In this comparison there are two groups obviously at highest risk. The less-than-1-year-riding-experience group shows an observed accident experience of 11.7% which is 39.3% greater than expected, while the accident experience for the 1-2 year experience group is 21.9% greater (the other two more experienced groups show observed values that are less by 17.1% and 6.3% respectively). From the observations just noted, one might well surmise that the groups that require most attention are those in the interval from zero to two years of riding experience. Concentration on the two lowest experience intervals (combining the < 1 and 1-2 intervals and testing against the 3-4 and > 4 interval provides a $X^2 = 4.88$, $.02 < p < .05$, Appendix 2, p. 105) would appear to be the first choice in terms of order of emphasis. The logical advantage of asigning top priority to the lowest experience (and youngest) groups can be counted in several dimensions. First, establishment of acceptable riding practices can be assumed to reduce accidents within the lowest experience intervals and provide a large overall proportional reduction in accidents. Of equal consequence would be the presumed reduction in HPAC proportions within each experience group and attributable reductions in levels of severe injury. A potential advantage, which may accrue, would be fewer accidents among riders with greater experience. Attention to intervals other than the two lowest would center on the greater-than-4-years of riding experience. In this

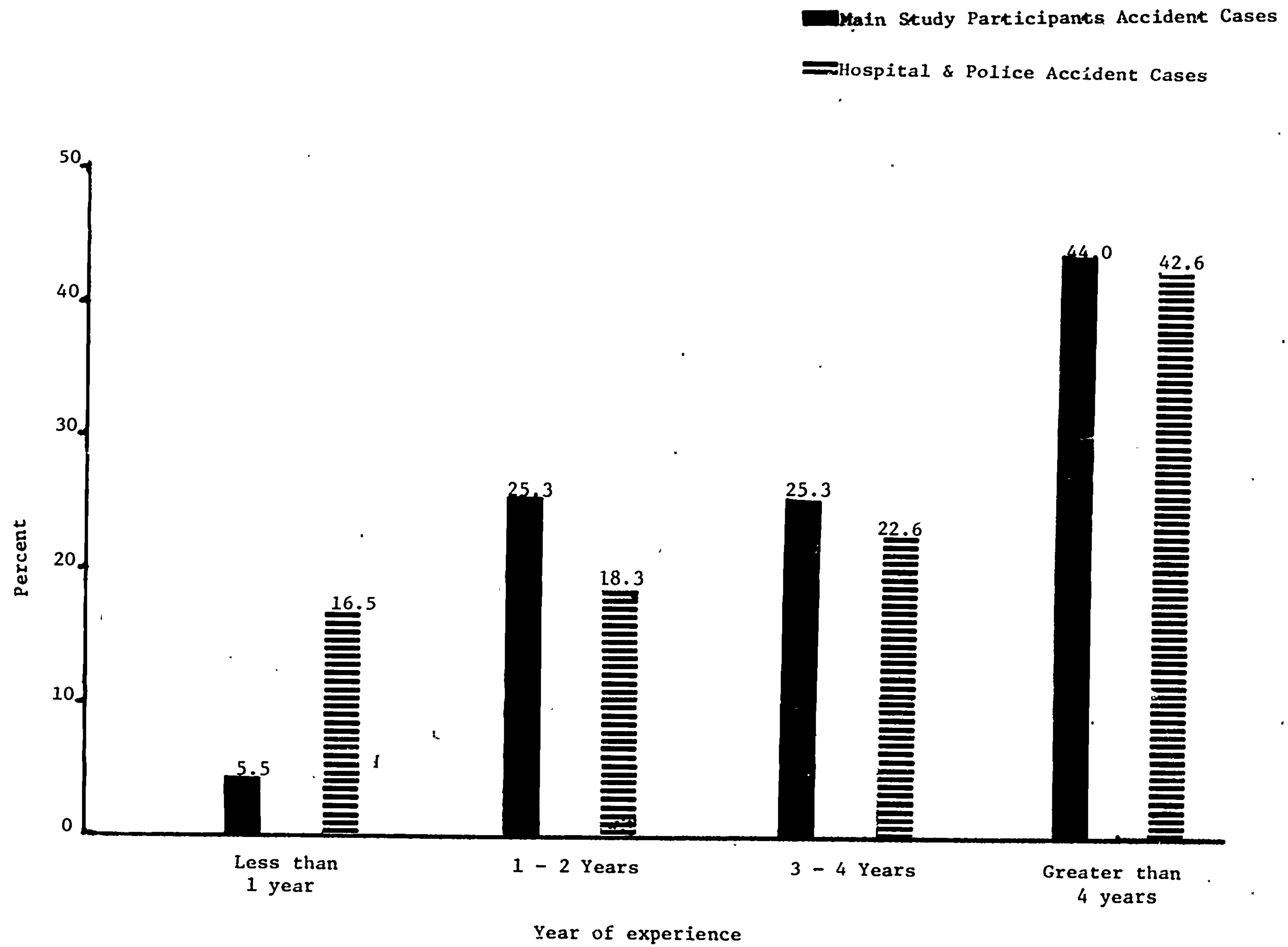
Graph 14

PREVIOUS BICYCLE RIDING EXPERIENCE



Graph 15

PREVIOUS RIDING EXPERIENCE



interval there may be gained the largest overall reduction in accident experience, both as a proportion (within an experience interval) and frequency as compared to all intervals. At this time it would appear that re-education of the bicyclist might be indicated with car-vs. bike situations reviewed most closely. A similar approach might well be developed for those in the 3-4 year experience group as "insurance" against the potential hazard of progressing to the next interval of higher risk experience.

Estimates of Exposure—Riding Time

To this stage in the study, bicycle ownership and accidents have been observed in terms of differences by bicycle type, sex, age and experience for the various sub-groups in the study. The plan also provides for examination of accident experience through two measures of exposure. One was an estimation of riding time, hours per day and days per week, as reported by the subject. This data establishes a link with other bicycle studies, which recorded similar estimates, and also provides for a test of the association between estimated hours of exposure and mileage as recorded on an odometer.

Tables No. 3 and No. 4 record estimated exposure in hours for the All Subjects (AS) and Main Study Participants (MSP) groups respectively. The tables specific for age and bicycle type show that in all but two of 18 comparisons (for both groups) males report greater riding time. In each group the highrise estimates are higher than for the standard and lightweight types. An interesting disparity between the two groups is seen in the $\Sigma\bar{x}$ column. For All Subjects (Table No. 3) there is a negative association with age while in the MSP group (Table No. 4) the association is positive. Conclusions drawn from this table must be restricted, but highrise bicycles seem to accumulate the most riding time, with males riding more than females. Age as a factor of use is less evident; it might suggest that the older riders who accumulate more time elected to join the study, which provided the MSP group (Table No. 4) with the positive gradient in the $\Sigma\bar{x}$ column.

In Table No. 4 the lower $\Sigma\bar{x}$ value for the 5-9 year group would appear to be attributable principally to reduced mean riding times recorded for highrise riders of both sexes.

Estimated Mileage

Incorporated into the design of the study was a method for objectively estimating mileage accumulated by the study sample.

Bicycle cyclometers (mechanical mileage counters) attached to front wheels of the MSP group provided the means for an objective estimate of mileage exposure. Two-hundred and thirty (230) boys and one-hundred and sixty-seven (167) girls contributed acceptable data towards the calculation of average mileage traveled (Table 1, p. 26) by bicycle type and accident experience, accumulating an estimated total of more than 79,000 miles of bicycle riding over the full course of the study. (For each subject who submitted a minimum of two monthly mileage reports, an average monthly mileage figure was calculated and multiplied by the number of reporting periods (six). This total was then summed for all of the subjects who qualified in this manner and the result was an estimated 79,360.3 total miles traveled by the 397 subjects over the six-month period.) It was determined, using a six-month base for calculations, that average yearly mileage for males was 313.5 miles/year and 159.5

Table 3

HOURS OF EXPOSURE PER WEEK FOR ALL MAIN STUDY SUBJECTS BY BICYCLE TYPE AND AGE AND SEX OF OWNER N=981 (AS)

	HIGHRISE						STANDARD						LIGHTWEIGHT							
AGE	M[1]	N[2]	F[3]	N	$\bar{X}$[4]	Σ N	M	N	F	N	$\bar{X}$	ΣN	M	N	F	N	$\bar{X}$	ΣN	$\Sigma\bar{X}$	$\Sigma\Sigma$N
5-9	9.7	130	7.5	82	8.9	212	8.7	65	5.9	98	7.0	163	5.1	8	2.0	2	4.5	10	8.0	385
10-14	8.6	169	7.6	67	8.4	236	8.0	78	5.3	136	6.3	214	7.2	69	5.3	26	6.7	95	7.3	545
15-19	9.9	7		0	9.9	7	4.3	11	4.8	15	4.6	26	9.8	12	7.3	6	9.2	18	6.9	51
ΣN		306		149		455		154		249		403		89		34		123		981
$\Sigma\bar{X}$	9.2		7.5		8.7		8.0		5.5		6.5		7.4		5.5		6.9		7.6	

[1] Males, Mean hours of exposure, [2] Observations for a cell, [3] Females, [4] Mean of preceeding means $\frac{\Sigma X}{N}$

Table 4

HOURS OF EXPOSURE PER WEEK FOR MAIN STUDY PARTICIPANTS
BY BICYCLE TYPE AND AGE AND SEX OF OWNER
N=408 (MSP)

	HIGHRISE						STANDARD						LIGHTWEIGHT							
AGE	M[1]	N[2]	F[3]	N	$\overline{X}$[4]	Σ N	M	N	F	N	$\overline{X}$	Σ N	M	N	F	N	$\overline{X}$	Σ N	Σ $\overline{X}$	Σ Σ N
5-9	8.0	59	4.6	39	6.7	98	6.8	28	5.2	43	5.8	71	6.7	3		0	6.7	3	6.3	172
10-14	8.1	77	6.1	25	7.6	102	8.0	27	5.3	44	6.3	71	7.4	36	5.1	16	6.7	52	7.0	225
15-19	9.0	3		0	9.0	3	2.0	3	21.0	1	6.8	4	10.0	4		0	10.0	4	8.5	11
Σ N		139		64		203		58		88		146		43		16		59		408
Σ $\overline{X}$	8.1		5.2		7.2		7.1		5.4		6.1		7.6		5.1		6.9		6.7	

[1]Males mean hours of exposure, [2]Observations for a cell, [3]Females, [4]Mean of preceeding means $\frac{\Sigma X}{N}$

miles/year for females, (Appendix 2, p. 101): accident experience relevant to those values is also given in the same reference. Interaction of sex, bicycle type, exposure and age are recorded in Tables No. 5 and No. 6. Accident rates were calculated using only the *reported* mileages as recorded by the respondents on the monthly mileage reports. This total of 60,109.1 *reported* miles obviously produces a higher accident rate than would the *estimated* six month total mileage of 79,360.3 miles.

Reading Table No. 5, in the row titled "Total", it is evident that all three bicycle types have similar accident rates and indeed they are not significantly different. When the highrise rate (1.4116) was tested vs. the standard rate (1.8051) the result was a $Z=1.0637$ and a $p>0.1357$. When male rates were compared by bike type with female accident experience, none of the sex differences (tested by totals) were statistically significant $Z=.855$. $p>.18$). However, in two of three comparisons, females tended toward higher accident rates. By age groups, the contrasts are less interpretable. Whereas the previous rates all had adequate cell frequencies, the increased number of cells decimated some sample sizes to unacceptable numbers. However, the behavior of the array is more or less consistent with the total row.

While rates serve the purpose of ascribing a mathematical measure of occurrence to a given class of events, they seldom answer the question of relative frequency or quantity in everyday terms. To provide a more comprehensible statement utilizing accident frequency and average miles traveled per year, let us examine the male values for these variables. It was determined that males traveled 313.5 miles per year and experienced accidents at a rate of 1.49 per 1,000 miles. These figures would suggest one to two accidents, of all severity levels, per three-year period. Extrapolating further, if 8% of all accidents require medical treatment (Appendix 2, p. 101) then a male bicyclist, on the average, could expect to accumulate more than 25 years of riding for each accident that requires medical attention. A female bicyclist, on the average, would expect to ride about twice that period of time for each medically treated accident experience.

Table No. 6 shows rates by sex for specific age intervals. Interpretation of this array is again restricted to those cells with adequate frequencies (taken to be ≥ 10). Accordingly, this eliminates the 15-19 year group for both sexes and all lightweight values except for the 10-14 year intervals for both sexes. In Table No. 6 there are 6 comparisons by bicycle type (discounting cells with an $n < 10$). In five of the six male age groups (Table No. 6), highrise rates tend toward lower values (within acceptable comparisons). For females, the highrise is lower in the 5-9 year group and intermediate in the 10-14 year group. Accident rates by bicycle type and sex calculated for data developed from this study were not found to be substantially different.

Accident rates may be accorded another dimension through examination of accident severity and other associated characteristics. Graphs No. 16 and No. 17 record injury severity by bicycle type, collected into injury categories: none, mild, moderate and severe. Graph No. 16 shows accident severity levels for all accident cases (Main Study Participant Accident Cases and Hospital and Police Accident Cases) by bicycle type. Injury distributions associated with highrise and standard bicycles appear to be substantially alike, but the lightweight distribution has a marked preponderance of mild injuries and somewhat more severe injuries than the other types. Graph No. 17, Accident Severity for Main Study

Accident Cases (MSAC), presents a somewhat more jagged curve due in part to fewer observed cases (238 vs. 87 for Graphs No. 16 and No. 17 respectively). In this array, the highrise now resembles the lightweight proportions with some variations. Proportions of mild injuries are roughly equivalent, but the highrise has a larger proportion of no-injury accidents and a smaller proportion of moderate injuries (it will be noted there are no severe injuries in the Main Study Participant Accident data set). When highrise is contrasted with standard, the larger proportion of no-injury accidents in the standard model is readily apparant; this is somewhat mitigated by the larger rate of moderate injury. Taken all together, there is very little to indicate that an advantage exists for any bicycle type, although the lightweight does seem to have the least favorable rates.

Visual examination of the three styles of bicycles could conceivably cause the observer to postulate differences in the anatomical location of injury incurred by style of bicycle. Graph No. 18 displays the distribution of injuries as reported for all accident cases by four ar , of the body. Each bicycle type is represented by a column within a given anatomical area. By anatomical section, the trunk seems to be least affected by accidents, then in succession come the head, arm, and leg, and in order of increasing frequency of injury. Quite unexpectedly, there is no discernable variation that discriminates one bicycle type from the others by this gross classification scheme. There is remarkable uniformity within the arrays by injurv site.

A principal contribution of this display is the frequency with which each body part sustains injury, seemingly an observation of practical value for designers of safety-oriented bicycles. From this graph it is apparent the extremities should receive first consideration, with the head singled out for special attention commensurate with sequelae common to this injury site.

If the inference of parity of accident rates for bicycle types is accepted, when corrected for exposure, other variables may be examined for evidence of group identification. Three variables—bicycle age, bicycle condition and passenger carrying practices—were analyzed as a function of class participation, grouped as Main Study Participants and Main Study Participants With Accidents. Rationale for selection of these data is obvious. It can be argued that bicycle age and condition are related, in some degree, to accident frequency, since these conditions are associated with operating performance. Tables No. 7, 8, and 9 refer to this question. In Table No. 7 bicycle age, when arranged by intervals for the two groups in question, show proportions that are apparently quite similar. When tested, a X^2 of 3.126 resulted for 3 df and a probability of $.30<p<.50$, a non-significant finding.

When bike condition and passengers carried were tested, the results followed the pattern established by bike age. The null hypothesis could not be rejected, and in the case of the latter two tests the frequencies being contrasted were almost identical. Here it might be well to review a methodological point. Data on bicycle age condition and passenger-carrying practices were recorded early in May, *before* any other data were collected. The assignment to groups thereby should be essentially unbiased. Thus, within the limits of the study and conditions prevailing, there seemed to be no difference for bicycle age or condition when tested by accident experience.

