THE UNIVERSITY OF CALGARY

AN EVALUATION OF THE INJURY SEVERITY SCORE IN A PEDIATRIC POPULATION

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF MEDICAL SCIENCE

CALGARY, ALBERTA

SEPTEMBER, 1986

ISBN Ø-315-32763-4

THE UNIVERSITY OF CALGARY

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "An Evaluation of the Injury Severity Score in a Pediatric Population," submitted by Beverly Francine White in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

Injuries constitute a major cause of death and hospitalization, particularly among children and youths. Injury research and the evaluation of emergency medical services and of medical care of trauma patients are important components in the fight against the occurrence of injury or trauma and the death and disability associated with this major health problem. Inherent in injury prevention and the appropriate assessment of emergency services and trauma care is the need for a valid method of categorizing injury severity as a means of quantifying the input (patient health status) into the health care system.

The Abbreviated Injury Scale is a method of rating severity of individual injuries which was developed by the American Medical Association for use in motor vehicle-related injury research. The Injury Severity Score (ISS) was then developed as a means of rating the overall severity of multiple injuries and is calculated from the Abbreviated Injury Scale. The purpose of this study was to validate the ISS on a pediatric population of blunt trauma victims and thereby determine its applicability in the research, evaluation and planning of pediatric trauma care as well as childhood injury research.

Through the use of logistic regression and multiple regression the ISS was found to be a significant predictor of mortality and hospital length of stay in pediatric motor vehicle crash victims. Probit analysis was used to examine the effect of age on the relationship between the ISS level and percent mortality. It was found that the pattern of mortality due to blunt trauma in children and youths most closely resembled the pattern of mortality found in the middle aged and elderly population.

The implications of the findings of the study for future research and for the use of the ISS in the pediatric trauma population are discussed.

ACKNOWLEDGEMENTS

Special thanks are due to Dr. J.H. Read, my supervisor, who inspired and encouraged me throughout the development and final stages of the research project. I would also like to thank the other members of my supervisory committee, Dr. A.W. Rademaker for assisting me in the statistical and analytical aspects of the project and Dr. G.D. Powell for contributing to the content of the project through his expertise in the area of Emergency Medicine. Thanks are also due to Dr. N. Grant for serving as external examiner.

I would like to acknowledge the invaluable assistance of Vladimir Panlilio (Injury Research Unit, University of Calgary) in tackling the complexities of the computer.

I would like to express my gratitude to Transport Canada for permitting the use of the Canadian Light Truck and Van Study data in the research project.

I also wish to thank Shane Chetner for typing and providing valuable assistance in reviewing and editing the thesis.

This research was supported in part by the National Health Research and Development Program, Health and Welfare Canada, through a National Health M.Sc. Fellowship.

DEDICATION

To my parents, Dorothy and Saul White,
who have fostered within me the desire
to strive for understanding, learning
and excellence in all my endeavors.

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Injuries: A Major Health Problem

Injuries represent an important health problem facing society today. Degenerative diseases have replaced infectious diseases as the major causes of death. However, injuries rank third as a cause of death in Canadians following diseases of the circulatory system and tumors. Injury is also one of the leading causes of hospitalization, following heart disease and stroke (Abelson, Paddon & Strohmenger, 1983).

Injuries tend to occur more frequently in the younger age groups, thereby having a significant effect on life expectancy and not just the number of lives lost. Abelson et al (1983) discuss the significance of premature death due to accidents and violence by examining the Potential Years of Life Lost (PYLL) between the ages of 1 and 70 years: ischaemic heart diseases are responsible for 25% of the deaths occurring between the ages of 1 and 70 years and 15% of the PYLL, while motor vehicle crashes are responsible for a similar percentage of PYLL despite being the cause of fewer deaths. Accidents and violence, which include motor vehicle crashes, account for almost 40% of PYLL. This highlights the fact that injuries, and particularly motor vehicle-related injuries, pose a significant health problem that is very prevalent amongst younger people, while ischaemic heart disease primarily affects the older population. Indeed, it has been recognized that injuries are the number one cause of death and an important cause of hospitalization in children and youths (Alberta Social Services and Community Health, 1982).

Evaluation of Trauma Care

Injury severity classification is an important component of the evaluation of emergency medical services and of medical care of trauma patients. In the past, evaluation studies have mainly employed resource and utilization measures in an attempt to assess the effectiveness and efficiency of different systems of care (Gibson, 1974). The following are examples of measures that are employed in this type of research: percentage of hospitals with an emergency department staffed at all times by a physician, percentage of hospitals with laboratory and x-ray facilities staffed at all times, percentage of ambulances equipped with a certain minimum of equipment, percentage of ambulance attendants with a certain level of training, number of ambulance runs to each hospital and number of hospital visits by patients for each hospital. These descriptive studies, unfortunately, do not provide a means of determining how well the system works.

Ideally, the study of patient outcome through the use of outcome measures such as patient survival, levels of disability and patient satisfaction provides a much more accurate evaluation of the needs of trauma patients and the quality of emergency medical services and trauma care available to these victims. This method of research, however, imposes some difficulties. In order that outcome studies be meaningful, it is essential to quantify the input into the emergency medical system, and this includes the quantification of the injury severity of the patients entering the system of care (Baker, Oppenheimer, Stephens, Lewis & Trunkey, 1980; Cayten & Evans, 1979; Headrick, Leonard & Goldman, 1978). Patient status or injury severity is as important in affecting the final outcome as is the actual type and quality of care. Cayten and Evans (1979) describe this phenomenon as a relationship between "input- process- outcome." This relationship, and particularly injury severity which has often been overlooked as an input measure, must be considered both when planning and evaluating emergency medical services and trauma care and when interpreting outcome studies.

Injury severity indices are therefore essential for the evaluation of different types of emergency medical services and trauma care, allocation of resources, triage and comparative studies of different medical facilities and systems of care. The ability to categorize groups of trauma victims according to overall injury severity, regardless of differences in the actual injuries sustained, enables a comparison of these patient groups. Consequently, a reliable and valid injury severity index is necessary for any research, planning or evaluation of care of the trauma patient.

Gibson (1981) defines indices of severity "as numerical ratings attached to selected patient characteristics which provide a reliable and valid means of assessing the probability of mortality or morbidity resulting from a traumatic insult to the body." Gibson suggests that indices must be evaluated according to their reliability, validity and data requirements (routinely collected data with ratings that are determined simply and objectively). Thirty scientists at the 1980 Woodstock Conference on Injury Severity Scoring identified similar ideal qualities of a severity index: "1)simple, easy to use; 2)feasible, data generally available; 3)reasonable, has face validity; 4)correlates with objective measures of outcome; 5)good inter-rater agreement; 6)makes it possible to factor out quality of care and 7)useful for patients with single or multiple injuries" (Trunkey, Siegel, Baker & Gennarelli, 1983). Over the past years many indices and methods have been devised in an attempt to categorize injury severity in trauma or injury victims (Champion, Sacco & Hunt, 1983).

