Epidemiologic Principles Applicable to the Study and Prevention of Child Accidents

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Something of the complexity of the childhood accident prevention program is underscored here in this review of epidemiologic studies that have been undertaken. Suggested are some additional areas that might, and should, be subjected to the same sort of analysis.

It is now generally recognized that accidents constitute a major problem in public health. The loss of life and incapacity resulting from accidents is as great as, or greater than, that from any disease entity. Accidental injury is the leading cause of death for persons between one and 24 years of age, and is second for those between 25 and 44. Since these persons are in the younger age groups, an enormous cost to the productive resources of the country in terms of life-years is implied. Simply counting deaths is less meaningful than measurement of how many life-years have been lost prematurely.

In 1953, 15 per cent of all deaths resulting from accidents in the United States were among children under 15 years of age.[1] In the age group one to four, accidents kill twice as many as do measles, scarlet fever, whooping cough, diphtheria, dysentery, tuberculosis, and poliomyelitis combined.[30] The death rates for diseases in children have decreased markedly during the past twenty years, but accidental death rates have improved only slightly, if at all. The foregoing refers only to deaths. Injuries of varying degrees of severity result from accidents far more frequently than does death. Permanent disabilities in children have far-reaching consequences in individual adjustments and productivity which may exceed those following disabling accidents to older persons. Serious injuries are believed to outnumber deaths in children's accidents by as much as 100 to one [30] or even 150 to one.[1]

Epidemiologic Approach to the Study of Accidents

It is not generally appreciated that accidental injuries follow some of the same biological laws as do disease processes, and are also amenable to the epidemiologic approach. Accident distribution shows geographic variations, seasonal changes, and variations by age, by sex, and in respect to other parameters. Accidental injuries correspond in their behavior to the endemic pattern of infection that characterizes so many communicable diseases. They can be interpreted as resulting from the total forces involved in the competition between man and his environment.[17]

The causes of accidents are thus to be sought in the interactions among the host, the agent, and the environment. Such an analysis can provide the basis for highly specific programs of accident prevention since the epidemiologic concept of causation emphasizes the role of multiple causes in accidents, and constitutes a framework within which the findings of specialists from diverse fields can be integrated. The method

is also useful in revealing the relative importance and urgency of various aspects of the accident problem. For example, analyzing accidental deaths by age (host) and type (agent and environment) reveals that home accidents are crucial problems in the very young and the very old.[27] This approach can be used to analyze special problems of particular communities, specific kinds of accidents, or accidents of selected segments of the population.

Gordon[17] and Armstrong[3] were among the first in this country to propose the epidemiologic study of accidents, as did Cruikshank, in England.[9] Preventive measures resulting from these initial studies have now been developed for accidents in the home,[26, 27, 29] in industry,[22] among children,[4, 20] on the highway,[24] and in aviation.[25]

In applying epidemiologic principles to the study and prevention of children's accidents, the "population at risk" comprises a particular segment of the total population. Since most existing data lump together persons between 15 and 24 years of age, consideration will be mainly of those below 15 years.

To find the causes of children's accidents, it must first be known who had the accidents, when, where, and how they happened, as well as all the circumstances attending their occurrence. At present most of the information available refers to fatal accidents. Some data on nonfatal injuries have appeared, based on hospital and clinic records,[20] the experiences of insurance companies,[18, 30, 31] medical practitioners,[20, 28] and epidemiologic field studies.[18] Such data reveal that age is of importance, in that accidental injury and death rates are highest in the range 0–4 years, and decline somewhat through the 10–14 range. Also different kinds of accidents are more prevalent at certain ages than at others. The home is the environment where most accidents occur to children apart from those involving motor vehicles.

Accident Prevention Through Control of Host Factors

The basic question involved in attempting to reduce accidents in children through attention to characteristics of the host is, simply—what are the characteristics of children themselves which contribute to the accident?