Graphs No. 19-19A-19B (Type of Accident) display the proportions that each accident category contributes to all accidents. The results are graphed for all accident cases (MSAC) by bicycle type. Falls, the greatest contributor, account for over two-thirds of all

TABLE 5

ACCIDENT RATES BY BICYCLE TYPE, AGE AND SEX OF DRIVER (MSPAC)

		HIGHRISE	LIGHTWEIGHT	STANDARD	TOTAL
TOTAL	Rate/1000 mi.	1.41	1.65	1.81	1.58
	Miles	30,462	9,704	19,944	60,109
	Accidents	43	16	36	95
	Subjects	191	57	149	397
MALE	Rate/1000 mi.	1.24	1.56	1.93	1.49
	Miles	22,538	8,334	11,385	42,257
	Accidents	28	13	22	63
	Subjects	129	41	60	230
FEMALE	Rate/1000 mi.	1.89	2.19	1.64	1.79
	Miles	7,924	1,369	8,559	17,852
	Accidents	15	3	14	32
	Subjects	62	16	89	167
5-9	Rate/1000 mi.	1.68	0.00	2.41	1.89
	Miles	16,029	780	9,139	25,948
	Accidents	27	0	22	49
	Subjects	95	3	74	172
10-14	Rate/1000 mi.	1.12	1.89	1.28	1.36
	Miles	14,279	7,925	10,192	32,396
	Accidents	16	15	13	44
	Subjects	94	49	71	214
15-19	Rate/1000 mi.	0.00	1.00	1.63	1.13
	Miles	154	998	613	1765
	Accidents	0	1	1	2
	Subjects	2	5	4	11

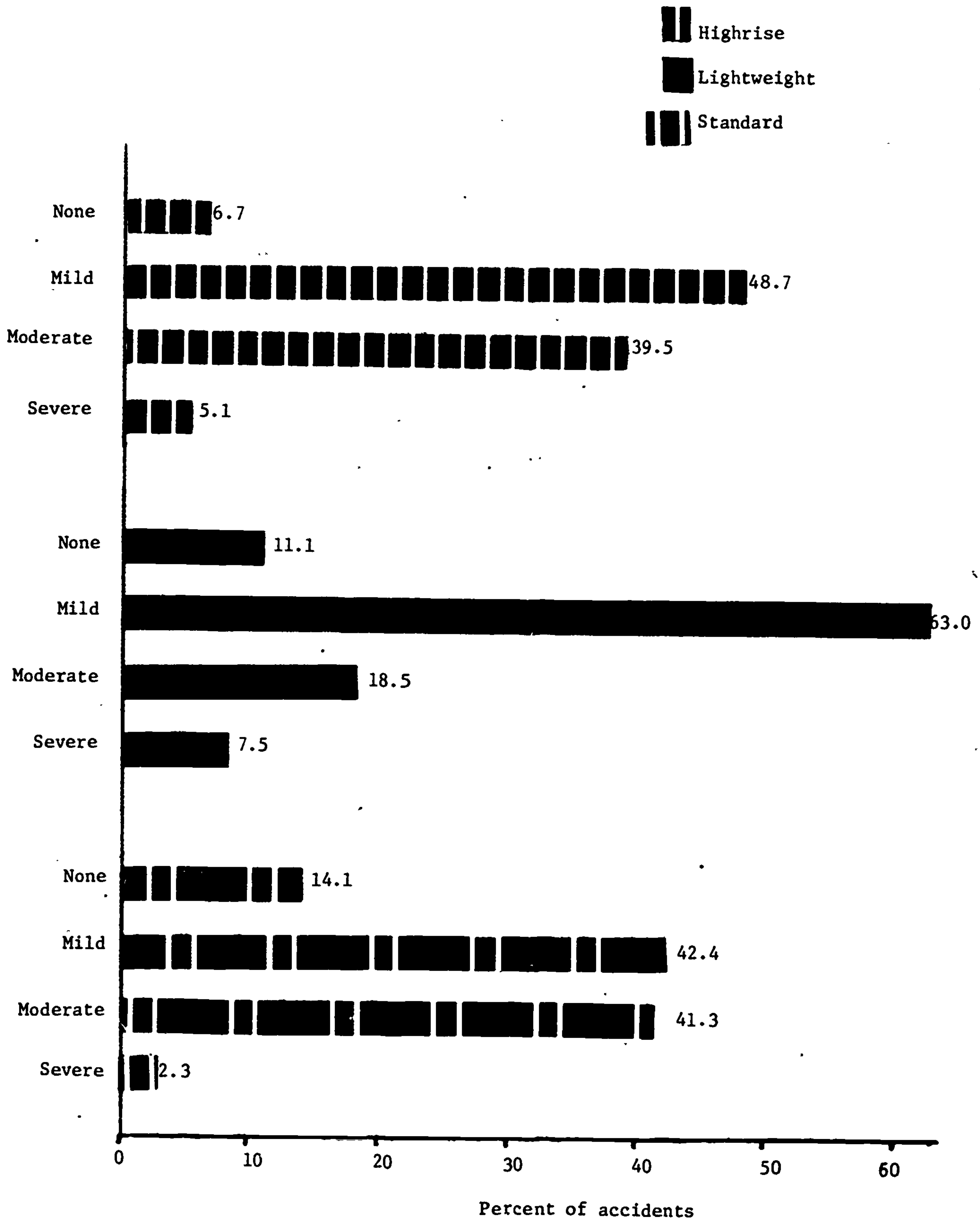
TABLE 6

ACCIDENT RATES BY BICYCLE TYPE, AGE AND SEX OF RIDER(MSPAC)

		HIGHRISE	LIGHTWEIGHT	STANDARD	ALL
MALE 5-9	Rate/1000 mi.	1.60	0	2.44	1.814
	Miles	10,627	780	5,132	16,539
	Accidents	17	0	13	30
	Subjects	56	3.	29	88
MALE 10-14		.94	1.83	1.56	1.33
		11,757	6,557	5,757	24,071
		11	12	9	32
		71	34	28	133
MALE 15-19		0.00	1.00	0.00	.607
		154	998	495	1,647
		0	1	0	1
		2	4	3	9
FEMALE 5-9		1.90		2.25	2.019
		5,402		4,007	9,409
		10		9	19
		39	0	45	84
FEMALE 10-14		1.98	2.20	.902	1.44
		2,521	1,369	4,435	8,325
		5	3	4	12
		23	15	43	81
FEMALE 15-19			0.00	8.53	8.503
			0.6	117	117.69
			0	1	1
		0	1	1	2

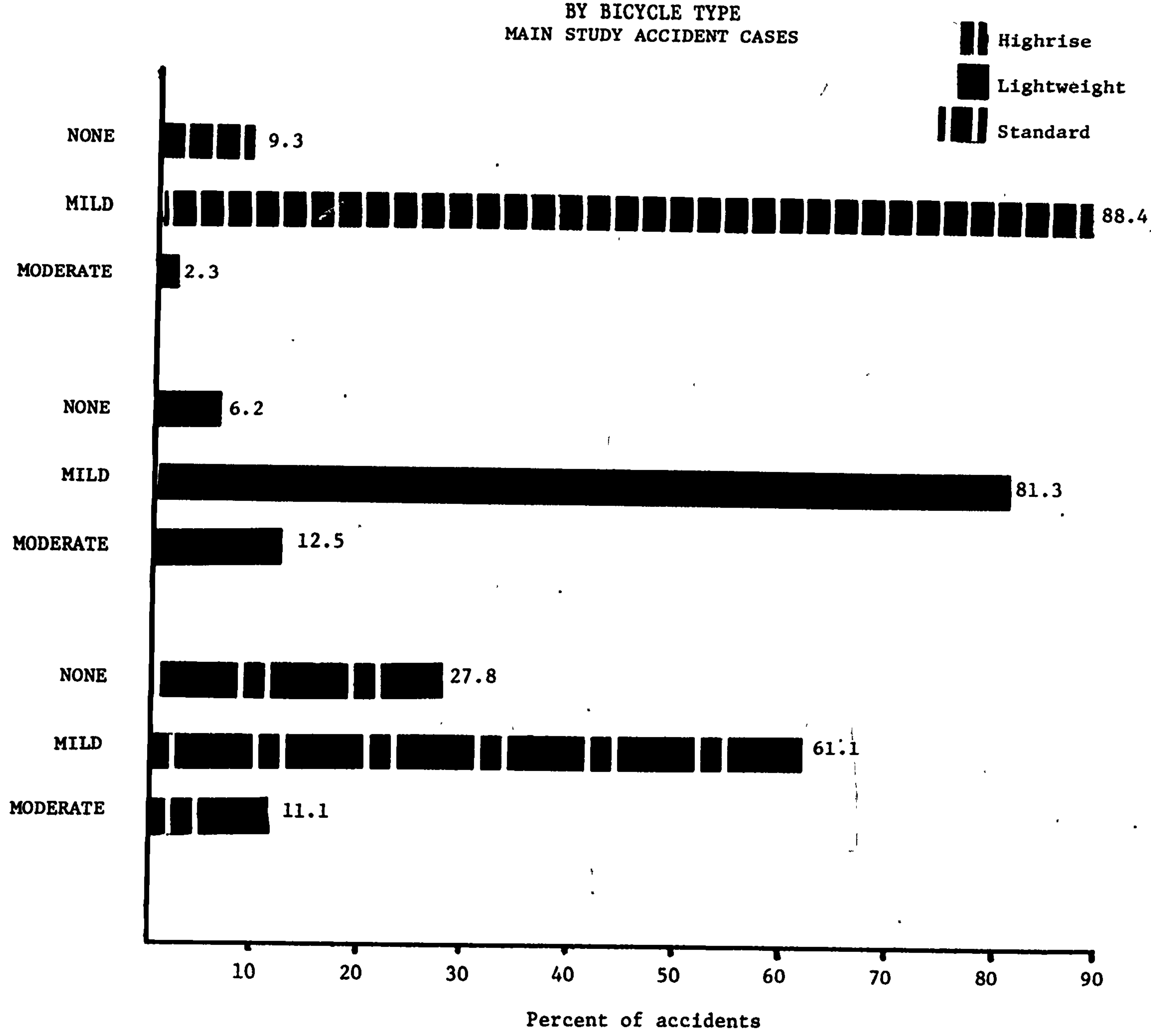
Graph 16

SEVERITY OF ACCIDENTS
BY BICYCLE TYPE
ALL ACCIDENT CASES
(MSAC)



Graph 17

SEVERITY OF ACCIDENTS
BY BICYCLE TYPE
MAIN STUDY ACCIDENT CASES



Graph 18

PART OF BODY INJURED BY TYPE OF BICYCLE
ALL ACCIDENT CASES
(MSAC)

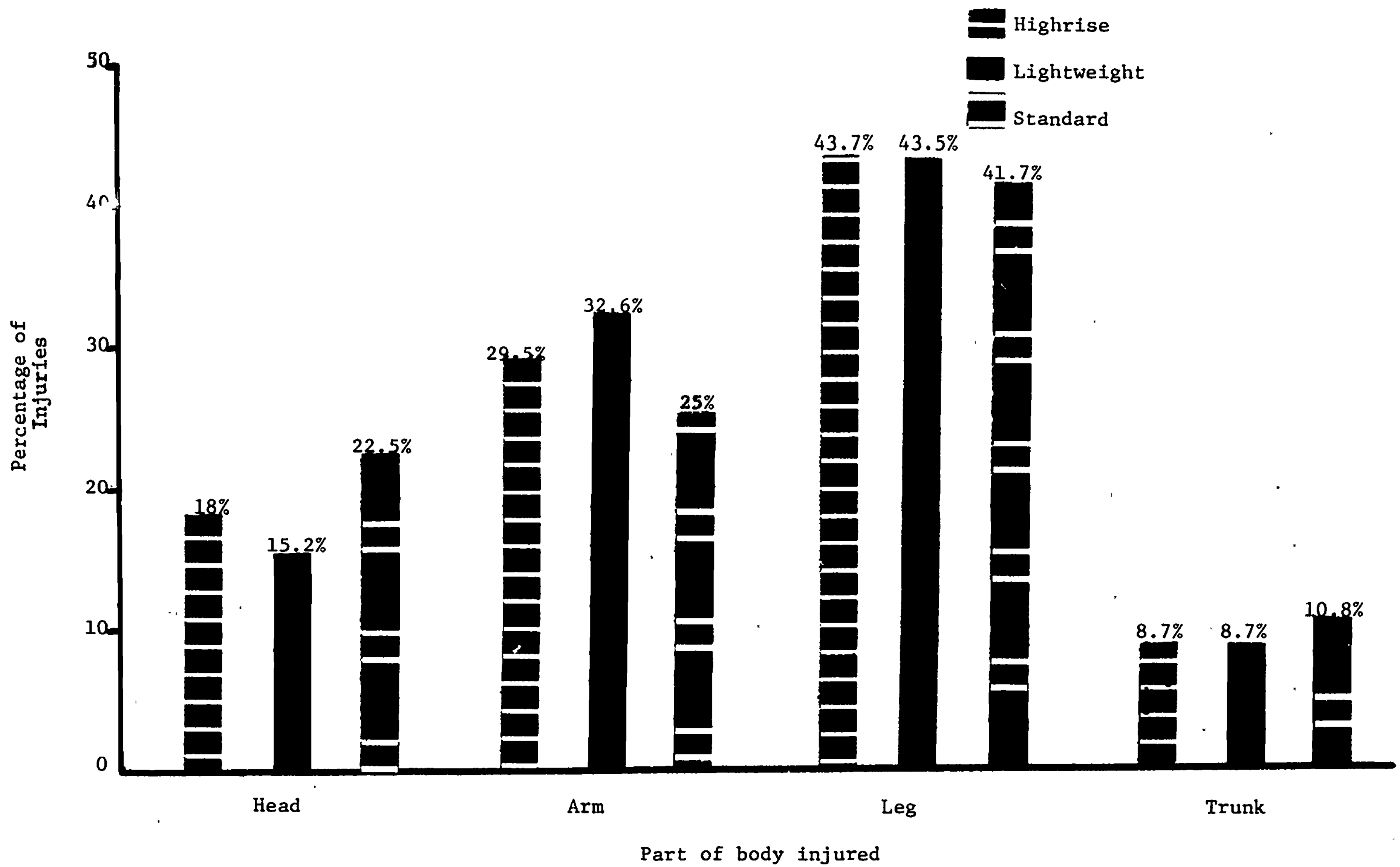


Table 7

Comparison of Main Study Participants with Main Study Participants Who Have Had Accidents by Bicycle Age

Bicycle Age	Main Study Participants	Main Study Participants (Accidents)	Total
<1	111	15	126
1-4.9	316	59	375
5-9.9	62	12	74
10 +	10	4	14
Total	499	90	589

$X_3^2 = .169 + .938 + .009 + .05 + .008 + .043 + .292 + 1.617 = 3.126 \quad .30 < p < .50$

Table 8

Comparison of Main Study Participants with Main Study Participants Who Have Had Accidents by Bicycle Condition

Bicycle Condition	Main Study Participants	Main Study Participants (Accidents)	Total
Excellent New in appearance and operation	101	19	120
Very Good Same as Excellent but showed some wear	155	31	186
Good Well cared for bike may be several years - Needs no obvious replacements	186	31	217
Fair All systems funct. but worn with some replacements indicated	48	7	55
Poor Needs immediate attention - Not operating properly	5	1	6
Total	495	89	584

$X_4^2 = .005 + .028 + .045 + .248 \pm .023 + .130 + .041 + .228 + .002 + .009$

$= .759 \qquad .90 < p < .95$

Table 9

Comparison of Main Study Participants With Main Study Participants Who Have Had Accidents by Passenger Carrying Status

Carry Passengers	Main Study Participants	Main Study Participants (Accidents)	Total
Never	388	70	458
Seldom	99	18	117
Often	7	1	8
Total	494	89	583

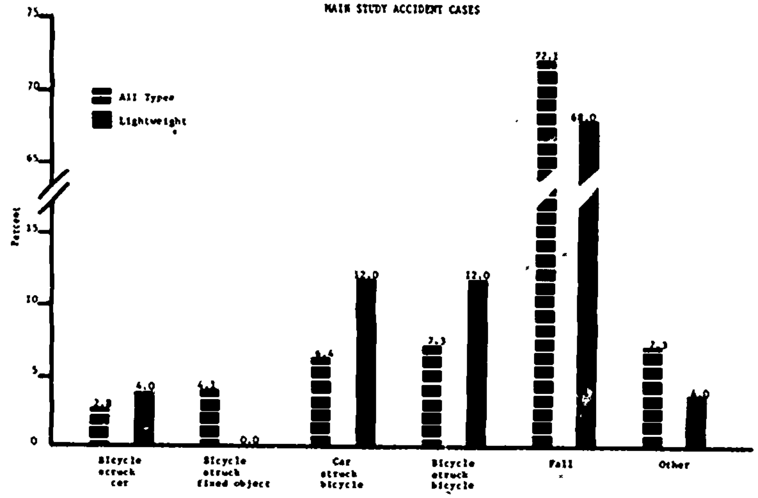
$X^2 = .000 + .000 + .000 + .001 + .007 + .040$