The Abbreviated Injury Scale

The Abbreviated Injury Scale (AIS) is a method of categorizing injury severity which was developed by the American Medical Association and its Committee on Medical Aspects of Automotive Safety, a group consisting of physicians, researchers and engineers, and introduced in 1971 under the sponsorship of the Joint Committee on Injury Scaling (Committee on Medical Aspects of Automotive Safety, 1971). The AIS was designed specifically for use in motor vehicle-related injury research with the purpose of providing scientists with a system for accurately rating and comparing injuries sustained in motor vehicle crashes and as a means of standardizing the language used in the description of those injuries.

The initial 1971 version of the AIS was very rudimentary, including only 75 injuries, but it provided a framework for further development of the scale. The Joint Committee on Injury Scaling, consisting of members of the

American Medical Association, the American Association for Automotive Medicine and the Association of Automotive Engineers, revised the scale several times and published the AIS in the form of a manual in 1976 along with the AIS Dictionary which listed descriptions of more than 200 injuries. Further significant revisions to the scale during 1978-1979 resulted in the publication of a third version of the AIS, the AIS-80, in 1980 (American Association for Automotive Medicine, 1980). The AIS-80 contains more than 500 injury descriptions. The fourth version of the AIS, the AIS-85, was published during the spring of 1986.

The AIS is a numerical scale of injury severity. The criteria that were taken into consideration when developing the AIS were threat to life, permanent impairment, treatment period, incidence and energy dissipation (Committee on Medical Aspects of Automotive Safety, 1972). The term "abbreviated" refers to the allocation of a single AIS value to a specific injury description. The values were assigned by the group of experts involved in the development of the scale through subjective evaluation of the severity of individual injuries. The scale values range between 1 and 6 with the values signifying the following:

AIS	SEVERITY
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum injury virtually unsurvivable in AIS-80

The AIS is divided into the following body sections: head, neck, thorax, abdomen and pelvic contents, spine, extremities and bony pelvis, and external (integumentary injuries and burns). Within each body section, AIS values are assigned to specific injury descriptions of individual body parts. For example, within the THORAX body section an AIS value of 5 is assigned to a "laceration" of the body part AORTA, and a value of 6 is assigned to a "severance, total" of the AORTA. Within the EXTREMITIES body section an AIS value of 2 is assigned to "clavicle fracture" in the UPPER EXTREMITY body part. Injuries are coded through information obtained from discharge records, autopsy reports, in-patient charts, emergency room reports, police reports and patient interviews (Petrucelli, States & Hames, 1981).

Petrucelli et al (1981) clearly outline several issues concerning the AIS and what it does not represent. Firstly, the AIS rates injury severity and not outcome. Injuries are assigned their specific AIS values regardless of whether or not the patient died. The value of AIS-6 (maximum injury virtually unsurvivable in AIS-80) can only be assigned to those injuries which have specifically been denoted as AIS-6 in the AIS dictionary and not to any injury from which the patient dies. Other outcomes which are not of themselves coded include blindness, deafness, pain, swelling, hemorrhage, asphyxia, obstruction, spontaneous abortion and drowning. Secondly, the AIS is not a linear progression but merely a means of categorizing injuries which are within approximately the same range of severity. The difference in severity between the AIS value 2 and AIS 3 may not be the same as the difference between AIS 4 and AIS 5. As well, within each value there is a range of severities so that even though two injuries may both have the same value, for example AIS 2, one could be more serious than the other although both would be considered moderate injuries. Thirdly, the AIS codes individual injuries and does not evaluate the overall severity of multiple injuries.

The AIS is used extensively in motor vehicle-related injury research around the world including Canada, the United States, Sweden, England, Germany, Japan, France and Australia. The validity and reliability of the AIS have been studied extensively. Gennarelli (1980) utilized the AIS-80 in a study of head injured patients and found a highly significant correlation ($p<0.0001$) between the AIS score and the outcome based on the Glasgow Outcome Scale. He also found that the AIS-80 correlated highly with the

Glasgow Coma Score, length of hospital stay, days in intensive care and hospital charges in victims of head injury. Hirsch and Eppinger (1984) have attempted to convert the injury data of the AIS into an impairment scale describing short- and long-term effects of injuries. Several authors have implied that although the AIS was initally meant to take into consideration the five criteria mentioned earlier, it is in fact based mainly on the "threat to life" criterion (Huang & Marsh, 1978; Reidelbach & Zeidler, 1983). Eastham (1984) examined the construct validity of the AIS as a measure of four injury severity dimensions: mortality risk, acute care length of stay, overall recovery period and permanent disability/activity limitation. This was done by means of subjective assessments by a sample of physicians involved in trauma care. The results indicated that the AIS correlated well with the mortality-risk and acute care length of stay but was not a good measure of overall recovery period or permanent disability/activity limitation.

MacKenzie, Garthe and Gibson (1978) evaluated the 1976 version of the AIS in terms of comparability of coding from different sources of information, inter-rater reliability and intra-rater reliability. They concluded that the in-patient chart was a more accurate and reliable source of information for AIS coding than was the emergency department record. The degree of inter-rater reliability amongst three coders was substantial with a kappa statistic of 0.68. Reliability was higher for vehicular than for nonvehicular injuries. Intra-rater reliability ranged from moderate to substantial with kappa statistics of 0.69, 0.60 and 0.55.

Reliability testing of the AIS-80 was recently completed (MacKenzie, Shapiro, Eastham & Whitney, 1981; MacKenzie, Shapiro & Eastham, 1985). Fifteen coders with various qualifications (physicians, nurses, emergency medical technicians and nonclinical technicians) rated the severity of individual injuries in 375 trauma patients. Inter-rater agreement calculated for those injuries recorded by each coder and compared to the modal AIS value was substantial with kappa statistics ranging between 0.66 and 0.81. Inter-rater agreement was only fair to moderate when calculated for those injuries recorded by each coder and compared to a reference group of injuries consisting of all injuries coded by eight or more of the raters. This difference represents the varying capabilities of the coders to identify and extract injuries from the charts. Agreement for blunt injuries (vehicular and nonvehicular) was significantly higher than that for nonvehicular penetrating injuries. Intra-rater agreement tended to be substantial with kappa statistics greater than 0.60 for all raters. Once again, intra-rater agreement was significantly lower for nonvehicular penetrating injuries.

The Injury Severity Score

The Abbreviated Injury Scale measures the severity of a single injury only. The need to adjust for multiple injuries when classifying injury severity resulted in the introduction of the Injury Severity Score (ISS) by Baker, O'Neill, Haddon and Long in 1974. The ISS is a numerical method of rating the overall severity of injury in persons who have suffered either multiple injuries or a single injury. It was developed from injury data generated from a study group in Baltimore, Maryland of 2,128 motor vehicle crash victims, both occupants and nonoccupants. Baker et al (1974) observed a nonlinear relationship between AIS values as reflected by mortality (percentage died) i.e. 1)mortality increased disproportionately with the AIS value of the most severe injury and 2)mortality did not correlate well with the sum of AIS values of the most severe injuries (mortality amongst patients with two injuries of AIS 4 and 3 was not equivalent to that amongst patients with values of 5 and 2). The investigation of a possible quadratic relationship by squaring the AIS values for the most severe injury in each body region and then adding them resulted in the development of the ISS.