One inference to be drawn from statistical analyses where age, sex, and activity have been related to types of agents and accidents, is that the level of development is a "host" characteristic of great importance. Understanding the role of host factors requires consideration of the behavior patterns which are characteristic at different ages. Wheatley has expressed this clearly in a discussion of the prevalence of poisoning accidents among children between one and three years of age. "The grasping functions and the drinking function are well developed. The child's most naturally developed method of learning about the physical properties of this world is to put the object or material in his mouth. This method of satisfying curiosity has full play during the run-about, exploring stage. This is the hand-to-mouth stage. This is the period of susceptibility to accidental poisoning." [32]

Temperamental factors and differences between the sexes also are variables which must be considered. In one series of fatal accidents among five- to 14-year-olds, more than a third were drownings, and nine-tenths of the vic-

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tims were boys. The drownings occurred during such activities as playing on thin ice, and on the banks of rivers, creeks, and canals. This may reflect more venturesome inclinations on the part of boys.[30] In contrast, girl's accidents have occurred chiefly indoors, involving falls, as on stairs, or touching hot objects.[26]

An implication of the foregoing is that the preventive measures adopted will show a shifting emphasis with age and sex. Initially, protecting children against accidents is the only possible procedure, but as the child acquires locomotion, rudimentary skills, and simple language, training and supervised experience become increasingly important. At later stages, protection becomes less possible, and perhaps less desirable. Education in safety then becomes the chief procedure for the control of host factors for the prevention of accidents.[4, 10]

The Question of the Unusually Susceptible Child

It has been proposed that some children are unusually susceptible to accidents, and that accidents can be reduced by identifying and treating such individuals. The psychiatric study of injured adults led to the concept that accidental injuries may resolve emotional tensions, particularly those resulting from unexpressed hostility and guilt,[6, 11] and this viewpoint has been extended to include the accidental injuries of children.

A few studies of children with repeated injuries have been made within this framework. Of 65 children with head injuries, about half had histories of two or more major injuries. The investigators concluded that the combination of a sadistic father and a passive, masochistic mother was significant, and that the children's accidents were aggressive reactions to frustration.[12] Tests were used in another study to compare accident-repeaters and accident-free boys in a junior high school. The accident-free were superior on tests of safety knowledge and of personal adjustment. The accident-repeaters were superior in gymnastic skill, and on strength tests, but gave more indication of emotion maladjustments. They also were observed to be more aggressive, to dominate social relationships by physical means, and to be poor losers and showoffs.[7]

A promising method for studying accident susceptibility in children has been developed at the University of Minnesota. Younger children were observed at play in a nursery school in an attempt to relate the frequency and kinds of injuries to their basic patterns of behavior. While children with the largest numbers of injuries showed few specific kinds of behavior in common, they all seemed to have difficulty adjusting to the group situation. The accident group was characterized by exceptional physical strength, dare-devil attitudes, emotional instability, impulsiveness and rudeness.[13, 14]

A pilot study of accident-repeater children at Columbia has raised questions concerning how prevalent "motivated" accidents may be, and whether conflicts about hostility and authority are as important in predisposing children to accidents as may be the case in adults. In this study, some accidents appeared to be a function of poor control when children overextended themselves in competing for status with other children, and some as a consequence of exposure to hazardous activities with which their older companions could cope safely. Only a limited number of accidents appeared to be serving the purpose of satisfying emotional needs, such as resolving tensions and gaining parental attention.[15, 21]

Further, well controlled studies are obviously needed. It is apparent that

the concept of the motivated accident, developed on a post-hoc basis for adults, may not be wholly applicable in the case of children, and cannot at present be used in the identification of individuals with undue susceptibility to accidents. Research has indicated that certain behavioral indexes may prove useful in identifying the accident repeater.[7, 21, 24] The individual treatment of children who have had repeated injuries may be effective in preventing subsequent accidents.