$= .048 \qquad .95 < p < .98$

Graph 19a

TYPE OF ACCIDENT FOR ALL BICYCLE TYPES VS. LIGHTWEIGHT BICYCLES

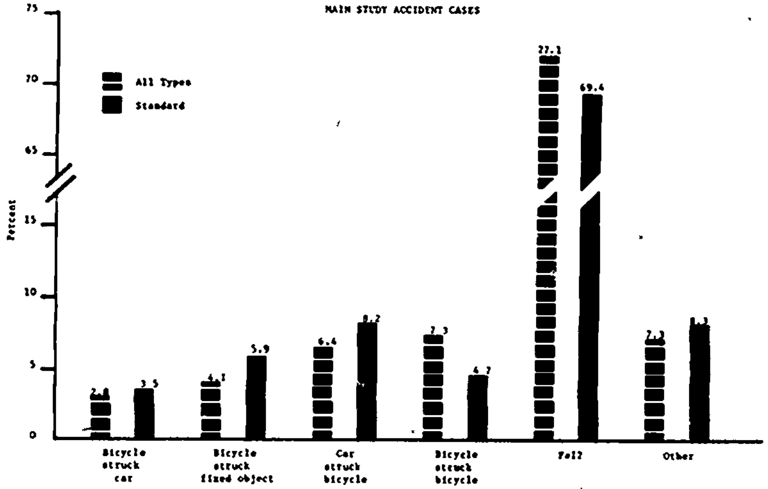
MAIN STUDY ACCIDENT CASES



Graph 19b

TYPE OF ACCIDENT FOR ALL BICYCLE TYPES VS. STANDARD BICYCLES

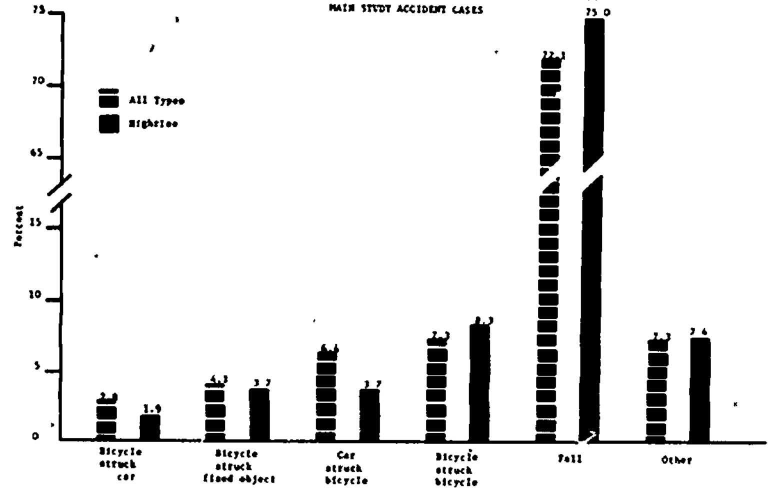
MAIN STUDY ACCIDENT CASES



Graph 19

TYPE OF ACCIDENT FOR ALL BICYCLE TYPES VS. HIGHRISE BICYCLE

MAIN STUDY ACCIDENT CASES



recorded accidents for each of the bicycle types. The other categories are relatively undifferentiated. Interpretations from this graph might best be limited to the observation that falls constitute the preponderance of accidents and that it is common to all bicycle types. Frequencies for the accident categories were tested by chi-square (Table No. 10, p. 56), and the result (X^2=8.15, $.50 < p < .70$) was not significant. This suggests that for these data there was no difference for category of accident related to bicycle type.

Equipment Failure

Equipment failure was recorded through accidents reported on the monthly report form (Appendix I, p. 87).. A standard procedure was followed according to a "Procedure For Telephone Interviews" form (Appendix 1, p. 76). Information was elicited in a manner which was presumed to permit the witness to develop the account without undue influence by the interrogator. Perusal of the form will reveal that the intent of the interview is to record a plain statement of fact in the witnesses' own terms and interpretation.

Table No. 10A, p. 57, lists kinds of mechanical failure by bicycle type. There are eight classes of failure, which were explained in the following manner: Forty percent (12 observations) of the failures were said to be wheel problems; in three of these cases passengers were being carried, while in one instance it was reported that the bicycle had been tampered with by unspecified individuals (retrospective recollection of accident situations, perhaps obscured by emotional and/or physical trauma, are not usually characterized by fluent replies that would increase one's confidence in the reliability of the report). Brake failures accounted for 20% of the reported failures, with half of the total of six being listed under the highrise type; lightweight had two failures and standard, one. This particular category may be prejudiced against the highrise and lightweight styles, as they are more likely to have hand brakes with exterior linkage components. In four instances (13.3%) the chain failed. Information described the failures as three disengagements from the sprocket and one breakage. Handlebars were cited in three instances, (10%) being in single cases loose, disengaged from attachment and misaligned. Two seats fell off, and pedals, gearshift and tires failed in one instance each.

Obviously, the categories requiring most attention are wheels, brakes, chains and handlebars in that order. It is notable that in each of the items of equipment mentioned there is some visible element of external vulnerability and adjustment. Wheels have spokes to be bent or broken, and also must be adjusted with some competence on the part of the mechanic. Hand brakes are patently complex with components demanding small tolerances for proper operation, with linkage being somewhat exposed to damage. Chains are especially critical of tension adjustment and require skill and some strength to anchor properly. Handlebars, by design, absorb high energy forces in pedalling, turning and perhaps impact upon falling or collision.

Handlebars and handlebar stems should be of highest quality stress-tested material of appropriate design, size, length and configuration, with rider safety as the first consideration. Conspicuous by their absence are failures of frame and cranks, hangars and sprockets. These items accept the highest stress of all and, of necessity, must be fabricated of the most resistant, durable and resilient material available, far exceeding any force or combination of forces a person might apply under any set of circumstances. In full recognition of the consequence, failures to these vital components should be so rare as to be virtually unknown.

Table 10

CATEGORY OF ACCIDENT
BY BICYCLE TYPE FOR
MSAC

Category of Accident	Highrise	Light-weight	Standard	Total
Bicycle Struck Car	2[1] 2.97[2] .97[3]	1 .69 .31	3 2.34 .66	6
Car Struck Bicycle	4 6.93 2.93	3 1.61 1.39	7 5.46 1.[illegible]4	14
Bicycle Struck Bicycle	9 7.93 1.07	3 1.83 1.17	4 6.25 2.25	16
Bicycle Struck Fixed Object	4 4.45 .45	0 1.03 1.03	5 3.51 1.49	9
Fall	81 77.78 3.22	17 18.00 1.00	59 61.22 2.22	157
Other	8 7.93 .07	1 1.83 .83	7 6.25 .75	16
Total	108	25	85	218

1. = Number of observations within cell.
2. = Expected number, determined by column x row/N=218.
3. = Absolute difference between observed and expected values.

$$X^2_{10} = .317 + 1.239 + .144 + .046 + .134 + .001 + .139 + 1.200 + .748 + 1.03 + .056 + .376 + .186 + .434 + .875 + .633 + .081 + .090 = 7.82, \; .50 < p < .70, \text{ Not Significant}$$

Table 10A

Frequency of Equipment Failure By
Type of Bicycle and Accident Category* (MSAC)

Failure Category	Highrise	Lightweight	Standard	Total
Brake Failure				
Brakes	1_g 1_h 1_p	1_f		6
Brake Cable		1	1	
Wheel				
Came Off	1_p		1 1_e 1	12
Locked	1			
Loose	1_p		1 1 1	
Wobbled (Loss of stability)	1_p	1*1*		
Chain Came Off	1 1_p		1 1_d	4
Handlebars				
Loose		1_c		
Fell Off			1	3
Misaligned			1*	
Pedal Broke			1	1
Seat Fell Off	1_b 1_a			2
Gearshift Failure		1_a		1
Tires				
Blowout			1	1

a Owner had just "adjusted" bicycle
b New bicycle
c Passenger on handlebars
d Chain failure
e Bicycle had been tampered with
f On fast downhill curve
g Rear axle also "gave way"
h Rear brake failed, front worked
p Passenger carried

* All accidents were falls except where noted

Ambient Conditions

Graphs 20-25 refer to the extrinsic characteristics of all recorded accidents with regard to ambient conditions and chronologic sequence.

Character of location makes evident the preponderance of the neighborhood type accident within the study group. Almost 88% of all recorded accidents occurred in residential areas (Graph No. 20) during daylight hours (Graph No. 21) and in clear weather (Graph No. 22). If the event takes place in the street, 67% of the time the bicycle is traveling with the traffic flow (Graph Nc. 23). Accidents by day of week (Graph No. 24) provide little discrimination in terms of increased likelihood of accidents. Logically, Saturday would appear to provide much more exposure than the week days and yet the accidents do not appear to increase proportionally. Sunday, with presumably all day in which one may ride, is lower in accident frequency than three of the week days. Accidents then are not strictly a function of opportunity. When the Chi square test for frequency of occurrence was applied to accidents by day or week, it was found to be non-significant ($.50 < p < .70$), suggesting that all seven days must be considered to have similar risk potential.

Perhaps the most unmistakable factor relative to accident potential is hour of the day (Graph Nc. 25). The afternoon has a greater proportion of accidents observed, beginning at 3 p.m. and continuing through 8 p.m. The four-hour period, 3 p.m. to 7 p.m., includes 64.0% of all reported accidents. If we were able to examine the data by age, we might possibly detect a bimodal distribution (a curve with two peaks) underlying the unimodal distribution displayed, suggesting differing periods of accident potential by age interval (viz., younger vs. older).

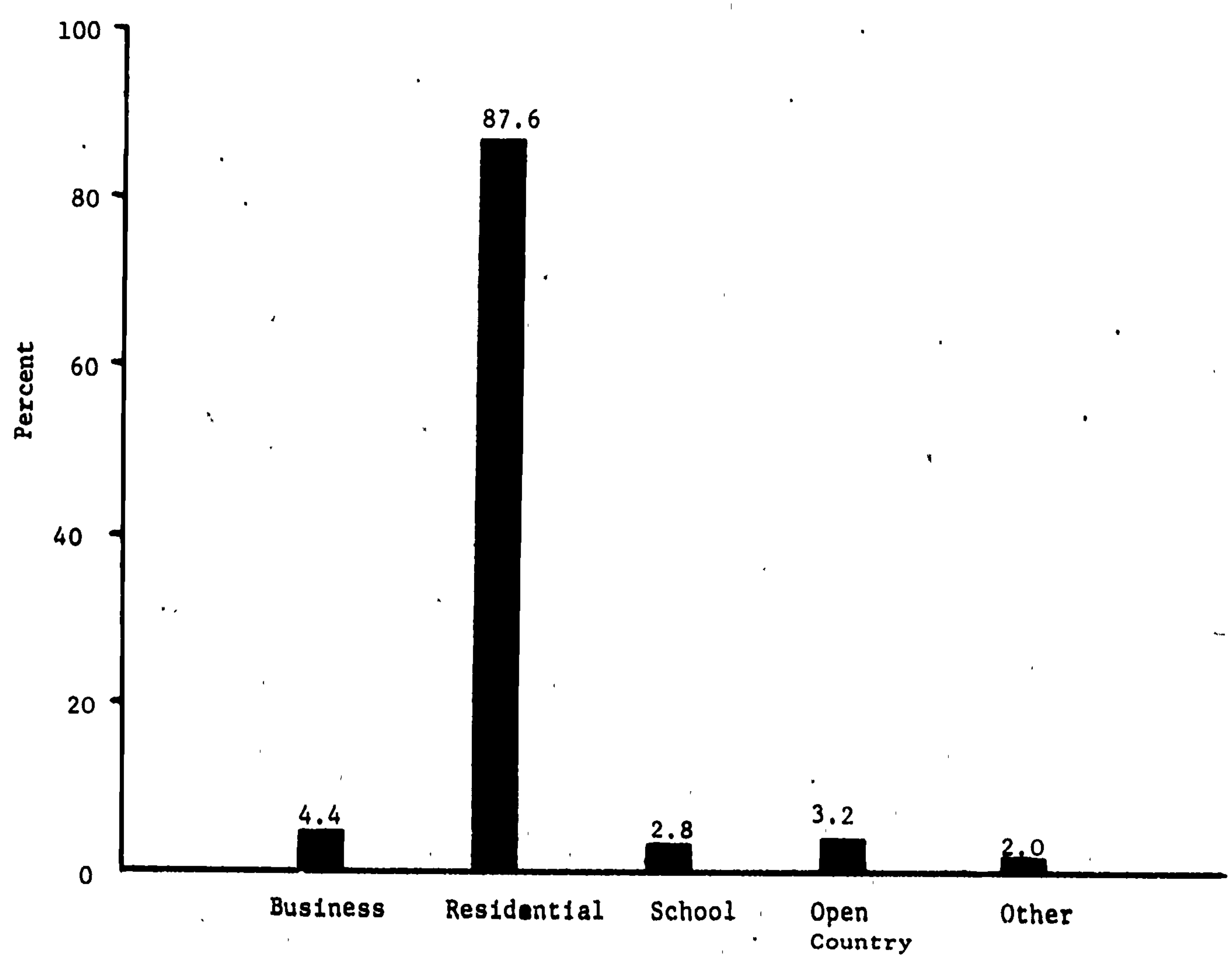
Frequency by month (Graph No. 26) implicates two months, May and June, as those found to be most productive of accidents. Since the decline from June is at first precipitous then quite gradual, the rest of the year may be considered as undifferentiated insofar as accident risk is concerned. Although our data do not include November through March, we will assume accident frequencies for these months to be lower than for May and June.

To further elucidate the exposure-accident relationship, average mileages were calculated for the months May through October. These monthly averages were collected into Table No. 11 by the three principal sub-groups according to class of participation.

One may now compare average monthly mileages by class of participation with the accident frequency (Graph No. 26) by month (with the Exception of April which has no mileage data). From Table No. 11 the All Participants (Main Study Participants) mileage averages show May to be the highest with June through September roughly equivalent and a drop for October. This does not agree with the All Accident Cases curve (MSAC) displayed in Graph No. 26. Participants With Accidents (MSPAC) provide a distinct contrast to the previously examined groups by showing virtually no change for the first two months with averages that are visibly higher, compared to the other two classes, over the full range of values. Participants With Accidents display a small drop in July and then an increase in August which is maintained in September. October has the lowest average, as it does for the other two classes. It is evident that the accident group (MSPAC) is a harder-riding breed of subjects, as they average eight miles per month more than Main Study Participants and almost ten miles more than Main Study Participants Without Accidents.