The ISS is calculated by first assigning AIS values to all injuries and then categorizing the injuries by the following ISS body regions: 1)head or neck, 2)face, 3)chest, 4)abdominal or pelvic contents, 5)extremities or pelvic girdle and 6)external. The ISS is then defined as the sum of squares of the highest AIS values in each of the three most severely injured body regions:

$$ISS = \sum (AIS\text{-}80)^2 \text{ in the 3 most severely injured body regions.}$$

The AIS value of 0 is given to a body region which is not injured. Possible ISS values range from 0-75. The highest ISS possible for a patient with only one body region injured is 25 or 5^2. The maximum ISS obtainable is 75 and anyone with any injury coded as AIS-6 is automatically assigned an ISS of 75.

Baker et al (1974) observed that, in comparison with the AIS, using the ISS increased the correlation between severity and mortality and explained 49% of the variance in mortality. Only 25% of the variance in mortality was explained when only the AIS value of the most severe injury was used. They suggested that the quadratic relationship between AIS values and mortality due to multiple injuries "may reflect fundamental aspects of response to injury that should be the subject of research on changes over time in basic biochemical and physiological variables."

Baker et al (1974) also observed that the relationship between mortality and ISS (the percentage of patients that died at a given ISS value) varied with age. Patients were categorized into three age groups: 0-49 years, 50-69 years and 70 years and over. For a given ISS, mortality was greater in the 50-69 age group than the 0-49 age group and was even more markedly increased in the 70 and over age group. In particular, the increased mortality in older patients was most evident among the less severely injured. These results demonstrate that age must be adjusted for or at least considered when classifying injury severity. It is also likely that age has an effect on morbidity and disability, although it may not be the same as its effect on mortality.

Since the ISS's introduction in 1974, it has been validated in other study populations (Bull, 1975; Bull, 1978; MacKenzie, Shapiro, Moody & Smith, 1984; Semmlow & Cone, 1976) and is being used in the evaluation of quality of trauma care and emergency medical services (Baker & O'Neill, 1976). It has also been emphasized that the ISS is useful in the analysis of outcome of patient groups but its use as a prognostic tool for individual patients is questionable (Baker & O'Neill, 1976; Bull, 1975).

Semmlow and Cone (1976) studied the Illinois Trauma Registry data and confirmed Baker et al's (1974) observations on the relationship between mortality and ISS in both vehicular and nonvehicular trauma victims. They also demonstrated a linear relationship between ISS and average length of stay in hospital and between ISS and percent of patients receiving major surgery. Bull (1975; 1978) analysed retrospective data on 1,333 patients in Birmingham, England with motor vehicle-related injuries. Using probit analysis he also determined that the relationship between mortality and ISS was distinctly similar to that found by Baker et al (1974).

Bull also demonstrated the phenomenon of greater mortality with increasing age using the age groups of 15-44 years, 45-64 years and 65+ years (there were insufficient cases in the 0-14 age group for probit analysis). He used the ISS to calculate an L.D.50, or injury severity which is fatal for 50% of the patients sustaining that level of severity (L.D.=lethal dose), for each of the age groups. The L.D.50's for the three groups from youngest to oldest were 39.7, 29.4 and 20.2. These were significantly different at the 0.05 level. In a later publication, Bull (1978) states that data for the 1975 study were inadequate for the younger ages but suggests that mortality for children follows similar patterns to that of young adults. This is a fairly bold assumption to make given all the evidence demonstrating the significant influence of age in the association between ISS and mortality. Once again, the results suggest that ISS scores that are age-specific or adjusted for age might be necessary (Gibson, 1981).

Other results obtained in Bull's 1975 study showed that 1)there was a positive relationship between ISS and treatment time in hospital of survivors and 2)the mean ISS was significantly different for different levels of residual disability. However, both treatment time and level of disability displayed a wide scatter for a given ISS. MacKenzie et al (1984) also showed that the ISS of trauma patients without significant brain injury was not a good predictor of functional disability at the time of discharge. The evidence from studies which have been done to date indicate that the ISS, a strong predictor of mortality and, to a lesser extent, hospital length of stay, may have less predictive abilities for other outcome measures of trauma.

The reliability of the ISS is, in part, dependent upon the reliability of the AIS since the ISS is calculated using AIS values. However, MacKenzie, Shapiro and Eastham (1985) correctly point out that the differences in even one AIS point result in large differences in the calculated ISS. What can be considered minor disagreements in coding individual injuries may, in contrast, result in very major differences in scoring overall injury severity.

MacKenzie et al (1985) measured the inter-rater reliability of the ISS amongst the different types of coders by calculating the intraclass correlation coefficient (ICC). The ICC was fairly high among the physicians (ICC=0.83) and nurses (ICC=0.80), indicating high agreement. Inter-rater reliability was lower for the emergency medical technicians (ICC=0.76) and the nonclinical technicians (ICC=0.66). The results imply that physicians and nurses tend to be more reliable coders than emergency medical technicians and nonclinical technicians.

The ISS has also been used in epidemiological studies of trauma mortality (Baker et al, 1980; Goris & Draaisma, 1982) and in the evaluation of emergency medical services and trauma care (Dove, Stahl & DelGuercio, 1980; Goris, 1983; Moylan, Detmer, Rose & Schulz, 1976). Dove et al (1980) reviewed 108 deaths in New York due to trauma and utilized the ISS as a means of comparing them to a control group of survivors in order to, among other things, identify errors in patient management. Goris (1983) also used the ISS to compare the response of three groups of blunt trauma patients to three different methods of management. Moylan et al (1976), commenting on the existence of management and diagnostic errors in the care of trauma patients as well as disparity in standards of care between different hospitals, observed that on retrospective analysis of charts of trauma victims the ISS was effective at identifying those patients who were at greater risk for inappropriate medical care. As the ISS increased there was a greater percentage of cases that received poor quality of care.

It is evident from a review of the literature that the ISS has been evaluated as a predictor of mortality and morbidity in many different studies. However, these studies have all dealt mainly with adult populations. A scarcity of information exists regarding the ISS's applicability in a pediatric population. Mayer, Matlak, Johnson and Walker (1980; 1981) utilized a Modified Injury Severity Scale (MISS) to categorize overall injury severity in pediatric patients with multiple trauma. For the MISS the Glasgow Coma Scale scores were converted to AIS values and used as the basis for an additional ISS body region, the "neurologic body region." The other body regions included in the MISS were face and neck, chest, abdomen and pelvic contents, and extremities and pelvic girdle. As the name implies, the ISS was not evaluated in its original form. As well, the study was done prior to the 1980 revision of the AIS and all the coding changes that that entailed.

There remains a need to evaluate the ISS (based on the AIS-80) as a predictor of mortality and morbidity in a pediatric population of trauma victims. It has been clearly demonstrated that age has an intervening influence on the relationship between the ISS and mortality, and possibly other outcome measures as well. This requires further investigation in our younger population. This research is necessary if researchers and clinicians are to have available to them a valid injury severity scale to use as a tool in the research, evaluation, and planning of pediatric trauma care as well as childhood injury research.

