overall injury problem to global health and the inadequate public health response. Each year, worldwide, an estimated 1.2 million people are killed and as many as 50 million are injured from road traffic crashes alone[1] and millions more die from violence and other injuries.[2] Seen in this light, the enormity of the overall injury problem composed of countless small scale but daily personal disasters and less frequent cataclysmic natural and man made disasters becomes clear. The challenge for us is to respond better and garner public attention on both types of loss: those that occur to a large number of people in a short period of time and those that are spread out over time but carry an even greater burden on all societies throughout the world.

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COMMENTARY

Use of ecological study designs for injury prevention

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This paper provides an overview of the ecological study design and its application to injury prevention. The advantages and disadvantages of ecological designs are described and the principle characteristics of the ecological design are highlighted. The paper concludes by highlighting the pivotal role that ecological studies can have in our understanding of the complex interaction between the environment and injury, and the application of this design in elucidating key population based strategies for injury prevention.

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The rationale for the use of ecological studies lies largely in their low cost, convenience, and the simplicity of analysis and presentation rather than any conceptual advantage.[1] Other reasons for using the study design have been due to the fact that measurement is often easier at the population or group level rather than at the individual level and a wider range of exposures can often be obtained.[2] The inherent qualities of the ecological design and its value have been demonstrated in descriptive and aetiological epidemiology, as well as in economics, social planning, and policy evaluation.[3 4]

More recently, there has been an increased interest in the ecological study design. This renewed interest is due, in part, to the recognition that environmental (both physical and social) determinants operating at a geographic level play an important part in the aetiology of disease and injury.[5] Acknowledgement of the complexities of the aetiology of disease and injury has resulted in disciplines, such as epidemiology, moving from a simple risk factor account of causation to one that takes account of the systems in which the individual operates. For example, the field of social epidemiology has evolved and focuses on macro levels and structural influences on the population while ecoepidemiology (as it is often referred to) integrates the multiple levels of a problem and focuses on all the relevant levels as a whole.[6]

The ecological study design has particular value in injury prevention where both environmental, population, and individual based solutions have been demonstrated to be effective in prevention. Importantly, the conceptual basis of the ecological design is consistent with models that underpin the public health approach to injury prevention and, as a result, researchers are increasingly making use of the ecological design.[7 8]

This paper provides an overview of the ecological design, illustrating the nature and extent of its current use and the opportunities for capitalising on its properties for future injury prevention research.

ECOLOGICAL DESIGN

The ecological design is characterised by its consideration of differences between groups rather than individuals.[9] The groups can be defined by place (multiple group design), by time (time trend design), or by a combination of the above. Mixed or multilevel designs can also be constructed where the units of comparison can include both group level and individual level data.[10] The ecological study uses data that generally already exists and is a quick and cost efficient approach compared with individual level studies. It is also particularly valuable when an individual level association is evident and an ecological level association is assessed to determine its public health impact. Concerns about the methodological weakness of the ecological study fundamentally arise from ecological bias—namely, that estimates of effect at the ecological level do not equate to estimates of biological effect obtained from individual level analysis.[2] Other criticisms of the design are that you cannot use it to obtain direct estimates of the rate of

injury in exposed and unexposed populations,[11] existing data sources are often flawed and it is difficult to control confounding.[9] Despite these issues, when measurement, analysis, and interpretation are all at the group level and the data sources are reliable, the problems with the ecological approach are minimised.[4]

Importantly, the ecological design can be used to examine structural or sociological effects on human behaviour and concomitant disease or injury.[12] The principal characteristic of the ecological design—namely, that it examines differences between groups—places it as a suitable design for injury prevention policy evaluation. As the ecological design assesses associations at the environmental level, it can also provide direct assessment of environmental effects on injury. Importantly, changes in the environment that follow from policy are amenable to measurement via the ecological research design as long as there is no attempt to draw inferences regarding individual level associations. This point is illustrated by an ecological study that evaluated the effects of a newly introduced law, graduated driver licensing, on the rate of road traffic fatalities and injury.[13 14]

More recently, multilevel studies have extended the ecological study design. By examining the affects of group level variables on individual level outcomes (which is the focus of multilevel analysis) we can now understand the complexities of interventions implemented at the group level and observed at the individual level. This application is well illustrated in a recent intervention study that was undertaken in schools to increase student bicycle helmet wearing.[15]

CURRENT USE OF THE ECOLOGICAL STUDY DESIGN

As highlighted in *The injury fact book*,[16] the use of the ecological design has been predominantly restricted to the descriptive presentation of rates by space, time, and population. Ecological correlational studies have also been widely used to evaluate road safety policies such as studies of the legislation related to low blood alcohol concentrations[17] and freeway speed limits.[18] The introduction of these laws at varying times and in different locations enabled mixed multigroup and time trend comparisons to be made. To a lesser extent, the ecological design has been used for aetiological purposes. However, a number of studies have utilised the ecological design with respect to the effect of neighbourhood characteristics[19] and socioeconomic status[20] on the risk of childhood injury.