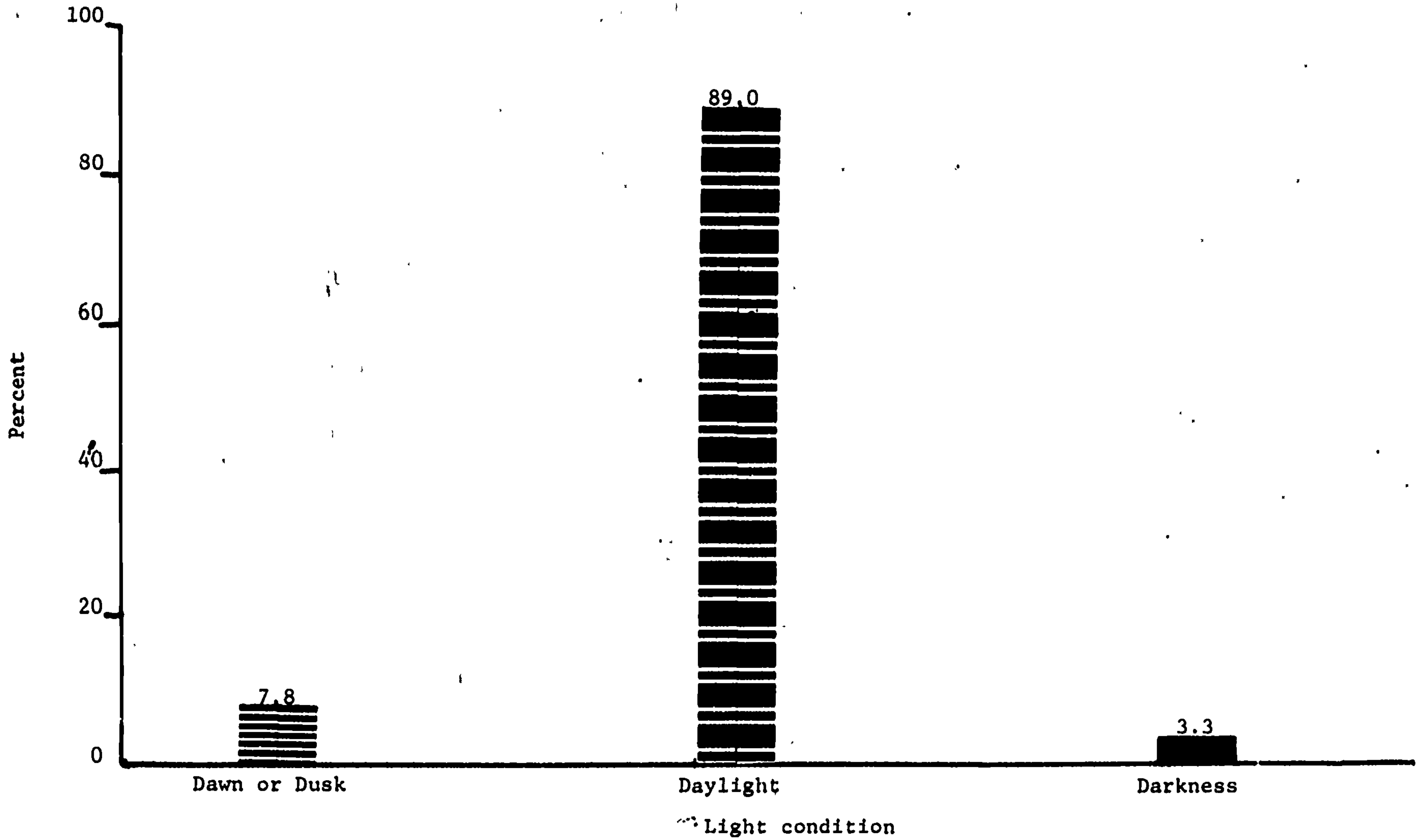
Graph 20

CHARACTER OF LOCATION
ALL ACCIDENT CASES
(MSAC)



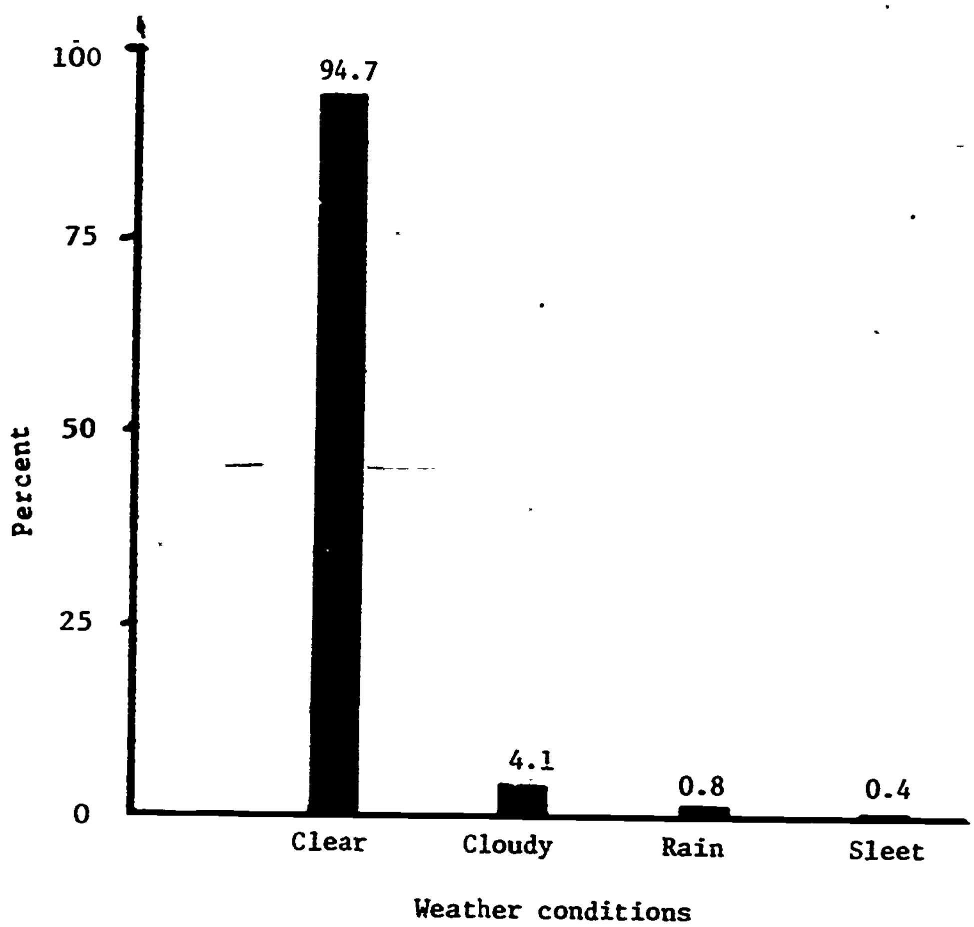
Graph 21

LIGHT CONDITION AT TIME OF ACCIDENT
ALL ACCIDENT CASES
(MSAC)



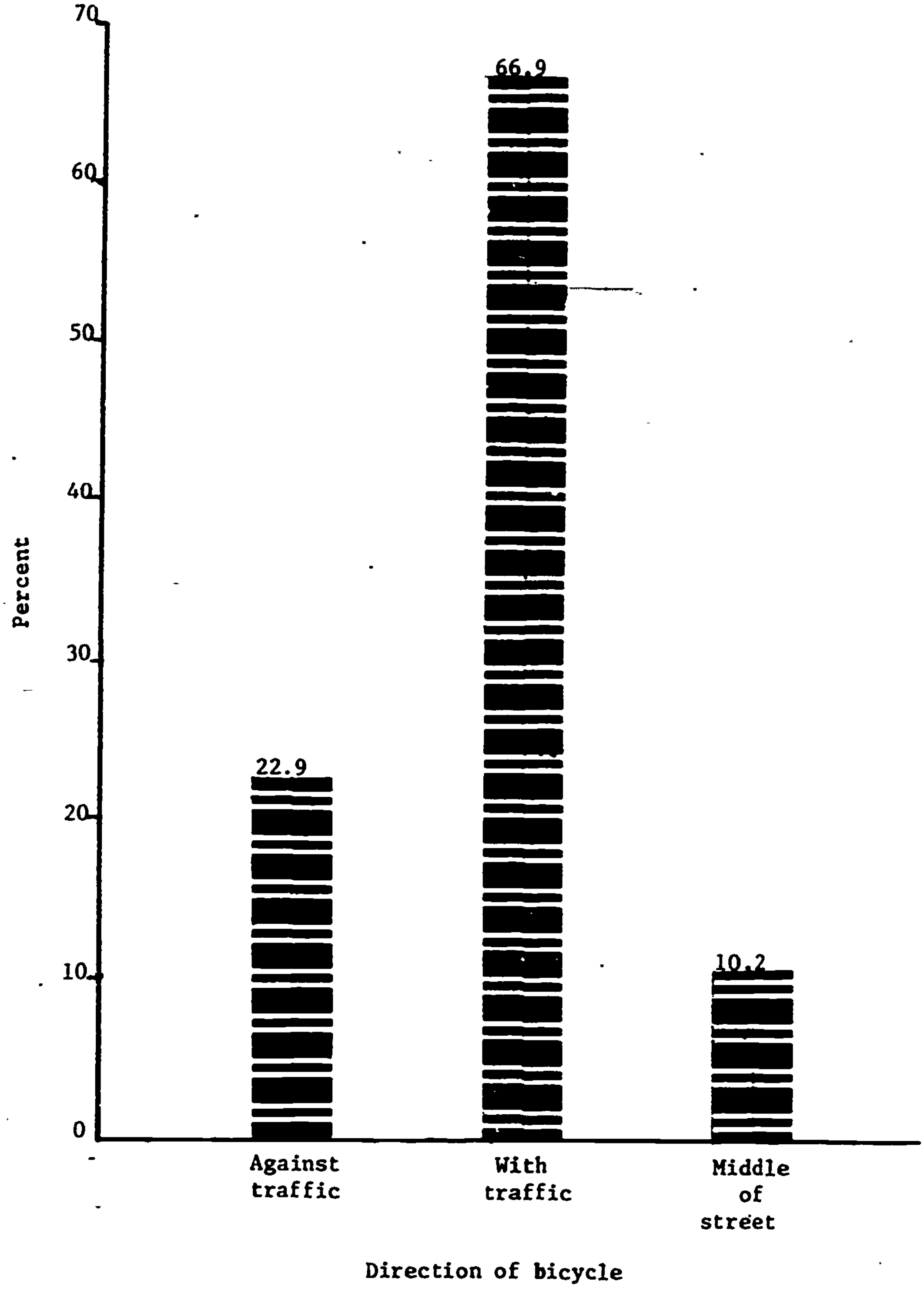
Graph 22

WEATHER CONDITIONS AT TIME OF ACCIDENT
ALL ACCIDENT CASES
(MSAC)



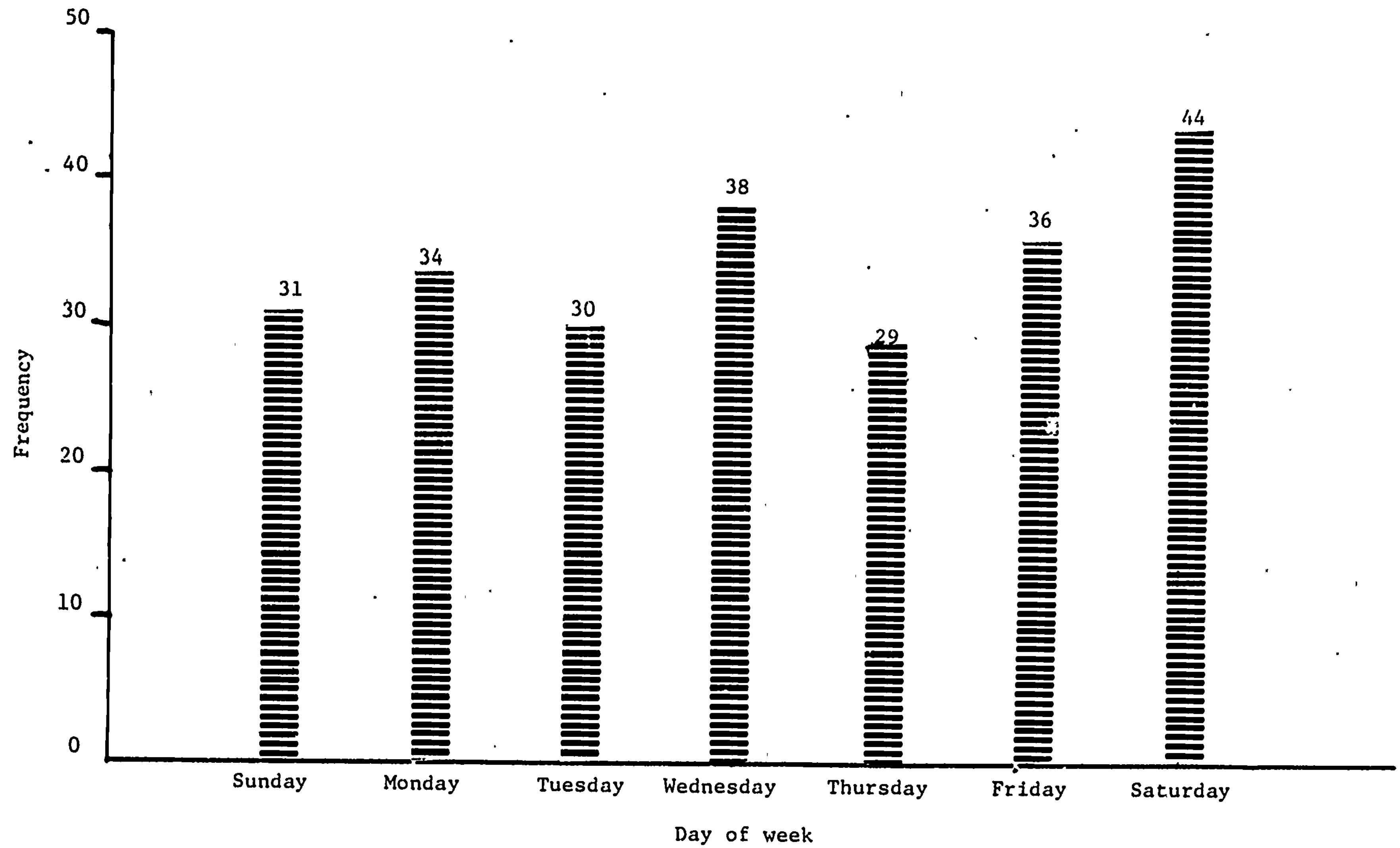
Graph 23

DIRECTION OF BICYCLE TRAVEL
AT TIME OF ACCIDENT
ALL ACCIDENT CASES
(MSAC)



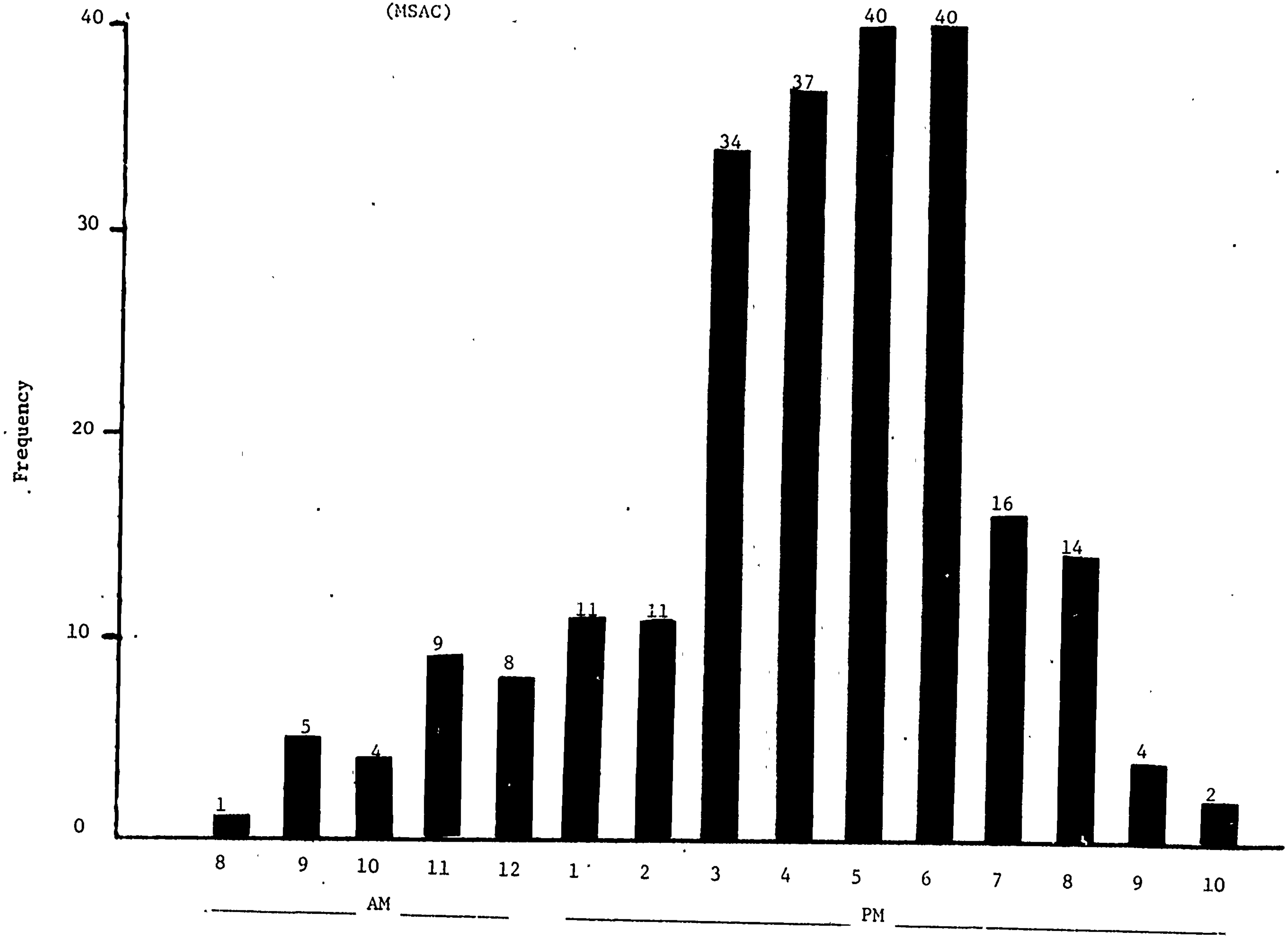
Graph 24

FREQUENCY OF ACCIDENTS BY DAY OF WEEK
ALL ACCIDENT CASES
(MSAC)