Objectives of the Study

The objective of the study is to evaluate the Injury Severity Score as a method of categorizing the severity of injuries sustained by children and youths who are victims of blunt trauma. Firstly, the ISS's ability to predict mortality and length of stay in hospital of survivors, the two outcome measures of this research, has been studied. Factors other than the ISS which have also been considered include age, sex, height, weight, body size, represented by the quetelet index (QUET) and defined as $QUET=100(weight/height^2)$, and whether the victim was a motor vehicle occupant or nonoccupant at the time of the injury event. Mathematical models which best explain the variance in the length of stay in hospital and best predict mortality have been determined and the ISS's applicability in a pediatric population has been ascertained. Secondly, the relationship between the ISS and mortality in a pediatric population has been examined and compared to that of other age groups, as reported in other studies, in order to determine the effect of age on this relationship.

Dependent and Independent Variables

The two dependent or outcome variables of this study are mortality and length of stay in hospital of survivors. It should be noted that these two variables are not necessarily the only or most appropriate outcome measures which can be studied. In particular, two points should be considered:

1)Mortality is an important outcome measure in the evaluation of medical services but, as Semmlow and Cone (1976) point out, it is certainly not always adequate. Indeed, resultant morbidity and levels of disability are often much more accurate descriptors of a patient's health status either at the time of hospital discharge or at the point of exit from the health care system (eg. upon termination of rehabilitation services or out-patient visits).

2)Length of stay in hospital of survivors does not solely reflect the severity of injury but may also be a function of several other factors including availability of beds, administrative policies, and variations in practice between hospitals and even physicians (Gibson, 1981).

However, given the time constraints of the study and, in particular, the limitations of the type of data available for analysis, mortality and hospital length of stay of survivors are the only outcome variables that have been included in this research. This is not, however, to be considered a major limitation of the study since these two variables are identical to those included in most other studies of the ISS and have therefore allowed a comparision of study results. In addition, these variables have not been studied previously, in relation to the ISS, in a strictly pediatric population and hence represent an important first step in determining the applicability of the ISS in children and youths.

The independent or predictor variables are of four types:

1)Demographic variables which include age, sex, status at the time of the injury event (i.e., motor vehicle occupant or nonoccupant) and geographic location.

2)Anthropometric variables which include height, weight and quetelet index, which is a measure of body size.

3)Severity variable: the Injury Severity Score.

4)Injury descriptor variables which include presence of: a)head/neck injury, b)chest injury, c)abdominal/pelvic injury and d)extremity injury. These injury descriptor variables have been determined according to the ISS body regions injured.

Hypotheses

The following set of hypotheses has been developed based on a critical review of the literature pertaining to the Injury Severity Score:

1.The Injury Severity Score alone will be a significant predictor of mortality in child and youth victims of blunt trauma.

2.The best predictor of mortality will be a set of variables which includes, in addition to the Injury Severity Score, one or more of the following variables: a)age, b)sex, c)height, d)weight, e)quetelet index and/or f)vehicle occupancy.

3.The Injury Severity Score alone will be a significant predictor of length of stay in hospital in child and youth survivors of blunt trauma.

4.The best predictor of length of stay in hospital of survivors will be a set of variables which includes, in addition to the Injury Severity Score, one or more of the following variables: a)age, b)sex, c)height, d)weight, e)quetelet index and/or f)vehicle occupancy.

5.The pattern of mortality in children and youths at different levels of injury severity will be similar to the pattern of mortality in young adults which has been reported in scientific journals, and will least resemble the patterns of mortality found in the middle aged and elderly population.

Chapter Two

THE RESEARCH METHODS

Source of Data

The data for this study were obtained from Transport Canada's Light Truck and Van (LTV) Study. The Accident Investigation Section of the Road Safety and Motor Vehicle Regulation Directorate undertook the LTV Study to determine the adequacy of safety standards in relation to light trucks and vans as well as to aid in the development of a program for in-depth investigations of motor vehicle crashes.

A Multidisciplinary Accident Investigation Program, established by the Road Safety Branch, set up investigation teams which were contracted to ten universities across Canada. The areas not represented by the teams are Prince Edward Island, Newfoundland and the Northwest Territories. The ten teams investigated 2,158 crashes during the years 1981 to 1983 inclusive as well as 14 crashes in 1980. These crashes involved more than 5,000 occupants and nonoccupants including fatalities, injuries and property damage only. Comprehensive data regarding many aspects of the crash (the crash itself, injuries sustained, vehicle information, driver information, restraints, vision limitation, etc.) were collected. The AIS-80 coding of the injuries was done by members of the investigation teams with medical, paramedical and/or science backgrounds or training.

The LTV Study was done in cooperation with law enforcement agencies. Crashes included in the study had to involve at least one vehicle classified as a light truck or van, be categorized according to police as a "reportable accident," involve over $400 in property damage and be selected by a statistical sampling plan (Accident Investigation Section, 1985).

Sample

Children and youths involved in crashes included in the Canadian Light Truck and Van Study were studied in this research. Occupants and nonoccupants (pedestrians, cyclists) fourteen years of age and under who sustained injuries to at least one ISS body region were included. Uninjured subjects were excluded from the study.

It was calculated that a sample size of 115 was necessary in order to a)explain at least 13% of the variance in mortality or length of stay of survivors, b)have a level of significance of 0.05, c)have a power of 0.80 and d)have up to 9 variables in the model. This was determined from Cohen's (1977) sample size tables for multiple regression/correlation analysis. An R^2 of 0.13 was chosen to represent a "medium effect size" as described by Cohen.

Data Collection

The comprehensive information collected for the Canadian Light Truck and Van Study is stored on a computer tape which was available for access. The data required specifically for this study were transferred from the master tape and recorded in a BMDP File on the mainframe computer at the University of Calgary. The data extracted from the master tape included age, sex, height, weight, which university team investigated the crash, vehicle occupant or nonoccupant, injury data including ISS body region and AIS severity, treatment-mortality and length of hospital stay of survivors if hospitalized. The Injury Severity Score was calculated for each subject using the injury data. The injury data were also categorized into the presence/absence of major head/neck injury, chest injury, abdominal/pelvic injury and extremity injury, where a major injury had an AIS value of 3 or greater. Body size or QUET was calculated for those subjects with sufficient information on height and weight.

Analysis of Data

The data for the study were analysed using BMDP Statistical Software and the second edition of SPSSx.

Descriptive statistics of the variables were obtained including the minimum, maximum, mean, median, standard deviation and frequencies where appropriate. Chi-square analysis was done to obtain measures of association and determine significant relationships between the variables.

Logistic regression is one of the statistical methods most suitable for analysing data when the dependent variable is dichotomous and the independent variables are either categorical or continuous. For this reason, logistic regression was used to estimate the effect or relative importance of the independent variables ISS, age, sex, height, weight, QUET and occupancy (singly, in combinations and all together) on the dichotomous outcome variable mortality.