Role of Fatigue and Other Temporary Variables

There is little information available on the part played by a variety of transient "host" conditions in children's accidents. For instance, an analysis of the frequency of accidental injury by age and time of day suggests that fatigue may be a predisposing factor. Under age 15, the greatest frequency was toward the end of the day, at about 5 p.m.; beyond 15, the peak hour for accidents advanced regularly toward 10 or 11 p.m. in adults.[28] There is even less evidence on the importance of other temporary states. The studies on accident-repeater children, mentioned earlier, indicated that the likelihood of accidents increases when children are emotionally upset or under stress, as a function of the disruption of control. Additional studies are needed, not only in relation to fatigue and emotional disturbances, but to other temporary conditions as well. For instance, the role of diet and blood sugar levels, and the influence of commonly used medications in children's accidents have received little attention.

Consideration of the "Agent" in Children's Accidents

Preventing children's accidents through control of the "agent" requires a knowledge of the frequencies with which various agents produce accidental injury, and relating this information to circumstances of the host and environment. For example, among accidental poisonings of children aged one to five, kerosene was found to be the substance most frequently swallowed.[32] The "agents" involved in choking or strangulation accidents vary with age. Objects taken into the mouth are more important up to five; between five and 15, play with belts, ropes, etc., is the cause of choking or strangulation accidents.[2] Lead poisoning is frequently associated with play near houses with cracked and peeling paint.[32] From 40 to 60 per cent of the burn injuries seen in various clinics result from burning clothing.[31]

Preventing an interaction between the child and the agent is one method of preventing accidents. Securing the sides of cribs, locking medicine cabinets, storing poisonous silver polish on upper shelves, blocking off traffic on "play" streets are illustrations. As children become older, isolating them from hazardous agents is less possible. Training in the recognition and avoidance of hazardous situations becomes especially important, and safety education can be so disposed to result in safe practices without unduly restricting the natural proclivities and development of children.[10]

One approach is to prevent accidents by eliminating recognized hazards in the design stages of the equipment children are to use. Some examples of the results of advance analysis are lollipops with paper handles, blunt tipped scissors which cut only paper, unbreakable drinking cups, and bicycles with outrigger wheels. At the request of the American Academy of Pediatrics, the American Standards Association has established a committee to consider safety standards for: (a) the flammability of children's clothing; (b) the proper labeling of toxic paints and

coatings; (c) the design of harnesses and sleeping garments; and (d) the design and manufacture of furniture, carriages, and toys.[19]

While eliminating known hazards such as flammability in clothing, lead in paint, or top-heaviness in high chairs is important, the design of equipment should also be based on a knowledge of capabilities and limitations of the group who use the equipment.[22] Numerous instances may be cited where a difference in the size or design of children's furniture, toys, or clothing would have prevented accidents, or resulted in less severe injury. When human engineering data are incorporated in the original design of equipment, fewer accidents should result. Advance analysis of children's equipment can be carried out so that those features increasing the likelihood of accidents due to incompatability between the child and his equipment can be eliminated at the design-board stage.

Some of the necessary data for applying the principles of human engineering in the design of children's equipment are available, as, for instance, distributions of the heights and weights of children, and descriptions of growth and behavior at various ages.[16] Human sizing data can be obtained from anthropometric studies. Analyses of the activities of children can be carried out to furnish the designers of equipment with information on what children of different ages can and cannot do.

Control of the Environment to Prevent Children's Accidents

The information available on the role of the environment in the interactions producing children's accidents emphasizes the location of the accidents, and the frequency of particular agents or types of accidents in these settings, rather than such variables as temperature and humidity, the levels of illumination, or the physical properties of the surroundings.

Study of the home environment is particularly necessary to prevent children's accidents. Accidental death (excluding those from motor vehicle accidents) among children under five occurs chiefly in the home, and a substantial number occurs in the home throughout the first 15 years.[20] Falls are the leading cause of nonfatal injury up to age 14, most frequently as a result of tripping or slipping. Burns and scalds are second in importance in the early years, with cuts, lacerations, and abrasions becoming more frequent over five years of age.[5]

Table 1 illustrates how the environmental setting of accidents shifts with age. The data cover injuries requiring medical attention, or absence from school a half day or more.