Graph 25

FREQUENCY OF ACCIDENT
BY HOUR OF DAY
(MSAC)



Graph 26

ACCIDENTS BY MONTH

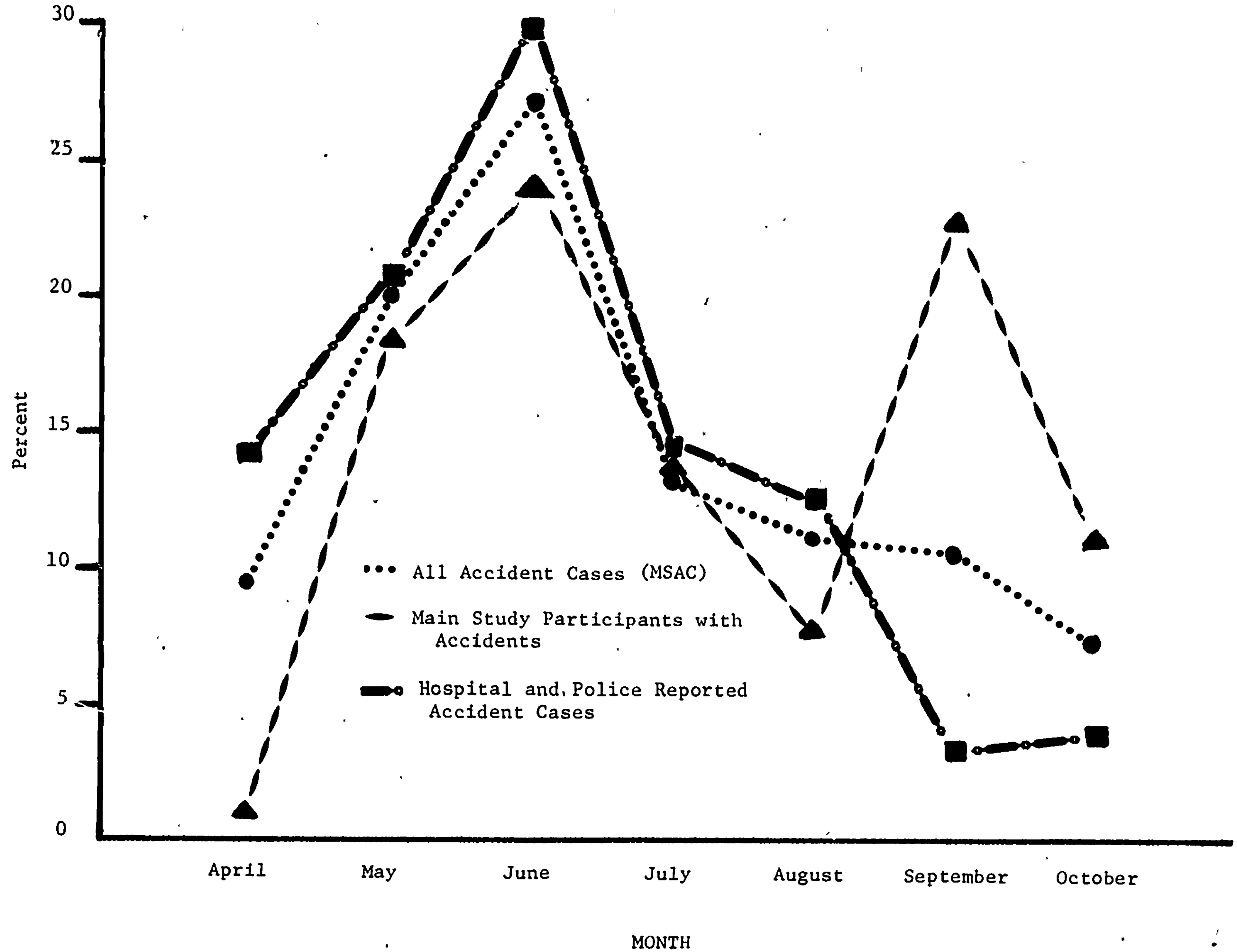


Table 11

Average Miles Traveled Each Month By Accident Experience (MSPAC)

	All Partic.	N	Partic. Without Accidents	N	Partic. With Accidents	N
May	37.6	468	36.3	377	43.2	91
June	33.6	447	31.3	362	43.0	85
July	33.0	397	31.3	318	39.5	79
Aug.	32.8	380	30.4	304	42.2	76
Sept.	31.9	368	29.4	292	41.6	76
Oct.	26.9	366	25.0	289	34.1	77
Average Miles Traveled	32.88		30.91		40.70	

When accident experience for Hospital and Police Accident Cases (HPAC) is contrasted with those accruing to Main Study Participants with Accidents (MSPAC) (Graph No. 26), the distinctive features of the two curves can be compared. Since the numerical size of the hospital and police combination is larger than that of the Main Study Participants, it would tend to dampen the curve of the smaller group and suppress its salient characteristics. As it is, the peak recorded in September for the Main Study Group (MSPAC) suggests increased accidents coinciding with the re-opening of schools. Riding conditions in September would tend to be altered through imposition of a strict daily routine likely placing the rider in heavier motor traffic than he experienced during the summer months. Once more there is the implication that exposure, as it is considered in this report, founded solely on mileage, is not a satisfactory explanation. Exposure may also be considered to possess qualitative components, relative to the individual, which vitally affect vulnerability to the development of accident situations.

SUMMARY AND CONCLUSIONS

A population study of youthful bicycle riders, and the events accruing to operation of their equipment, was initiated in Raleigh, North Carolina, in May of 1970. The questions posed to the researcher (viz., accident rates and characteristics of use by population subgroups) operationally defined the procedures to be employed in the research design. It was necessary to generate exposure data (mileage) on a selected sample of the target population. Among other variables collected were type of bicycle owned and riding experience over the course of the six-month data collection period. Preliminary to the main study, a pilot phase on a sub-sample of the population was conducted to test tactical and executory systems (i.e., sample selection, mail contact and initial response rate) and to supply information essential to estimation of bicycle ownership rates.

The sample of bicycle riders for the main study was drawn from selected elementary and junior high schools (from second through ninth grades inclusive) in a manner designed to produce an approximately equal probability of selection for each student in the Raleigh City School system. This process enumerated 2,369 students who were sent questionnaires (495 of the questionnaires (21%) were completed and returned) and an invitation to participate in the data collection phase. The questionnaire (Appendix 1, p. 81), the basic element of data collection, provided the researchers with demographic (e.g., biographical and socioeconomic) data, information related to bicycle ownership and mechanical features of the vehicles owned.

The design of the study provided for an estimate of exposure through use of cyclometers (bicycle mileage meters), which were attached to the front wheel of the subject's bicycle. Five hundred twenty-three of the devices were affixed with almost 400 of the subjects eventually reporting acceptable mileage data. Subjects were also asked to estimate riding time in terms of hours per day and days per week. This measure was found to demonstrate poor statistical association with mileage and was excluded from further calculation. Accumulated mileages and accidents were reported by means of a monthly report form (Appendix 1, p. 87), a stamped self-addressed fill-in instrument which was mailed at regular intervals to all participants.

Accidents were categorized by anatomical location—a stick figure was included for this prupose—(See Monthly Report Form, Appendix 1, p. 87), degree of injury by type of treatment, and by type of injury. For each accident recorded in this manner, a standardized telephone interview (Appendix 1, p. 76) was initiated to gather additional information. To obtain another kind of accident experience, Raleigh hospitals participated by agreeing to provide information on all bicycle accidents treated in their emergency rooms. To make the accident representation more nearly complete, the Raleigh Police Department supplied the study with data from accidents they processed in their official capacity.

The study groups thus formed consist of:

1. Main Study Participants, (MSP), N=523;
   a. Main Study Participants with Accidents, (MSPAC), N=93;
   b. Main Study Participants without Accidents, (MSPWA), N=430;
2. Hospital Accident Cases, (HAC), N=117;

3. Police Accident Cases, (PAC), N=14;

4. Hospital and Police Accident Cases, (HPAC), N=131;

5. Main Study Accident Cases, (MSAC) = (MSPAC) + (HAC) + (PAC), N=224;

6. Main Study Non-Participants, (MSN-P), N=499;

7. No bicycle, (ASNB), N=51;

8. All Subjects, (AS) = (MSP) + (HAC) + (PAC) + (MSN-P) + (ASNB), N=1,204.

Findings suggested that for MSP the age range 7-12 years was somewhat over-represented (compared to the AS Group), which tended to provide more data in the area of greatest concern. It was found that accident subjects were younger than those who did not sustain accidents, with highrise and standard owners demonstrating lower mean ages than lightweight owners (8.9, 9.1, and 11.5 years respectively). Females were younger than males in all study groups, a finding which held when controlled for bicycle type. Hospital Accident Cases (8.7 yrs.) were the youngest of the accident groups with Main Study Participants With Accidents (8.9 yrs.) and Police Accident Cases (11.2 yrs.) showing substantially greater mean ages.

These data suggest that the younger child will sustain the most serious accidents, as evidenced by the average age (8.7 yrs.) of the hospital accident subjects. The older (11.2 yrs.) youngster is more likely to become involved in a police-reported situation, with those intermediate in age experiencing the bulk of the accidents that are less serious in nature and need only to be treated at home, if any attention is necessary.

It was found that the less-than-one-year- and the one-to-two-year-experience groups sustain accidents at greater than expected values by a statistically significant margin. It was proposed that bicycle riding instructions might well be organized by experience of the rider as well as male/female specific riding instruction. Younger riders possibly could benefit from basic instruction of riding mechanics and from warnings to stay on the sidewalks. Older riders (greater-than-4-years-experience group) might benefit from instruction that includes problems experienced by the automobile operator, and from motor vehicle statutes, which provide for regulation of traffic patterns. This would tend to eliminate some of the guessing on the part of the bicyclist when he becomes part of a traffic pattern.

M outnumbered females in the study (311 and 212 respectively for MSP), and the boys preferred highrise, lightweight, and standard bicycles by decreasing order of preference. Females, lagging somewhat behind males in the switch to highrise bicycles, preferred standard, highrise, and lightweight by decreasing order of preference. For all Subjects (AS) the preference (same order as above) was highrise, standard and lightweight.

The average male in the study (MSP) was 10.3 years old, 56.4 inches tall and weighed 82.8 pounds. The average female was 9.6 years old, 55.1 inches tall and 74.7 pounds in weight. By bicycle type (Table 1A, p. 27) highrise and standard owners were nearly equivalent in age, height, and weight, while the lightweight owner was older, taller and heavier.

Bicycle condition was evaluated by age and a six point scale developed from assessment of structural and mechanical features at time of induction into the study. These factors were found to be statistically non-significant. This suggests that for the data collected in this study, bicycle age and condition (and also whether passengers were carried) produced no differences between subjects who had accidents and those who did not.

Equipment failure, reported through accidents recorded on the monthly report form, listed eight classes of failure. Thirty failures in all were recorded with the four classes of greatest failure being: wheels, brakes, chains, and handlebars listed in descending order of frequency. It was noted that each of the items of equipment have some element of external vulnerability and adjustment. It is considered that reduction of the more vulnerable and difficult-to-adjust components of the bicycle would be a very logical means of improving mechanical reliability of the mechanism. As a class mechanical failures are relatively infrequent, but they demonstrate visible weaknesses which, presumably, are remediable with application of adequate engineering ingenuity.

Exposure was measured by two methods in this study. Respondents were asked how much they usually rode their bicycles in terms of hours per day and days per week. Mileage was estimated by use of a mechanical mileage counter (cyclometer) which was attached to the front wheel of the participating subjects bicycles (MSP). When the two measures were compared statistically, the agreement was found to be poor and the respondents estimate was excluded from further calculations.

Exposure, as estimated by mileage, was carefully interpreted from monthly report forms and organized by main study effects. Males traveled almost twice as far per year as females (an estimated 313.5 miles vs. 159.5 miles respectively). By bicycle type, lightweights accumulated the most mileage, followed closely by highrise with standard bicycles recording the lowest mileage figure (Table 1, p. 26).

Accident rates (estimated for 1,000 miles of exposure) were developed by bicycle type, age, and sex for all MSPAC. Rates of accident occurrence for the three types of bicycles (estimated from more than 60,000 miles reported) were not found to be statistically significant. Highrise bicycles demonstrated the lowest rate followed by lightweight and standard types. It might be well to remark that rates describe accidents for a given amount of use. If gross numbers of accidents are counted, highrise bicycles would record the greatest amount. This would be due to the larger number of highrise bicycles in use and the greater mileages they accumulate. When these accidents are corrected for exposure, the differences suggested by examination of gross numbers alone tend to disappear with equivalence of rates being the rule.

Males generally show lower accident rates than females when compared by bicycle type (Table No. 5). Only for the standard bicycle does the female experience fewer accidents per 1,000 miles of use. By age the younger rider (5-9 years) is most frequently involved in accidents followed by the 10-14 group. None of these comparisons were found to be statistically significant.

In view of the age effect, the factor of disaccomodation might be given some attention. Other studies (Vilardo and Anderson, 1969, and the Ontario Dept. of Transportation, 1970) cited the factor of mismatched riders and bicycles. These studies suggest that if the first bicycle is too large for the youngster, elevated accident experience may ensue.

It was found that accidents happen most in daylight hours (from 3 p.m. to 7 p.m.), in clear weather, in a neighborhood situation. There seemed to be no clear dominance of any day of the week. May and June appear for these data to be the most productive months for accidents.

Riders should have more effective instruction prior to operating a bicycle unattended. Females, it would appear, require advanced (or perhaps more detailed) instruction earlier than males. Males, it would seem, require more intensive instruction in the 10-14 year interval with traffic situations reviewed most closely. It was suggested that instruction on motor vehicle regulations might assist the bicyclist in coordinating his movement with the flow of motor vehicle traffic.

Another approach was introduced through examination of riding experience and accident occurrence. It was found that the less-than-one-year and the one-to-two-year experience groups sustain accidents at greater than expected values by a statistically significant margin. Examination of these data suggest the most dangerous period is from zero to two years of experience. The 3-4 year experience group is the "Safest" while the greater than 4 year experience group shows intermediate accident involvement. Bicycle safety program planners might well apply this finding in the definition of groups for instructional purposes.

APPENDIX I

Covering Letter to Parents
Telephone Interview
Study Situation Map, Raleigh, N. C.
Bicycle Ownership Questionnaire
Bicycle Description Report Form
Monthly Mileage Report Form
Cyclometer Adjustment Letters
Subject Data Report Form
Medical Form
Accident Report Form

THE UNIVERSITY OF NORTH CAROLINA
HIGHWAY SAFETY RESEARCH CENTER
CHAPEL HILL 27514

Dear Parents:

The University of North Carolina Highway Safety Research Center is conducting a study of the way bicycles are used in the Raleigh area. National statistics show that bicycle accidents and injuries are increasing yearly. We hope the information gathered on how bicycles are used will help suggest ways to prevent bicycle accidents, particularly among children. Our only means of collecting this information is through the cooperation of interested Raleigh citizens.

To provide some of the necessary facts, we have developed a bicycle ownership and usage questionnaire. We hope that you will fill out the enclosed questionnaire and return it in the self-addressed, postage-paid envelope as soon as possible. If there are no bicycles in your household, please fill out the first question of Part I (your name, address and occupation) and return it to provide important general information.

Later we would like any or all of your children (under 18), who are willing, to participate in the second phase of this study. Participation would only take a short amount of time and require your children to cooperate in the following ways:

1) Meet one time at a specified place near your home (such as the school playground) on a weekend or after school, to have a cyclometer (mileage meter) installed free on each child's bicycle.