Multiple regression analysis was employed to study the magnitude, direction and strength of the relationship between the continuous outcome or dependent variable length of stay in hospital of survivors and the independent variables. The combination of independent variables which best explained a significant amount of the variation in length of stay was determined. The relationship between length of stay and ISS alone was analysed and then looked at adjusting for the other independent variables age, sex, height, weight, QUET and occupancy.

One-way analysis of variance was performed to test the equality of the group mean ISS scores in the following five groups: 1)victims who died, 2)survivors whose length of stay was greater than 30 days, 3)survivors whose length of stay was 8-30 days, 4)survivors whose length of stay was less than 8 days and 5)survivors who were not admitted to the hospital. It was determined which populations had significantly different mean ISS scores through the use of T statistics.

Probit analysis was undertaken in order to analyse the relationship between mortality and ISS. The L.D.50 of children and youths, the injury severity at which 50% of the victims died, was calculated. This type of statistical analysis has enabled the results of this study to be compared with the results from other ISS studies which have used probit analysis as a method of analysing data.

Limitations of the Study

The results of the study are not automatically generalizable to all pediatric victims of blunt trauma. Motor vehicle crash victims are a subset of blunt trauma victims and further studies will be necessary to determine whether the results will be similar for other types of nonvehicular blunt trauma (falls, child abuse) as well as penetrating trauma (stab and gunshot wounds).

This study shares a common limitation with other studies of the Injury Severity Score, namely the reliability in the assignment of the AIS values to the individual injuries (Dove, Stahl & DelGuercio, 1980). Reliability studies have been done, but the assignment of AIS scores still remains vulnerable to a certain amount of subjective differences between recorders, dependent upon their experience and familiarity with the sources of information as well as the varying degrees of accuracy, clarity and completeness of injury descriptions found in the different sources of data available to them. The accuracy of the results of the study is dependent upon the quality of AIS coding as well as the quality of the other information obtained from the LTV Study databank.

Nevertheless, some observations can be made regarding the quality of the data utilized in this study. One would expect the quality of the injury coding in the LTV Study, in terms of reliability and accuracy, to be comparable to that found in MacKenzie et al's 1985 study on the reliability of the AIS-80, documented previously in the literature review. The various qualifications of the coders in both studies were similar. As well, there was a high level of expertise amongst the members of the Canadian crash investigation teams, many of the teams having been in existence 5 to 10 years prior to the commencement of the LTV Study. This would have had a positive effect on the quality of the data, including injury data, collected during the LTV Study.

Another important limitation of the study involves differences in emergency services and quality of medical care at the facilities found within and across the ten regions involved in the Canadian Light Truck and Van Study. Krischer (1979) explores this issue by questioning whether measures of severity must predict outcome if the patient goes untreated, receives optimal care or average care. He suggests that when a severity measure or index is being evaluated, it is necessary to include some model of medical care (although this is not a concern when actually using an index to control for caseload severity in a comparison of two or more health care systems).

Dove et al (1980) and Moylan et al (1976) are amongst the many researchers that have stressed the persistence of patient management errors and improper hospital care of trauma patients. As previously discussed in the literature review, Moylan et al demonstrated that a difference in acceptable care exists between different hospital settings (urban, rural, academic). They also found that higher Injury Severity Scores were useful for identifying patients at risk for inappropriate care. The question must be asked: What effect does this disparity in hospital care have on the final outcome of the patient, irrespective of the Injury Severity Score and, in relation to this study, what are the implications of this? Unfortunately, the effect of differences in emergency services and quality of medical care across and within the ten sampled regions cannot be accounted for in this study.

Overview

The following chapters present and explore the results of the study in an in-depth manner and test the stated hypotheses. Chapter Three describes the characteristics of the study sample and the relationships between the variables. Chapter Four examines the outcome measure mortality and its relationship with the independent variables through the use of logistic regression. Chapter Five examines the outcome measure length of stay in hospital of survivors and its relationship with the independent variables through the use of multiple regression analysis. In Chapter Six, the results of the one-way analysis of variance are reported. The results and implications of the probit analysis, which investigates the relationship between mortality and ISS, are presented in Chapter Seven. Chapter Eight provides a summary and discussion of the results and analyses the implications of the findings for future research.

Chapter Three

DATA DESCRIPTION

A total of 221 subjects in the Canadian Light Truck and Van Study met the criteria for inclusion into the study. Of these 221 subjects, 35 were excluded because of an inability to calculate an Injury Severity Score due to lack of sufficient injury data. The final sample therefore consisted of 186 children and youths involved in motor vehicle crashes across Canada.

The sample was comprised of 98 males (53%) and 88 females (47%). One hundred and forty-three victims (77%) were occupants of a motor vehicle at the time of the crash while 43 (23%) were nonoccupants, which included pedestrians and bicyclists. Table 3-1 describes the geographic distribution of the subjects according to the locations of the investigation teams and also provides the number of fatalities in each location.

Age, Height and Weight

The mean age of the sample was 8.3 years (standard dev.=4.3) with subjects ranging in age from one month to fourteen years. As shown in Table 3-2, a description of the age distribution of the sample, seventy five percent of the subjects were five years of age or older.

The mean height of the sample was 50.2 inches (standard dev.=11.6) with a range from 22 to 72 inches. The mean weight was 72.8 pounds (standard dev.=37.0) and ranged from 11 to 180 pounds. As one would expect, age was highly correlated with height (r^2=0.78) and weight r^2=0.65). Height and weight were also extremely highly correlated (r^2=0.83).

TABLE 3-1

Number of Cases and Fatalities Classified According to Geographic Location

Investigation Team Location	No.	Fatalities (%)
Nova Scotia Technical University	11	2 (18)
University of New Brunswick	31	1 (3)
Ecole Polytechnique, Montreal	18	0 (0)
McGill University	5	0 (0)
University of Toronto	6	1 (17)
University of Western Ontario	19	2 (10)
University of Manitoba	39	14 (36)
University of Saskatchewan	25	5 (20)
University of Calgary	14	3 (21)
University of British Columbia	18	3 (17)
Total	186	31 (17)

TABLE 3-2

Age Distribution

Age (years)	No.	(%)
<1	9	(5)
1-4	37	(20)
5-9	56	(30)
10-14	84	(45)
Total	186	(100)

Injury Severity Score

The Injury Severity Scores of the sample ranged from 1 to 75. The mean ISS was 10.8 (standard dev.=19.6), signifying that the majority of the subjects sustained relatively minor injuries. The median ISS was 2.0. From Table 3-3, one can see that over 75% of the subjects had an ISS of less than 10.