When the environmental foci have been identified by such analyses, the role of particular features in the interaction between host, agent, and environment can be identified, and control measures devised. For example, of 1,000 serious burns in an English city, 70 per cent occurred in children, with girls outnumbering boys 3 to 1. In 53 per cent of these, the injury resulted from clothing being set afire by contact with unguarded heating appliances. Improved guards for heaters were a result of this analysis.[8] The much publicized "ice-box deaths" in this country provide another example. No reliable data are available on the frequency of these mishaps, the 29 deaths in 1953 were based upon newspaper accounts.[1] Environmental control, either through design for safety, e.g., doors that can be opened from inside, or enforced removal of doors from discarded refrigerators, is necessary to offset the appeal of these objects for children.

The part played by the environment in the causation of accidents must also be understood in terms of the physio-

Table 1—Injury Rates by Location and Grade Level *

	School Building	School Grounds	Going to or from School	Home	Other
All grades	4.0	4.7	0.8	3.3	3.8
Kindergarten through third grade	1.4	3.4	0.8	3.5	2.1
Fourth through sixth grades	2.4	5.4	1.0	3.6	3.9
Seventh through ninth grades	7.8	5.5	1.0	3.5	5.9
Senior high school	9.0	7.1	0.6	2.2	5.2

* Source: Accident Facts.[1]

logical and psychological effects on human performance, and in terms of the relationships between the capacities and limitations of children and the physical properties of their environment. For instance, some falls on stairways have been traced to the faulty design of carpeting. The pattern and coloring of the stair covering did not provide the contrast necessary for accurate perception of the position of the treads and risers, and the edges of the stairs could not be distinguished against their background. The concept of advance analysis for accident hazards which are known to result from environmental features should have an increasingly important place in accident prevention as more specific information is collected.

In addition to the physical environment, accidents are also influenced by social or sociological factors. For instance, the relative exposures to certain agents and certain physical features of the environment reflect the socioeconomic level of the family and the community. The ignorance, or knowledge, of parents regarding hazards and their behavior offered as models to the child also affect the possibilities of accidents.[5, 10] Parent-child relationships are important in the production of unusual susceptibility to accidents.[6, 11] Acceptance by other children in the group is important.[13, 14] Maintaining status among playmates can involve increased hazard.[15, 21]

Education and mental and emotional hygiene are preventive measures in this area. Physicians are in an especially advantageous position while treating parents or children to carry out indoctrination in safety. They can teach, not only specific preventive measures but also the principles of prevention based on knowledge of the host, interacting with factors of the agent and the environment.

Summary and Conclusions

The control of accidents falls within the province of preventive medicine and public health, because of the strictly medical aspects of accidental injuries and because of the important role played by human variables. Accidental injuries and deaths follow some of the same biological laws as do disease processes, and are amenable to epidemiologic methods of study and prevention. In most instances, there is multiple causation, and attempts at control should involve consideration of the agent, host, and environment. Although the host is of primary medical concern, the agent and the environment must also be considered in effective preventive measures. These principles apply

to the child population as well as to adults.

Attempts should be made first to set forth the basic physical, physiological, and psychological characteristics of children at various steps of development. When such facts are associated with the agent under given environmental conditions and at specific times and places, information can be obtained which should be helpful in understanding and preventing children's accidents. Factual information of this type can be discovered only by carefully controlled experimental studies, epidemiologic surveys, and statistical analysis. A dynamic and continuous safety program can produce positive results only by the constant application of the fundamental principles resulting from such studies. A successful program to prevent children's accidents requires the combined efforts of parents, the physician, the educator, the architect and engineer, and the public administrator.

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