2) Once a month after the cyclometer is installed, each child will receive a self-addressed, postage-paid form (the monthly mileage report). On this form he will simply write in the mileage showing on his cyclometer and then mail the form to the Safety Center. For every month that the mileage report form is returned, each child will receive a quarter (unless you object to your children receiving this money).

Please be assured any information you give us will be considered confidential and will be used only for the purpose of this study. Once again, we urge you to fill out and return the enclosed questionnaire as soon as possible -- even if there are no bicycles in the household and your children cannot participate in the second phase of mileage reporting. We are looking forward to your cooperation in helping to provide this much needed information.

Sincerely,

B J Campbell

B. J. Campbell, Ph. D.
Director, Highway Safety Research Center

PROCEDURE FOR TELEPHONE INTERVIEWS

1. Identify yourself as a staff member of the Highway Safety Research Center of the University of North Carolina.

2. Briefly explain the purpose of the call (i.e., something like the following will be sufficient: "The Safety Center is currently conducting a study of bicycle safety in the Raleigh area. We are investigating bicycle accidents to provide information which may help to reduce the number of such accidents in the future.")

3. If the child is one of our randomly selected subjects, proceed as follows: (If not, skip to step 5) "As you know, your child ( ) has been sending reports to us for several months now. In his/her (name of month) report, he/she indicated that he/she had an accident. I trust that he/she is OK now. For the purposes of our study, we need a little more information about the accident. Let me assure you that any information you give will be held in strict confidence and used only for the purpose of gaining as much information as possible about the nature of bicycle accidents so that bicycling can be made safer. I would appreciate it if you could tell me all you know about the accident or let me talk to (name of child) if he/she knows more about it. (NOTE: If child is young or not available, it would be better to talk to parents.)

4. At this point the person will probably begin telling about the accident. Some people will give enough information so that you will need to ask only a few additional questions and others will require you to ask almost every question on the form. (NOTE: In asking the questions, be sure to ask in such a way that you do not influence the subject's answer.)

5. For reports we have received from hospitals proceed as follows: "According to the records from the hospital emergency room, your child (child's name) had an accident on (date of accident). If possible, we would like to have some additional information about the accident. This information will be used to give us an accurate picture of the bicycle population in Raleigh, and enable us to suggest ways to make bicycle construction and bicycle riding safer. Any information will be kept strictly confidential. Could you tell me all you know about the accident or let me talk to (child's name) if he knows more about the accident?" (Complete form as subject talks asking specific questions where they fail to supply needed information.)

HINTS AND SPECIFIC INSTRUCTIONS:

Be polite and courteous.

Do not give the impression that you are in a hurry to complete the interview. Ask open ended questions that do not give an indication of a specific answer. For example, do not ask, "Was the weather clear that day?" Instead ask "What was the weather?" There are three questions which do not appear on the form which MUST BE ANSWERED:

1. "Is there any particular part of the design and construction of the bicycle which may have (a) inflicted the injury, (b) increased the severity of the injury or (c) increased the likelihood of the occurrence of the accident?" If so please note.

2. "Where is the bicycle stored (question 64)?"

1=outside	3=porch
2=carport (garage)	4=other shelter

3. "Does the bike have any type of auxiliary reflectorization, i.e., reflectorized paint, strips, etc.? If so, where is it located?"

65=front
66=rear
67=left side
68=right side for 65-68 1=yes 0=no
blank

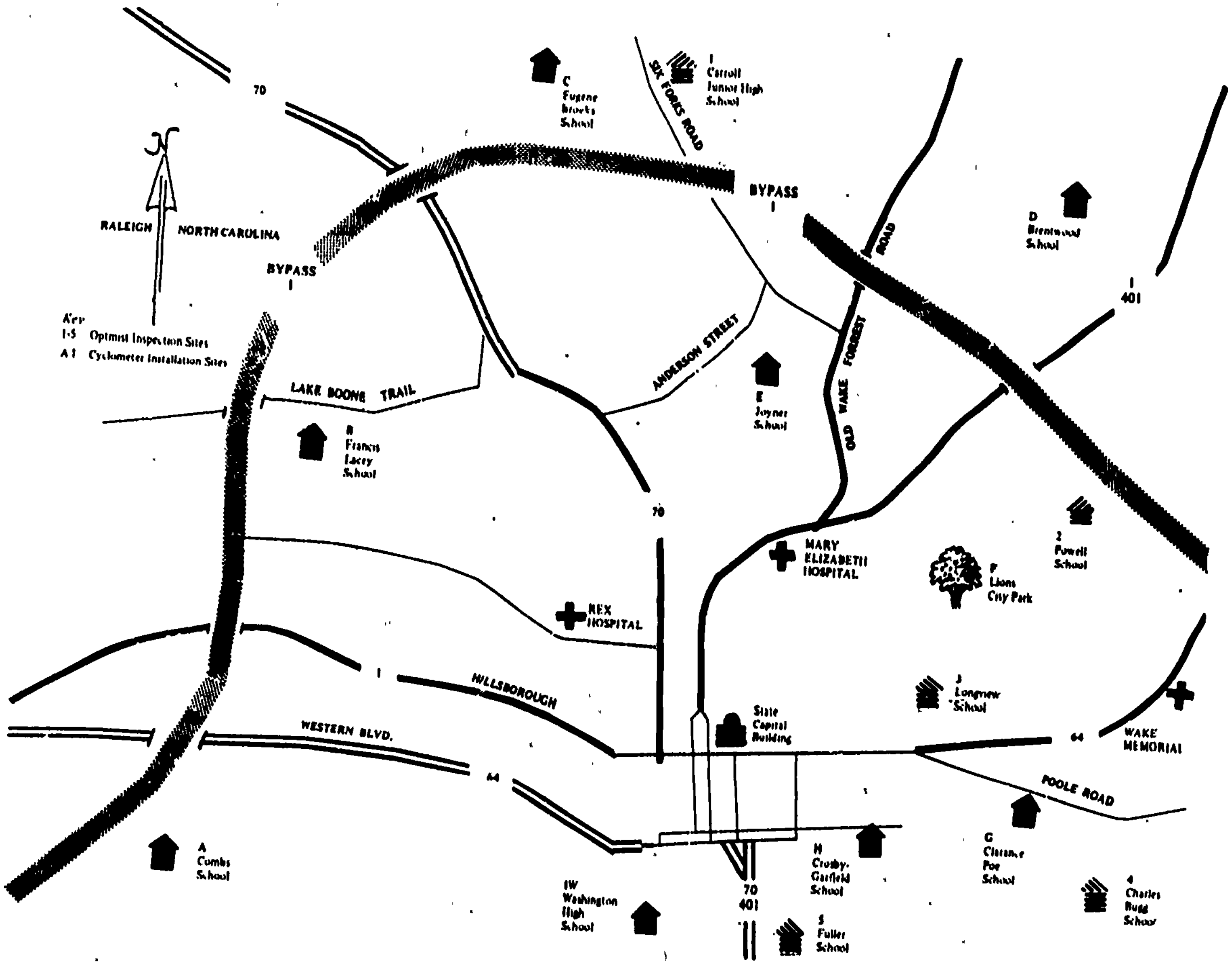
For details of accident briefly summarize in 2 or 3 sentences what happened, how it occurred, and why it occurred. Fill in the diagram appropriately; for example, T intersection, driveway, etc. Note any unusual circumstances, i.e., physical characteristics of location (hill, curve). Could child have been trying to avoid something? Was he riding alone or in a group of friends? Could he have been distracted by them or was he careless? ....or any others you can think of (unusual stress?).

In question 46, find out if child was treated at home or by a physician. In case of a fatality or serious injury, do not call before checking with one of us here at the Center.

Remember, for accident reports we receive from hospitals fill out the Subject Data Report in addition to the Accident Report Form which is filled out for all subjects.

If subject does not know specific answer to a question, try to get his best estimate. Use 9's for any missing information.

In occupation of parents we are not interested in where he works, but in only one of the nine categories (professional, clerical, etc.).


RALEIGH NORTH CAROLINA
Key
1-5 Optimist Inspection Sites
A-I Cyclometer Installation Sites
70
BYPASS 1
C Eugene Brooks School
1 Carroll Junior High School
SIX FORKS ROAD
D Brentwood School
401
LAKE BOONE TRAIL
B Francis Lacey School
ANDERSON STREET
E Joyner School
OLD WAKE FORREST ROAD
70
MARY ELIZABETH HOSPITAL
2 Powell School
F Lions City Park
REX HOSPITAL
HILLSBOROUGH
WESTERN BLVD.
64
State Capital Building
3 Longview School
WAKE MEMORIAL
POOLE ROAD
A Combs School
IW Washington High School
70 401
H Crosby-Garfield School
5 Fuller School
G Clarence Poe School
4 Charles Bugg School

NOTICE TO PARENTS AND GUARDIANS

If more than one questionnaire form is received please complete only one. Only one questionnaire form is required per household.

There are five copies of Part II in each questionnaire form. Please complete one copy of Part II for each bicycle in the household and discard the remainder.

Please enclose in the return envelope:

1) One Part I
2) One copy of Part II for each bicycle

Thank you for your cooperation.

Highway Safety Research Center

Bicycle Ownership Questionnaire

Part I. (To be filled out by head of household).

1. Name ______________________________________
   first   last

   Address ______________________________ ____________
   Number and Street   Zip Code

   Occupation ____________________ Telephone number ______________

2. Are there any bicycle riders living in the household? Yes [] No []

   If yes please fill out the following question for each rider.

3.

Name of Rider (first and last)	Sex	Age	School and Grade (if applicable)	Does he have his own bike?
____________	[] M [] F	___	____________	[] yes [] no
____________	[] M [] F	___	____________	[] yes [] no
____________	[] M [] F	___	____________	[] yes [] no
____________	[] M [] F	___	____________	[] yes [] no
____________	[] M [] F	___	____________	[] yes [] no

4. About how many bicycle accidents occurred during the year of 1969 in which the rider was injured and/or the bicycle damaged (for all bicycle riders in the household combined)?

   [] None [] 1 [] 2 [] 3 [] 4 [] 5 or more

5. About how many of the above accidents required medical treatment by a nurse or doctor?

   [] None [] 1 [] 2 [] 3 [] 4 [] 5 or more

6. My children are willing and have my permission to participate in the second phase of this study.

____
signature of parent or guardian

Part II.

We would like to have more detailed information on each of the bicycles in the household. Please complete this section for each bicycle and its owner as listed under Question 3, Part I.

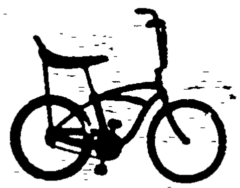
1. Name of owner ____
first last

2. Make of bicycle (on the label above the front fork) ____________________

3. Wheel size (printed on the side of the tire) (check one).
[] less than 20 in. [] 20 in. [] 24 in. [] 26 in. [] 27 in. [] don't know

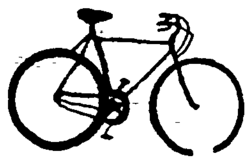
4. Type of bicycle (Circle the bicycle most like that being describe)

Highrise



or

Lightweight



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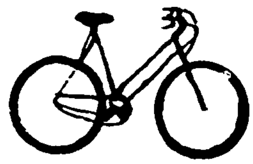
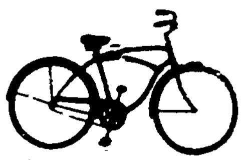


Standard



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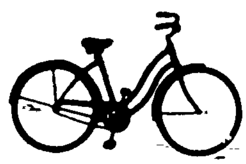


5. Type of handlebars

Highrise

Standard

Racer

6. How long has the owner been riding a bicycle (check one).
[] less than a year [] 1–2 years [] 2–4 years [] more than 4 years

7. Age of the bicycle (check one)
[] less than a year old [] 1–4 years [] 5–9years [] more than 9 years

8. Condition of the bicycle (check one)
[] Excellent [] Very Good [] Good [] Fair [] Poor

9. About how many days a week is the bicycle used? ______________

10. About how many hours each day? ______________

11. What is the bicycle used for (check as many as apply)?
[] Pleasure [] A means of transportation [] Exercise/Conditioning

12. How often does the bicycle owner carry a passenger (check one)?
[] Never [] Seldom [] Often [] Always

13. Type of Equipment (check one box for each item).

None	Good	Broken	
[]	[]	[]	Rear view mirror
[]	[]	[]	front light
[]	[]	[]	tail light
[]	[]	[]	Reflectors
[]	[]	[]	Reflectorized strips
[]	[]	[]	Basket(s)
[]	[]	[]	Horn or Bell
[]	[]	[]	Gear shift
[]	[]	[]	Hand brake(s)
[]	[]	[]	Foot brake
[]	[]	[]	Training wheels
[]	[]	[]	Blocks on pedals
[]	[]	[]	Other: Describe ______________________________

Highway Safety Research Center
Bicycle Study
Bicycle Description Report

Part II.

Please fill out this Report when the cyclometer is installed on the subjects bicycle.

1. Name of owner____
first last

1a. Height____________________ Weight ____________________

2. Make of bicycle (on the label above the front fork) ____________________

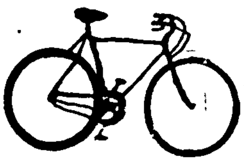
3. Wheel size (printed on the side of the tire) (check one).
[] less than 20 in. [] 20 in. [] 24 in. [] 26 in. [] 27 in. [] don't know

4. Type of bicycle (Circle the drawing of the bicycle most like that being describe)

Highrise

or

Lightweight



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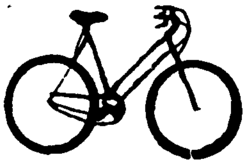
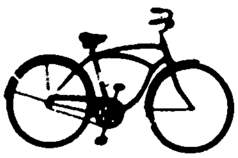


Standard



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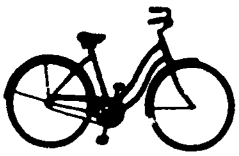


5. Type of handlebars (circle one)

Highrise

Standard

Racer

6. How long has the owner been riding a bicycle (check one).
[ ] less than a year [ ] 1–2 years [ ] 3–4 years [ ] more than 4 years

7. Age of the bicycle (check one)
[] less than a year old [] 1–4 years [] 5–9years [] more than 9 years

continued on other side

8. Condition of the bicycle (check one)
[] Excellent [] Very Good [] Good [] Fair [] Poor

9. About how many days a week is the bicycle used? ______________

10. About how many hours each day? ______________

11. What is the bicycle used for (check as many as apply)?
[] Pleasure [] A means of transportation [] Exercise/Conditioning

12. How often does the bicycle owner carry a passenger (check one)?
[] Never [] Seldom [] Often [] Always

13. Type of Equipment (check one box for each item).

None	Good	Broken	
[]	[]	[]	Rear view mirror
[]	[]	[]	Front light
[]	[]	[]	Tail light
[]	[]	[]	Reflectors
[]	[]	[]	Reflectorized strips
[]	[]	[]	Basket(s)
[]	[]	[]	Horn or bell
[]	[]	[]	Gear shift
[]	[]	[]	Hand brake(s)
[]	[]	[]	Foot brake
[]	[]	[]	Training wheels
[]	[]	[]	Blocks on pedals
[]	[]	[]	Other: Describe ______________

Date: ____________

Highway Safety Research Center
Bicycle Study
Monthly Milage Report

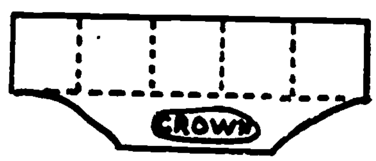
This is your monthly report form with your quarter enclosed in the small envelope. Please write in the mileage now showing on the cyclometer and the other information requested. After filling in the form, follow the directions below to make the form into its own stamped self-addressed envelope.

1) Fold the top section down
2) Fold the bottom section over the top
3) Look to make sure the Highway Safety Research Center's address is on the outside of the envelope you have just made
4) Seal the envelope by moistening the glue at the bottom
5) Mail it as soon as possible

Thank you for your continued cooperation.

SECTION I

How many miles are there on the cyclometer now?



(Write in all the numbers as they appear on the cyclometer.)

Is the cyclometer still working? [ ] yes [ ] no. If no, about when did it stop working? ________ ________ ________
Month Day Year

Have you had an accident on a bicycle in the past month? [ ] yes [ ] no.
If yes, please fill out section II below. If no, you are finished.