TABLE 3-3

Distribution of Injury Severity Scores

ISS	No.	(%)
1-9	144	(77)
10-24	11	(6)
25-34	10	(5)
35-50	7	(4)
51-75	14	(8)
Total	186	(100)

Mortality

Mortality in the study population was 17% with 31 deaths. The mean ISS ($\pm$ standard deviation) of the survivors was 3.4($\pm$5.5) while that of the fatalities was 47.6($\pm$22.9). The highest ISS of a survivor was 41 while the ISS of the fatalities ranged from 9 to 75. Table 3-4 demonstrates a significant association between ISS and mortality, when the ISS is divided into five categories of increasing severity, with the percentage of fatalities increasing in the higher ISS categories. Except for one death, mortality was absent in the ISS range of 1-9 but rose to 27% in the ISS range of 10-24. Mortality then increased rapidly to 70% in the 25-34 range. Beyond this range mortality increased steadily to 100% in the ISS range of 51-75. The association between ISS and mortality remained significant when the sample was divided into two age groups of 0-4 years and 5-14 years (Table 3-5). There was no association between sex and either ISS or mortality.

TABLE 3-4

Relationship Between ISS and Mortality

Fatality	ISS 1-9	10-24	25-34	35-50	51-75
YES	1(.7%)	3(27.3%)	7(70%)	6(85.7%)	14(100%)
NO	143	8	3	1	0
TOTAL	144	11	10	7	14

X^2=141.8, d.f.=4, p<0.0001.

TABLE 3-5

Relationship Between ISS and Mortality for Different Age Groups

Fatality	ISS 1-9	10-24	25-34	35-50	51-75
		0-4 Years[a]			
Yes	0(0%)	1(33.3%)	4(66.7%)	3(100%)	6(100%)
No	28	2	2	0	0
Total	28	3	6	3	6
		5-14 Years[b]			
Yes	1(0.9%)	2(25%)	3(75%)	3(75%)	8(100%)
No	115	6	1	1	0
Total	116	8	4	4	8

[a]n=46. X^2= 36.6. d.f.=4. p<0.0001.
[b]n=56. X^2=102.6. d.f.=4. p<0.0001.

Major Injuries and Body Regions Injured

A single injury was considered to be major if it was assigned an AIS value greater than or equal to 3. One hundred and forty-three subjects, or 77% of the sample, sustained no major injuries in the motor vehicle crash, that is, their most severe injury was assigned an AIS value of 2 or less. Twenty-three percent of the sample sustained at least one major injury.

For each subject, the presence or absence of major injury to each body region was noted without regard to the number of major injuries to that region. Table 3-6 summarizes the body locations of major injuries (AIS=3, 4, 5 or 6) sustained by the sample.

The head and neck body region was the most frequently injured region with major head injuries present in 18% of the subjects. Eight percent of the subjects sustained at least one major chest injury, 9% sustained major abdominal or pelvic contents injuries and 7% sustained major injuries to the extremities.

TABLE 3-6

Distribution of Major Injury Classified According to Body Region

Body Region	No. of Subjects with Major Injury[a] (% of Total Sample)
Head and Neck	33 (18)
Chest	15 (8)
Abdomen and Pelvic Contents	17 (9)
Extremity	13 (7)
Any Body Region	43 (23)

[a]Refers to the presence of at least one injury of AIS$\geq$3 in a specific body region.

There were no fatalities among the 143 subjects who sustained no major injuries. In contrast, major injury occurring to any one body region was significantly associated with mortality, regardless of the body region injured (Table 3-7). Mortality was observed to be higher amongst those subjects who, for example, suffered a major head injury (79% mortality) than those subjects who did not suffer a major head injury (3.3%), as seen in Table 3-8. The same was true for the other body regions. Any interpretations of Tables 3-7 and 3-8 must, however, be made with caution since the analysis was done at the simplest level, looking at each body region separately without taking into account the effect of simultaneous major injury in other body regions in the same subject.

TABLE 3-7

Relationship Between Presence of Major Injury and Mortality for Different Body Regions

Fatality	Presence of Major Injury: Yes	No	Total
Head and Neck Body Region[a]			
No	7	148	155
Yes	26	5	31
Total	33	153	186
Chest Body Region[b]			
No	2	153	155
Yes	13	18	31
Total	15	171	186
Abdomen and Pelvic Contents Body Region[c]			
No	4	151	155
Yes	13	18	31
Total	17	169	186
Extremity Body Region[d]			
No	5	150	155
Yes	8	23	31
Total	13	173	186
Any Body Region[e]			
No	12	143	155
Yes	31	0	31
Total	43	143	186

[a] $X^2=111.5$. $p<0.0001$.
[b] $X^2=57.6$. $p<0.0001$.
[c] $X^2=48.2$. $p<0.0001$.
[d] $X^2=20.3$. $p<0.0001$.
[e] $X^2=118.6$. $p<0.0001$.

TABLE 3-8

A Comparison of the % Mortality in Subjects With and Without Major Injury for Different Body Regions

Body Region	% Mortality	
	Major Injury	No Major Injury
Head and Neck	78.8	3.3
Chest	86.7	10.5
Abdomen and Pelvic Contents	76.5	10.7
Extremity	61.5	13.3
Any Body Region	72.1	0.0

Length of Stay in Hospital

The mean length of stay in hospital of survivors was 1.5 days (standard dev.=4.9) with values ranging from 0 to 31 ("31" represents "greater than 30 days"). Only 3 survivors had a length of stay value equal to 31. The median length of hospital stay was 0 days. Table 3-9 illustrates the distribution of the hospital length of stay. Seventy six percent of the survivors were not admitted to hospital while 19% had a length of stay of one to seven days.

As shown in Table 3-10, the mean length of stay of survivors increased in the higher ISS categories. When the ISS was not broken down into categories, the length of stay of survivors was fairly strongly linearly associated with the ISS (r^2=0.71).

TABLE 3-9

Distribution of Length of Stay (LOS) in Hospital of Survivors

LOS (Days)	No.(%)
Not Admitted	110(76%)
1-3	20(14%)
4-7	8(5%)
7-14	4(3%)
15-30	0(0%)
31+	3(2%)
Total	145(100)

TABLE 3-10

Mean Length of Stay (LOS) in Hospital of Survivors by ISS

ISS	No.	LOS(Days) Mean	Range
1-9	135	0.6	0-13
10-24	7	9.0	1-31
25-34	3	25.0	13-31
35-50	0	-	-
51-75	0	-	-
Total	145	1.5	0-31

Summary

The study sample consisted of 186 children and youths of whom 53% were male, 23% were nonoccupants and 75% had an ISS of less than 10. The mean age of the sample was 8.3 years. The mean and median ISS were 10.8 and 2.0 respectively. The mean and median length of stay in hospital of survivors were 1.5 and 0 days respectively, with 90% of the survivors either not admitted to the hospital or in hospital for less than four days. There was a significant relationship between hospital length of stay of survivors and ISS, with the length of stay increasing as the level of ISS increased.

Mortality in the sample was 17%. There was a significant association between ISS and mortality, with the percent mortality increasing as the level of ISS increased. Twenty three percent of the sample sustained at least one major injury (AIS $\geq$ 3). The most frequently occurring major injuries were to the head and neck body region, affecting 18% of the sample. Without taking into account the effect of simultaneous major injury in other body regions of a subject, there was a significant association between mortality and the presence of major injury to any one body region. There were no fatalities amongst the 77% of the sample who sustained no major injuries.