The potential benefit of using existing population data sources for ecological research, particularly the linking of these data sources, has not been fully realised in Australia and elsewhere. For example, a recent study of diabetes in Western Australia utilised linked hospital morbidity data (admissions), Medical Benefit Scheme data (a record of doctor visits), Pharmaceutical Benefit Scheme data (pharmaceuticals), and mortality data in order to undertake health services research.[21] If one adds to the linked data source's geography codes which is needed for spatial analysis, the potential for linked population based data is enormous. For example, in injury prevention it will be possible to link census and environmental data to local morbidity and mortality data sources in order to better understand the effects of the environment on injury. Linked databases will enable researchers to consider the complex environmental interactions by considering causal pathways that integrate systems defined at multiple levels namely, suburbs, towns, cities, and regions.[22]

Despite the benefits of linked population data, there is an urgent need for accurate estimation of environmental exposure if valid associations between spatial or geographic risk factors and injury are to be drawn.[23] To date, obtaining reliable environmental exposure data has been a limitation of much of the ecological research in injury prevention. The limitation is highlighted in a recent ecological study of residential fire mortality and the prevalence of smoke alarms.[7] In this study the only available exposure data (the prevalence rates for smoke alarms) did not reflect the functional status of the alarms. In fact, the actual estimates were expected to vary as much as one third depending on the geographic area.[7] In other areas of epidemiology, particularly where exposure sampling or biological monitoring is undertaken, this issue is not such a problem. However, seldom is this level of accuracy in exposure data available in injury research applications.

To overcome these issues, researchers have used surrogate measures, such as the distance from a licensed premise, when studying the association between drinking at a licensed premise and subsequent alcohol related motor vehicle crash[8 24]; however, these estimates are often unreliable. The estimates can only be improved by knowledge of the time, activity, and behavioural patterns—in the absence of these, exposure assessment in injury prevention will be crude and will contribute little to our understanding of the interaction between the environment and injury.

In some jurisdictions, there is geographically coded injury mortality and morbidity data. However, to our knowledge, there are few repositories of environmental exposures that also have standardised geocoded data that could be used to investigate causal associations as well as evaluate population based injury prevention policies. Because the future gains in injury prevention can be gleaned from an understanding of the environment and its various complexities, there is a need to establish environmental exposure repositories that provide reliable estimates of exposure and that can be integrated into a comprehensive network of linked population based data.

THE FUTURE

The application of simple linear and logarithm regression techniques have been used to assess average estimates of exposure and potential confounders on injury rates.[7 25 26] Until now, these approaches have provided an efficient investigation of the exposure–injury relationship. However, with the increased complexity of available data sources, more sophisticated analytic approaches are required if ecological studies are going to contribute to our understanding of the exposure–injury relationship and its potential usefulness in evaluating policy.[27]

In order to investigate the complex exposure–injury relationship it will be necessary that ecological studies include exposure data from the individual (the child, youth, or adult) as well as from the areas they live (both social and physical environmental data).[22] These data need to be available at the level of the neighbourhood (suburb), town or city, the workplace, school, or sporting club. Also, in order to determine the effects of the duration of exposure along with the changes of exposure over time (whether traffic density, prevalence of isolation pool fencing, or gun ownership) ecological studies will need to be longitudinal. Longitudinal ecological studies will also be capable of determining the effect of moving from one neighbourhood to another in relation to injury outcomes; this is particularly important when observing the effects of moving from established neighbourhoods to those more ''liveable'' that have safety incorporated into the design. To date, this has not been considered.[22]

Ecological research that considers the multiple levels of the data will play a pivotal part in our future understanding of the complex interaction between the environment and injury. Unlike the future of other areas of public health where gene:environmental interactions will enhance the understanding of complex causal pathways, there are few areas in

injury prevention (risk taking and injury is one) where the gene:environment interaction will provide the focus for injury prevention initiatives. Instead, by unravelling the complex environmental interaction using the ecological design as one of the tools, we will be able to elucidate key strategies for injury prevention; strategies that are implemented at a population level. With an understanding of the complex environmental interaction in injury and with policies that target change in the environment we will achieve the now well established adage for prevention namely, to significantly lower the incidence of disease (or injury) one needs to shift the whole (population) curve of the incidence in a ''favourable direction''.[28]

CONCLUSION

The occurrence of injuries is largely determined by characteristics of the environment[16] and opportunities for injury prevention have most clearly been recognised after modifications to the physical, social, technological, political, economical, and organisational environments.[29] While host factors (for example, age, sex, behaviour) are acknowledged as components in the web of causation, injury prevention often takes the form of structural and population focused interventions rather than individually targeted efforts to change behaviour.[30] It is necessary to consider these complex environments and how they interact in relation to injury. Recent advances in ecological approaches, such as multilevel designs, provide the opportunity to explore these interactions.

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