SECTION II

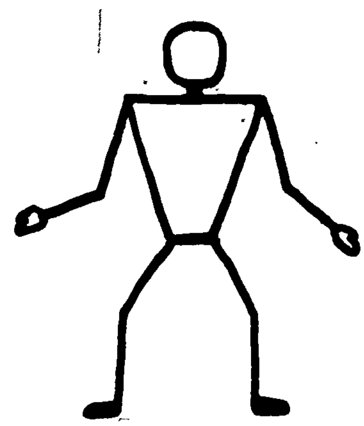
Date of the accident: ________ ________ ________
Month Day Year

Day of the week: ________________ Hour of the day: ______ : ______ am [ ] pm [ ]

Degree of injury:
[ ] None
[ ] Mild (first aid only)
[ ] Moderate (treated and released)
[ ] Severe (held for treatment)

Type of injury: (check as many as apply)
[ ] Bruises
[ ] Abrasions
[ ] Cuts
[ ] Sprains
[ ] Broken bones
[ ] Other

Area of body injured: (check as many as apply)
[ ] Head
[ ] Arms and/or hands
  [ ] Elbows
  [ ] Other
[ ] Legs and/or feet
  [ ] Knees
  [ ] Other
[ ] Body
  [ ] Groin
  [ ] Buttocks
  [ ] Other



Please show the part(s) of the body injured on the figure above by x-ing (X) in the part(s) injured.

INFORMATION FOR THE INSTALLATION OF CYCLOMETERS

Everyone who participates in the mileage collection phase of the study will have a cyclometer (mileage recording meter) installed free of charge on their bicycle. These cyclometers will be installed on Saturday, May 9 from 9 a.m. to 12 noon by members of the Raleigh Optimist Clubs who will be conducting their annual bicycle safety inspection program in association with the study. Enclosed are yellow identification tags to be attached to the handlebars of your bicycle before coming to the installation center. This is to identify the bicycle and rider as participants in the Highway Safety Research Center Bicycle Study and that a cyclometer should be mounted.

To permit you to chose the safest and most convient installation center in relation to your home, the schools being used as installation centers are listed below. Please indicate the center your children will most likely use by circling that location on each list printed below. After circling the chosen location, tear off the bottom list and include it with the completed questionnaire in the self-addressed envelope enclosed.

J. Y. Joyner	1221 Brookside Drive
A. B. Combs	1600 Lorimer Road
E. C. Brooks	Northbrook Drive
Brentwood	Ingram Drive
Francis Lacy	Ridge Road
Crosby-Garfield	E. Lenoir Street
Clarence Poe	Peyton Street
Washington High	Fayetteville Street
Lions Park	Watkins and Dennis

Circle the center your children plan to go to, tear off, and include with completed questionnaire.

J. Y. Joyner	Frances Lacy
A. B. Combs	Crosby-Garfield
E. C. Brooks	Clarence Poe
Brentwood	Washington High

Lions Park

THE UNIVERSITY OF NORTH CAROLINA
HIGHWAY SAFETY RESEARCH CENTER
CHAPEL HILL 27514

July 3, 1970

Dear Bicycle Study Member:

It has come to our attention that some cyclometers are not operating correctly due to what may be a change in alignment. After several weeks of use the position of the instrument may change enough to:

1) Prevent firm contact with the driving clip which is mounted on the spoke.

2) Cause contact with the hub of the cyclometer.

Either of these two conditions can be corrected with a simple adjustment.

First, test the adjustment of the axle cones (the nuts insi . the forks) to make sure there is not excessive play in the axle. Then, discard the old plastic washers and use the two metal washers enclosed with your quarter (placing one on each side of the mounting bracket) to reposition the cyclometer so that it is making proper contact with the driving clip. Draw the outside nut up tightly--the metal washers will take more pressure than the plastic type and should hold better.

We feel certain this will solve the existing problem and any that are likely to develop.

Thank you for your help and cooperation. We hope you have a happy and safe Summer.

Sincerely,

Edw. A. Pascarella

Edward A. Pascarella, Ph.D.
Staff Associate

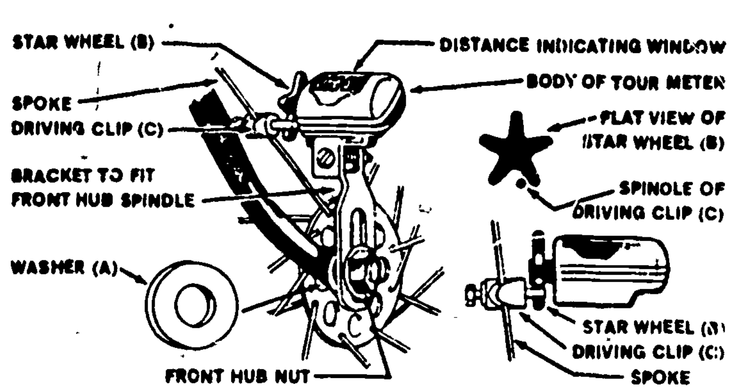
EAP:dml

INSTRUCTIONS:

Remove the nut from the right-hand side of the bicycle front wheel. Place washer (A) on axle. Mount the cyclometer in a vertical position on the axle making sure the STAR WHEEL (B) is on the inside facing the spokes. See illustration. Replace nut and only hand-tighten at this point. Loosen screw on Driving Clip (C) and fit to a spoke.

Adjust the position of the cyclometer and the DRIVING CLIP until it engages with the underside of the STAR WHEEL (B) as illustrated. The DRIVING CLIP must first engage the STAR WHEEL just above the end of the tooth.

Securely tighten the front axle nut. Check to see that the DRIVING CLIP and the STAR WHEEL engage correctly as the bicycle wheel is turned. Check and see that the DRIVING CLIP is firmly secured to the spoke.



Highway Safety Research Center
Bicycle Study
Subject Data Report

Information from: ______________________

Date of report: ______________________

INFORMATION ABOUT BICYCLIST

Name (1-16) ______________________

ID Number (17-20) ______________________

Sex (21) ____________ Age (22-23) ______

Parents Occupation (24) ______________________

Grade (25-26) ______________________

School (27-28) ______________________

Height (29-30) ______ ft. ______ in.

Weight (31-33) ____________ lbs.

How long has the owner been riding a bicycle (check one) (34)

[ ] 1. less than a year [ ] 2. 1–2 years
[ ] 3. 3–4 years [ ] 4. more than 4 years

INFORMATION ABOUT THE BICYCLE

Make of bicycle (on the label above the front fork) (35-37)

____

Wheel size (printed on the side of the tire) (check one) (38)

[ ] 1. less than 20 in. [ ] 2. 20 in. [ ] 3. 24 in.
[ ] 4. 26 in. [ ] 5. 27 in. [ ] 6. don't know

Type of bicycle

(39) [ ] 1. Highrise [ ] 2. Lightweight [ ] 3. Standard

(40) [ ] 1. Boys [ ] 2. Girls

(41) Type of Handle Bars
[ ] 1. Highrise [ ] 2. Standard [ ] 3. Racer

Type of equipment (check one box for each item).

None (1)	Good (2)	Broken (3)	
[ ]	[ ]	[ ]	Rear view mirror (42)
[ ]	[ ]	[ ]	Front light (43)
[ ]	[ ]	[ ]	Tail light (44)
[ ]	[ ]	[ ]	Reflectors (45)
[ ]	[ ]	[ ]	Reflectorized strips (46)
[ ]	[ ]	[ ]	Basket(s) (47)
[ ]	[ ]	[ ]	Horn or bell (48)
[ ]	[ ]	[ ]	Gear shift (49)
[ ]	[ ]	[ ]	Hand brake(s) (50)
[ ]	[ ]	[ ]	Foot brake (51)
[ ]	[ ]	[ ]	Training Wheels (52)
[ ]	[ ]	[ ]	Blocks on pedals (53)
[ ]	[ ]	[ ]	Other: Describe (54) ____________

Age of the bicycle (check one) (55)

[ ] 1. less than a year old [ ] 2. 1–4 years
[ ] 3. 5–9 years [ ] 4. more than 9 years

Condition of the bicycle (check one) (56)
[ ] 1. Excellent [ ] 2. Very good [ ] 3. Good
[ ] 4. Fair [ ] 5. Poor

About how many days a week is the bicycle used? (57)

____

How many hours per day? (58-59) ______________

What is the bicycle used for (check as many as apply)?

(60) [ ] Pleasure (61) A means of transportation
(62) [ ] Exercise/Conditioning

How often does the bicycle owner carry a passenger (check one)? (63)

[ ] 1. Never [ ] 2. Seldom [ ] 3. Often [ ] 4. Always

Form (79-80):01

Highway Safety Research Center
Bicycle Study
Medical Form

Date of report ____________________

Reporting Agency ____________________

INFORMATION ABOUT BICYCLIST

Name ____________________

Age __________ Sex __________

Address ____________________
STREET NUMBER AND NAME

____
CITY STATE ZIP

Telephone Number ____________________

DATE OF ACCIDENT

Month ______ Day ______ Year ______

Day of week
- [ ] Sunday
- [ ] Monday
- [ ] Tuesday
- [ ] Wednesday
- [ ] Thursday
- [ ] Friday
- [ ] Saturday

Hour of day ______
(use 24 hour system to nearest hour)

INJURY INFORMATION

Treatment administered:

____

____

____

____

Degree of injury (check one)
- [ ] None
- [ ] Mild (first aid only)
- [ ] Moderate (treated and released)
- [ ] Severe (held for treatment)
- [ ] Fatal

Type of injury (check as many as apply)
- [ ] Bruises
- [ ] Abrasions
- [ ] Cuts
- [ ] Sprains
- [ ] Broken bones
- [ ] Other

Area of body injured:
- [ ] Head
- [ ] Arms and/or hands
  - [ ] Elbows
  - [ ] Other
- [ ] Legs and/or feet
  - [ ] Knees
  - [ ] Other
- [ ] Body
  - [ ] Groin
  - [ ] Buttocks
  - [ ] Other

Comments: ____________________

____

____

____

____

____

____

Highway Safety Research Center
Bicycle Study
Accident Report Form

Name (1-16)________________________

ID Number (17-20)________________________

WHEN ACCIDENT HAPPENED:

Mileage on Cyclometer (21-25)__________

Month (26-27)______ Day (28-29) ______ Yr. (30-31) ______

Day of Week (32)

[ ] 1. Sunday [ ] 5. Thursday
[ ] 2. Monday [ ] 6. Friday
[ ] 3. Tuesday [ ] 7. Saturday
[ ] 4. Wednesday

Hour of Day (33-34) ______
(use 24 hour system to nearest hour)

Light Conditions (35)

[ ] 1. Dawn or dusk
[ ] 2. Daylight
[ ] 3. Darkness

Weather Conditions (36):

[ ] 1. Clear [ ] 4. Snowing
[ ] 2. Cloudy [ ] 5. Fog
[ ] 3. Raining [ ] 6. Sleet or hail

Construction of road (37):

[ ] 1. Concrete
[ ] 2. Smooth asphalt
[ ] 3. Coarse asphalt
[ ] 4. Gravel
[ ] 5. Dirt or Sand
[ ] 6. Other:________________

LOCALITY OF ACCIDENT:

Character of Location (38):

[ ] 1. Business
[ ] 2. Residential
[ ] 3. School
[ ] 4. Open country
[ ] 5. Industrial
[ ] 6. Other:________________

Location (39)

[ ] 1. Street intersection
[ ] 2. Street between intersection
[ ] 3. Alley
[ ] 4. Driveway
[ ] 5. Alley or driveway intersection with street
[ ] 6. Sidewalk
[ ] 7. Parking lot
[ ] 8. Playground
[ ] 9. Other.________________

If Accident occured in the street, was the bicyclist riding (40):

[ ] 1. Against traffic
[ ] 2. With traffic
[ ] 3. Middle of street

At time of accident, the bicyclist was (41):

[ ] 1. Going or coming from errand
[ ] 2. Going or coming from friends
[ ] 3. Going or coming from school
[ ] 4. Playing a game
[ ] 5. Using bicycle in work
[ ] 6. Just riding around
[ ] 7. Other:________________

Was there a passenger on the bicycle? (42):

[ ] 1. Yes [ ] 2. No

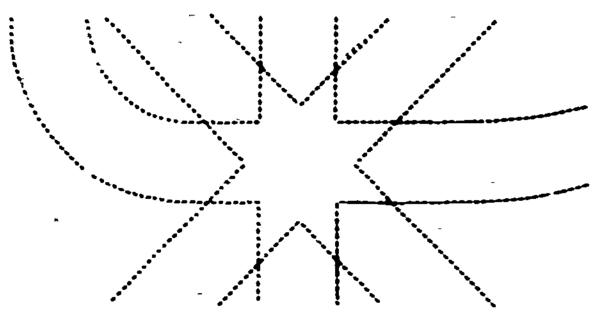
If Yes, where was he riding?________________

DESCRIPTION OF ACCIDENT

Type of accident (43):

[ ] 1. Bicycle hit car
[ ] 2. Car hit bicycle
[ ] 3. Bicycle collided with another bicycle
[ ] 4. Bicycle hit fixed object
[ ] 5. Fall
[ ] 6. Other:________________

DETAILS OF ACCIDENT



____

____

____

____

____

____

Was there a defective part on the bicycle? (44):

[ ] 1. Yes

[ ] 2. No

If Yes, (45):

[ ] 1. Brakes failed

[ ] 2. Handle bars fell off

[ ] 3. Wheel fell off

[ ] 4. Seat fell off

[ ] 5. Frame broke

[ ] 6. Other: ____________________

INJURY TO BICYCLIST

Degree of injury (46):

[ ] 1. None

[ ] 2. Mild (only first aid required)

[ ] 3. Moderage (patient treated and released)

[ ] 4. Severe (patient held for treatment)

[ ] 5. Fatal

Area of body injured:

[ ] Head (47)

[ ] Arms and/or hands (48)

If checked, [ ] Elbow (49)

[ ] Other (50)

[ ] Legs and/or feet (51)

If checked, [ ] Knee (52)

[ ] Other (53)

[ ] Body Trunk (54)

If checked, [ ] Groin (55)

[ ] Buttocks (56)

[ ] Other (57)

TYPE OF INJURY (check more than one if applicable):

[ ] Bruises (58)

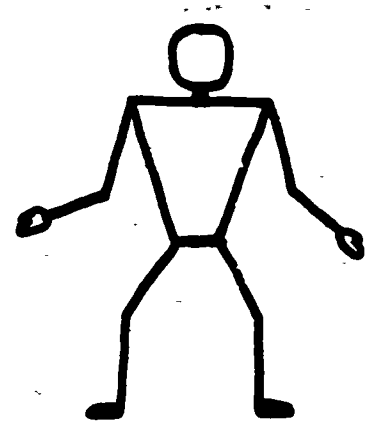
[ ] Abrasions (59)

[ ] Cuts (60)

[ ] Sprains (61)

[ ] Broken bones (62)

[ ] Other: (63) ____________________



Please show the part(s) of the body injured on the figure above by x–ing (X) in the part(s) injured.

Please write any comments you may have on the back of this sheet.

Form(79-80):02

APPENDIX II

Calculation of Estimated Bicycle Ownership Rates
Estimation of Yearly Mileage Traveled
Estimation of Accident Rates from Yearly Mileage
Estimation of Proportions by Degree of Injury
Test for Age Distribution (Main Study)
Test for Sex Distribution (All Subjects Vs. Main Study Participants)
Test for Occupation Proportions (All Subjects Vs. Main Study Participants)
Test for Bicycle Type (All Subjects Vs. Main Study Participants)
Test for Riding Experience by Class of Participation (All Subjects Vs. Main Study Accident Cases)
Test for Accident Rates by Type of Bicycle (Highrise Vs. Standard)

APPENDIX II

Calculation of Estimated Bicycle Ownership Rates

This inclusion elucidates the development of the proportion of bicycle owners in the pilot study population, the extrapolation into Raleigh and United States populations, and the estimate of total mileage/yr. by sex, and occurrence of accidents by severity level for the previously mentioned populations.