Chapter Four

LOGISTIC REGRESSION ANALYSIS WITH MORTALITY AS THE OUTCOME VARIABLE

Logistic Regression

Logistic regression, a method of investigating the relationship between a dichotomous dependent variable and categorical or interval-scaled independent variables, was employed to analyse the relationship between the outcome variable mortality and the predictor variables ISS, age, sex, height, weight, QUET and occupancy.

Logistic regression concerns itself with the natural log odds of an outcome which, in this study, was the natural log odds of death (ln(odds of death)). The ln(odds of death) is referred to as the logit or logistic transform and is related to the probability (P) of death as follows:

$$\ln(\text{odds of death}) = \ln[P(\text{death})/(1-P(\text{death}))]$$

As the P(death) increases, so does the ln(odds of death). Some examples of logit transformations for different probabilities of death are presented in Table 4-1.

TABLE 4-1

Logit Transformations for P(Death)

P(Death)	ln(Odds of Death)
0.00	$-\infty$
0.10	-2.20
0.25	-1.10
0.50	0.00
0.75	1.10
0.90	2.20
1.00	$+\infty$

The ln(odds of death) is a linear function of a set of independent variables and can be represented by the linear logistic model:

$$\ln(\text{odds of death}) = B_0 + B_1X_1 + B_2X_2 + \ldots + B_kX_k,$$

where B_0 is a constant, the B_i's are the logistic regression coefficients and the X_i's are the independent variables. Maximum likelihood estimates of the parameters B_0 and B_i are computed for a particular population sample. In other words, the parameters are chosen so that the likelihood function, or the overall probability of that sample occurring out of all possible samples, is maximized (Anderson, Auquier, Hauck, Oakes, Vandaele & Weisberg, 1980; Somers, 1981).

The BMDP PLR program, stepwise logistic regression, was used to carry out the analysis. PLR selects predictor variables in a stepwise manner by adding or removing independent variables according to preassigned enter and remove limits, which were set at 0.05 for the study.

Variables with an F-to-enter p-value of less than 0.05 are entered into the model in stepwise fashion, while variables already included in the model are removed if their F-to-remove p-value is greater than 0.05. This procedure continues until no variables pass the enter or remove limits. PLR allows higher-order interaction terms to enter the model only if all of their lower-order interaction terms and main effects are in the model (hierarchical rule). Maximum likelihood estimates of the parameters of the model (the logistic regression coefficients and the constant) are computed. Included in the output is a report, at each step, of the log likelihood and the improvement chi-square, which tests the hypothesis that prediction is significantly improved by the variable entered or removed at that step. It is also possible for the user to specify the variables to be included in the model, thereby eliminating the stepwise procedure and allowing an analysis of a specific model to be carried out.

Results

Logistic regression analysis was carried out on two groups, group A and group B. Group A included all 186 cases in the study of which 31 were fatalities. The predictor variables included in this analysis were ISS, age, sex and occupancy. Group B consisted of a subset of 102 cases that had complete data regarding height, weight and QUET. Twelve of the 102 cases were fatalities. In an attempt to determine whether measures of body size might be important predictors of outcome, the predictor variables height, weight and QUET as well as ISS, age, sex and occupancy were incorporated into this analysis.

Group A (186 cases)

When ISS, age, sex, occupancy and their higher-order interaction terms were regressed against mortality, ISS was the only term to be entered into the model (Table 4-2). Thus, for group A, ISS was the only significant predictor of mortality and the estimated linear logistic model was:

$$\ln(\text{odds of death}) = -4.63+0.191(\text{ISS})$$

TABLE 4-2

Stepwise Logistic Regression for Group A

Step	Variable Entered	Log Likelihood	Improvement X^2	D.F.	P-Value
1	ISS	-22.5	122.7	1	<0.001

Note. n=186. Predictor variables included in the model were ISS, age, sex, occupancy, age^2, age^3 and higher-order interaction terms.

Group B (102 cases)

Logistic regression analysis performed on group B to determine whether measures of body size were important predictors of mortality produced similar results to those of group A. Height, weight and QUET as well as age, sex, occupancy and their higher-order interaction terms were regressed against mortality. Once again, ISS was the only term to be entered into the model (Table 4-3). Thus, the only significant predictor of mortality for group B was ISS. The estimated linear logistic model was:

$$\ln(\text{odds of death}) = -5.08 + 0.232(\text{ISS})$$

TABLE 4-3

Stepwise Logistic Regression for Group B

Step	Variable Entered	Log Likelihood	Improvement X^2	D.F.	P-Value
1	ISS	-10.8	52.3	1	<0.001

Note. n=102. Predictor variables included in the model were ISS, age, sex, occupancy, height, weight, QUET, age^2, age^3, $height^2$, $height^3$, $weight^2$, $weight^3$, $QUET^2$, $QUET^3$ and higher-order interaction terms.

Discussion

Table 4-4 illustrates the relationship between ISS, the ln(odds of death) and the P(death) for groups A and B.

The relationship between ISS and mortality was linearized using logit transformation and, therefore, ISS and the predicted ln(odds of death), calculated from the estimated linear logistic equations stated in the Results section, are linearly related. The ln(odds of death) increased as the ISS increased. The predicted P(death), which was determined directly from the predicted ln(odds of death) using a table of logit transformations for proportions (Armitage, 1971), also increased as the ISS increased. For both groups, percent mortality rose rapidly towards 100% in the middle range of the ISS, that is a small change in ISS resulted in a large change in the P(death). At either end of the ISS range a much larger change in ISS was necessary to obtain a noticeable change in the P(death). Group B had a higher proportion of deaths than group A at a given ISS level.

TABLE 4-4

Relationship Between ISS, Ln(Odds of Death) and P(Death) for Groups A and B

	ISS	Predicted Ln(Odds of Death)	Predicted P(Death)
Group A (n=186)	5	-3.68	0.03
	10	-2.72	0.06
	15	-1.77	0.15
	20	-0.81	0.31
	25	0.15	0.54
	30	1.10	0.75
	35	2.06	0.89
	40	3.01	0.95
	45	3.97	0.98
	50	4.92	0.99
	75	9.70	approx.1.00
Group B (n=102)	5	-3.92	0.02
	10	-2.76	0.06
	15	-1.60	0.17
	20	-0.44	0.39
	25	0.72	0.67
	30	1.88	0.87
	35	3.04	0.95
	40	4.20	0.99
	45	5.36	approx.1.00
	50	6.52	approx.1.00
	75	12.32	approx.1.00

Hypotheses Testing

The results of the logistic regression analysis enabled the first two hypotheses stated on page 21 to be tested. The findings supported the first hypothesis which states that "the Injury Severity Score alone will be a significant predictor of mortality in child and youth victims of blunt trauma." The second hypothesis dealing with the best model to predict percent mortality was not supported by the findings. The model which best predicted mortality was not one which included a set of other predictor variables in addition to the Injury Severity Score but rather, a model containing the Injury Severity Score alone.

Chapter Five

MULTIPLE REGRESSION ANALYSIS WITH LENGTH OF HOSPITAL STAY OF SURVIVORS AS THE OUTCOME VARIABLE

Multiple Regression

Multiple regression analysis was utilized to investigate the relationship between the continuous outcome variable length of stay in hospital of survivors and the predictor variables ISS, sex, age, occupancy, height, weight and QUET. The BMDP P2R program, stepwise regression, was used to carry out the analysis.