Determination of Bicycle Ownership Rate from Pilot Study Data with Projections into Raleigh and U. S. Populations

Questionnaires Sent to Pilot Study Subjects	Responses	Bicycle Owners	Non-Owners
301	180	132 (73.3%)*	48 (26.7%)

*Proportion of Bicycle Owners by sex Male 56.1% Female 43.9%

Children in Grades 2-9 in Raleigh Schools (estimated):

Public 16,184
Private 750
Total 16,934 x .733 = 12,413 Bicycles owned by children in grades 2-9. Assuming this to be 90% of all bicycles in Raleigh, the Total bicycle enumeration becomes: (12,413) (1.111) = 13,790 Bicycles (Males = 7,736, Females = 6,054) in Raleigh exclusive of those owned by College and University students and others attending schools at the post-secondary school level.

Estimation of Yearly Mileage Traveled

From our data on Main Study Participants the average rider, by sex, traveled: Males 313.5 miles/yr. (From 250.8 mi/6 mo. Study Period arbitrarily taken to represent 80% of Total Yearly Mileage); Females 159.5 miles/yr. (From 127.6 mi/6 mo.)

Applying these results to the above enumeration values provides an exposure value: (7736) (313.5) + (6054) (159.5) = 3,390,849 mi./yr. for Raleigh bicycling population as described earlier.

Estimation of Accident Rates from Yearly Mileage

Employing the estimated accident rate of 1.577 accidents per 1,000 mile exposure yields: (3390.849) (1.577) = 5347 accidents/yr. for Raleigh bicycling population. This number (5,347) includes all accidents, both injury-producing and those producing no injury. Injuries are classified by the following breakdown:

No Injury	= No treatment of any nature required
Mild Injury	= First aid only
Moderate Injury	= Treated and Released
Severe Injury	= Hospitalized

Estimation of Proportions by Degree of Injury

In the main study participant group 95 accidents occurred. Of these accidents, 15 resulted in no injury, 73 in mild injury, 7 in moderate injury. No severe injuries were recorded. From the hospital and police accidents, however, a substantial portion of the reported injuries was of the moderate and severe variety. To estimate the proportion of severe injuries occurring in the Raleigh bicycling population, the following convention was adopted. The ratio of moderate to severe injuries in the HPAC group (calculated to be 0.1) was applied to the MSPAC group, and the following percentages were developed by class of injury:

No Injury	= 15.7%
Mild Injury	= 76.3%
Moderate Injury	= 7.3%
Severe Injury	= 0.7%

If we apply each of these percentages to the estimated 5,347 accidents there will result the following assignment by frequency:

839	- No injury accidents
4,081	- Mild injury accidents
390	- Moderate injury accidents
37	- Severe injury accidents
Total 5,347	

These results could be further extrapolated to estimate number and types of accidents in the total United States bicycling population. This requires accepting the assumption that in the proportion of school aged children in Raleigh, bicycle ownership and average exposure observed and estimated are reasonably typical of the overall U. S. population. This, it would seem is an acceptable proposition, as there are 145 cities in the U. S. with populations between 75 and 150 thousand (1970 Commercial Atlas and Marketing Guide). While the Raleigh population, by the U.S. census 1970, was fixed at 117,000, the total population of the 145 cities equals 14,575,500, having a mean population estimated to be 100,521 with a standard deviation of 10,720.

If the above factors are applied to the population of the U. S. (1970 census), taken to be approximately 207,000,000, the total number of accidents occurring yearly could be derived by:

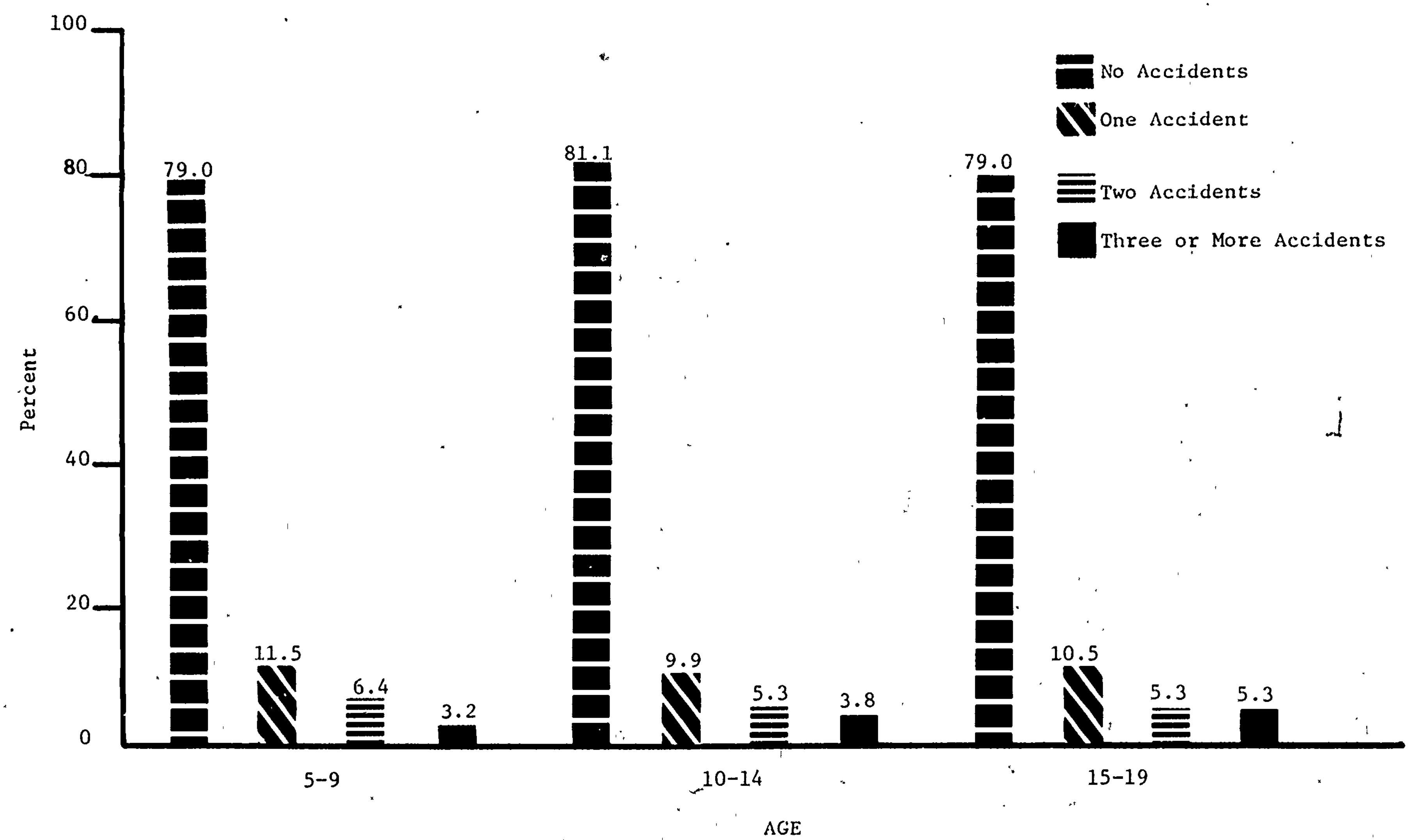
$$\frac{207 \times 10^6}{117 \times 10^3} \times 5347 = 9{,}460{,}077/\text{yr.}$$

Of this number (9,460,077) however, only 8% or 756,806 would be expected to result in injuries severe enough to require medical (professional) attention.

In response to a question (an inclusion in the questionnaire) that requested information on accidents experienced in 1969, the research staff was able to record the family accident experience for the year (Graph No. 1, this appendix, p.). It may be seen that for each of the three age groups, approximately 80% of the respondents reported no accidents in 1969. Thus, if these data are to be interpreted literally, one of five children experienced accidents in the calendar year of 1969. If this 20% accident rate is applied to the estimated 13,790 bicycles in Raleigh, the resulting value of 2,758 is approximately half of the estimate derived from the application of the exposure-based accident rates of this study. This would strongly suggest that approximately half of the accidents that occur during the course of a year fail to be recollected when the answer is dependent entirely upon recall over a period of months.

Graph 1 - Appendix 2

ACCIDENT FREQUENCY PERCENTAGES FOR 1969
AS REPORTED BY FAMILIES
FOR AGE GROUPS, N=440



Test for Age Distribution

Main Study Participants vs. All Subjects

Expected	27	79	112	104	68	27	7
Observed	27	86	140	119	45	10	2

$X^2 = 0 + .6203 + 7.0 + 2.1635 + 7.7794 + 10.7037 + 3.5714 = 31.84$ $p < .005$

Test for Sex of Owner

All Subjects vs. Main study Participants

$$Z = \frac{.595 - .561}{\frac{(.561)(.439)}{523}} = \frac{.034}{.022} = 1.55, \qquad p = .0606$$

Test for Occupation Proportions,

Main Study Participants vs. All Subjects

$$Z = \frac{.826 - .808}{\frac{(.808)(.192)}{431}} = \frac{.018}{.019} = .947$$

$p = .17$

Test for Bicycle Type by Class of Participation

All Subjects vs. Main study Participants

	Highrise	Lightweight	Standard
Observed	245	69	186
Expected	225	64	212

$X^2 = 1.778 + .391 + 3.698 = 5.86,$ $.05 < p < .10$

Test for Riding Experience by Class of Participation

All Subjects vs. Main Study Accident Cases plus

Hospital and Police Accident Cases

Study Group	2	3+	Total
AS[1]	296	876	1172
MSAC[2] & HPAC[3]	68	138	206
Total	364	1014	1378

[1]All Subjects [2]Main Study Accident Cases [3]Hospital and Police Accident Cases

$X^2 = 4.88$ $df=1, .02 < p < .05$

Test for Accident Rates by Type of Bicycle,

Highrise vs. Standard

Mann-Whitney U Test

Highrise		Standard		Highrise		Highrise		Highrise
.9356		1.0367		1.5997		1.8510		1.98
	Standard			Standard		Standard		
	2.25			2.40		2.44		

$U=13$; $P(u \geq 13) = .10$

APPENDIX III

Distribution of Accidents as a Function of Exposure

A Comparison of Two Measures of Exposure

DISTRIBUTION OF ACCIDENTS AS A FUNCTION OF EXPOSURE

It seems reasonable that bicycle accidents should occur within a fixed population of bicycle riders in a fairly random manner as a function of their overall exposure (aggregated mileage), that the number of accidents occurring in non-overlapping intervals of exposure should be independent, and that the expected number of accidents occurring in a given interval of exposure should be proportional to the length of the interval (amount of exposure). The above considerations indicate that a Poisson process might be a reasonable model for the number of accidents occurring as a function of exposure. Thus, if X(d) is the number of accidents occurring in d units of exposure (d miles), then to a good approximation the probability distribution of X(d) might be given by ·

$$P\,[X(d)=K] = \frac{e^{-\lambda d}(\lambda d)^k}{k!}$$

To test this hypothesis, the first reported mileages from each participant were collected into intervals of one thousand miles and the number of accidents occurring in each of these intervals was recorded. This resulted in twenty-two one thousand mile intervals with no accidents in three intervals, one accident in nine intervals, two accidents in six intervals, three accidents in three intervals, and six accidents in one interval. The following figure shows the sample histogram together with the fitted probability function..An estimate of the parameter X (accident rate) is given by the sample mean X=1.636 A X^2 goodness of fit test yields the result

$$X^2_{(3)} = 1.36, \qquad p>.90$$

Thus, the hypothesis cannot be rejected and the assumption of a Poisson process seems quite reasonable.

A COMPARISON OF TWO MEASURES OF EXPOSURE

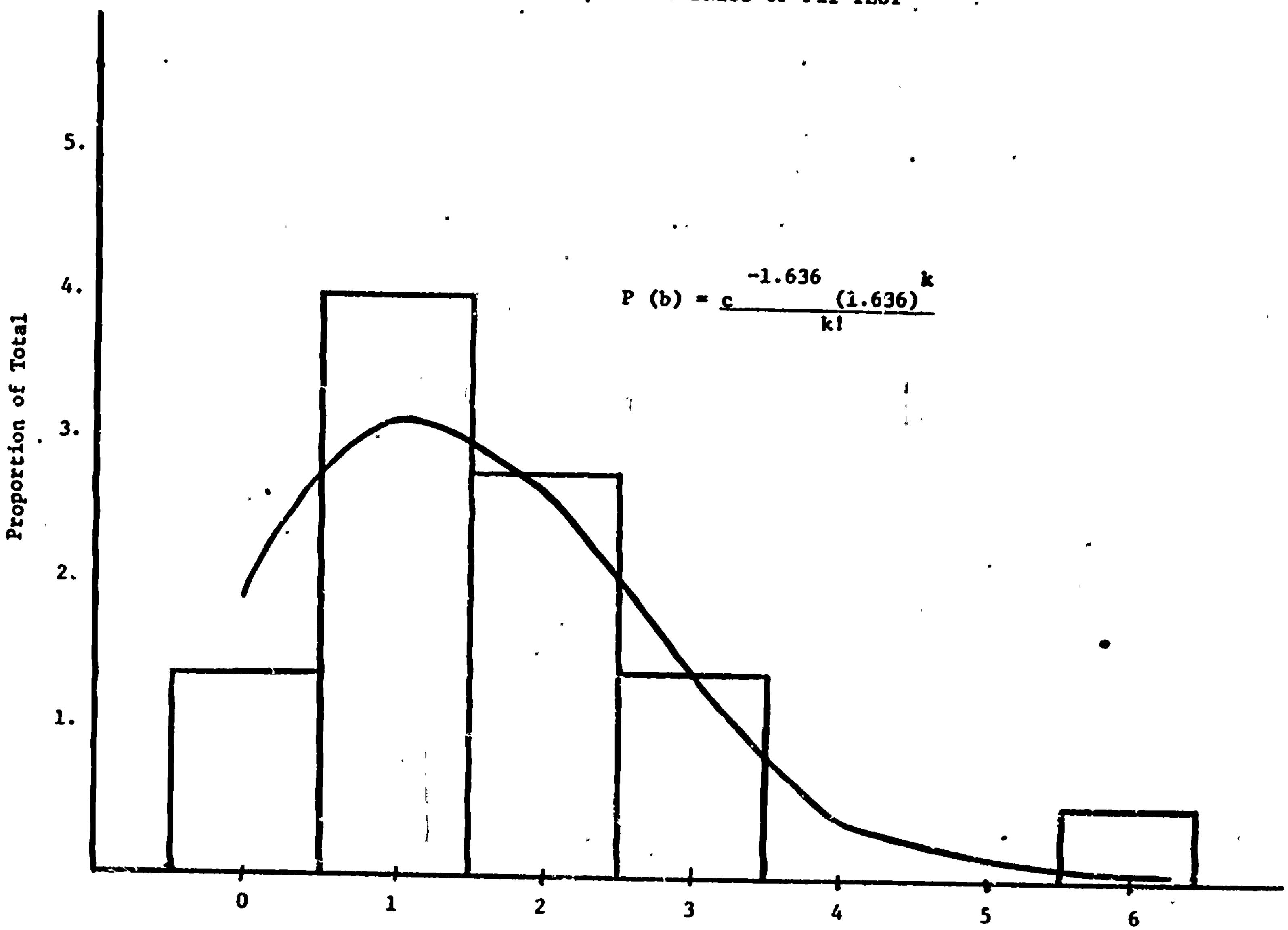
For each participant in the study, two measures of exposure were recorded. The first (estimated hours/week) was obtained from the respondents' answers to the questions concerning the number of days/week and the number of hours/day his bicycle was ridden. The second (avg. miles/month) was obtained from the monthly reported cyclometer readings submitted by the subject. While cyclometers were occasionally broken and mileage reports sometimes missed, average miles/month was, in general, considered to be a reasonably good measure of exposure. It is therefore of interest to make comparisons of the degree of agreement between these two measures. It should be noted that two subjects riding in quite different situations might ride the same length of time, but the number of miles each rides might be somewhat different. Nonetheless, it would seem that if the subjects were able to give good estimates of hours/week ridden, this measure should be highly correlated with miles/month.

Comparisons of the two exposure measures were made using contingency table analysis and regression analysis for all main study participants, participants without accidents, and participants with accidents. The X^2 derived from this test (95.53) is significant, even though a substantial contribution is derived from cells with low expected numbers. Thus, the hypothesis of no difference between the two measures must be rejected.

It would seem the general conclusion must be that estimates of exposure based upon estimated hours/week are of questionable reliability.

Graph 1 - Appendix 3

CHI-SQUARE GOODNESS OF FIT TEST



$$P\ (b) = \frac{c^{-1.636}\ (1.636)^{k}}{k!}$$

$X^2 = 1.3614 \quad p > .90$

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