P2R estimates the best regression model in a stepwise manner by adding and removing the independent variables according to the preassigned F-to-enter and F-to-remove values. These values were set at 4.0 and 3.9 respectively for the study. The method of forward stepping was employed in the study. In this method, the variable with the highest F-to-enter value is added at each step until no more variables meet the F-to-enter criterion of 4.0. Variables are removed if their F-to-remove value is less than 3.9. P2R estimates the regression coefficients using the least squares regression method. This method "chooses the best-fitting model to be that model which minimizes the sum of squares of the distances between the observed

observed responses and those predicted by the fitted model" (Kleinbaum & Kupper, 1978). Included in the output at each step is the multiple, or overall, R^2 which represents the percentage of the variance in the dependent variable explained by that model, the analysis of variance table for the regression, the regression coefficients and the F-to-remove and F-to-enter values of the variables. The increase in R^2 accounted for by the addition of the variable at each step is also reported at the end of the output. From the increase in R^2 one can calculate what proportion of the overall explainable variance (overall R^2) is attributable to each independent variable in the model.

Results

As with the logistic regression analysis, multiple regression analysis was performed on two groups, group 1 and group 2. Group 1 consisted of all survivors with sufficient data regarding the hospital length of stay, a total of 145 cases. The independent variables regressed on length of stay were ISS, age, sex and occupancy. To determine whether body size was important in the prediction of length of stay, a second analysis was performed on a subset of the first group. Group 2 consisted of 88 cases with complete data on body size. The independent variables studied in this group included height, weight and QUET as well as ISS, sex, age and occupancy.

Group 1 (145 cases)

When the independent variables ISS, age, age^2, age^3, sex and occupancy were regressed against hospital length of stay of survivors, ISS, age and occupancy were entered into the model. However, Table 5-1 shows that the contribution of age and occupancy to the prediction of length of stay was minor in comparison to that of ISS.

Firstly, with a critical F equal to 3.9 (α=0.05), the computed F-to-enter values of age (F=4.35) and occupancy (F=4.50) at steps two and three respectively, although just significant at the 0.05 level, were not significant at the 0.01 level.

Secondly, the model containing the variables ISS, age and occupancy explained 59% of the variance in length of stay of survivors (overall R^2=0.59). However, as seen in Table 5-1, age and occupancy accounted for an increase in R^2 of only 0.01 and 0.02 respectively. The proportion of the overall percentage of explainable variance attributed to age was only 2% (0.01/0.59) and the proportion attributed to occupancy was only 3% (0.02/0.59). This was in sharp contrast to the 95% of the overall percentage of explainable variance attributed to ISS (0.56/0.59). The regression equation obtained for this model was:

predicted length of stay=

-0.5924+0.7831(ISS)-0.1540(age)+1.3817(occupancy).

The regression model containing only the variable ISS had an overall R^2 of 0.56. The regression equation for this model was:

predicted length of stay= -0.8537+0.7921(ISS).

TABLE 5-1

Multiple Regression Analysis for Group 1

Step	Variable Entered	F-to-Enter	Overall R^2	Increase in R^2	Proportion of Overall R^2
1	ISS	181.16	0.56	0.56	0.95
2	Age	4.35	0.57	0.01	0.02
3	Occupancy	4.50	0.59	0.02	0.03

Note. n=145. Predictor variables included in the model were ISS, age, age^2, age^3, sex and occupancy. Overall R^2=0.59.

<u>Group 2 (88 cases)</u>

The multiple regression analysis performed on group 2 in order to determine whether body size was important in the prediction of hospital length of stay of survivors, resulted in very similar findings to those found in group 1 (Table 5-2). The regression of ISS, age, sex, occupancy, height, weight, QUET and higher-order terms against length of stay resulted, once again, in ISS, age and occupancy being the only variables entered into the regression model. The variables measuring body size were not important predictors of hospital length of stay.

The computed F-to-enter values of age (F=6.24) and occupancy (F=6.49) at steps two and three respectively were significant at the 0.05 level (critical F=3.96, α =0.05), although still not significant at the 0.01 level. This regression model explained 75% of the variance in hospital length of stay of survivors (overall R^2=0.75), but once again the contribution of age and occupancy was minimal. Age accounted for an increase in R^2 of 0.02, only 3% of the overall R^2. The proportion of the overall percentage of explainable variance attributed to occupancy was only 3%, with an increase in R^2 of 0.02. The ISS, on the other hand, accounted for 94% of the overall R^2. The regression equation obtained for this model was:

predicted length of stay=
-1.0065+0.9474(ISS)-0.2177(age)+1.7893(occupant).

The regression model containing only the variable ISS explained 71% of the variance in the length of stay (overall R^2=0.71). The estimated regression equation obtained for this model was:

predicted length of stay= -1.4993+0.9390(ISS).

TABLE 5-2

Multiple Regression Analysis for Group 2

Step	Variable Entered	F-to-Enter	Overall R^2	Increase in R^2	Proportion of Overall R^2
1	ISS	206.87	0.71	0.71	0.94
2	Age	6.24	0.73	0.02	0.03
3	Occupancy	6.49	0.75	0.02	0.03

Note. n=88. Predictor variables included in the model were ISS, age, age^2, age^3, sex, occupancy, height, $height^2$, $height^3$, weight, $weight^2$, $weight^3$, QUET, $QUET^2$ and $QUET^3$. Overall R^2 =0.75.

Discussion

Table 5-3 illustrates the linear relationship between ISS and the predicted length of stay in hospital for groups 1 and 2. As ISS increased, the predicted hospital length of stay increased. Compared to group 1, the predicted length of stay for survivors in group 2 was slightly longer for an ISS over 25.

TABLE 5-3

Predicted Length of Stay (LOS) in Hospital of Survivors by ISS for Groups 1 and 2

	ISS	Predicted LOS* (Days)
Group 1 (n=145)	5	3.1
	15	11.0
	25	18.9
	35	26.9
	45	34.8
	55	42.7
Group 2 (n=88)	5	3.2
	15	12.6
	25	22.0
	35	31.4
	45	40.8
	55	50.1

*Calculated using the estimated regression equation for the model containing only the variable ISS.

Hypotheses Testing

The results of the multiple regression analysis enabled the third and fourth hypotheses stated on page 21 to be tested. The findings supported the third hypothesis which states that "the Injury Severity Score alone will be a significant predictor of length of stay in hospital in child and youth survivors of blunt trauma." The fourth hypothesis dealing with the best model to predict length of stay in hospital of survivors was also supported by the findings. The model which best predicted hospital length of stay of survivors was one which included a set of variables (ISS, age and occupancy), rather than a model containing the Injury Severity Score alone. However, the contribution of age and occupancy to the overall R^2 of that model was minor compared to that of the ISS.

Chapter Six

ANALYSIS OF THE INJURY SEVERITY SCORE USING ONE-WAY ANOVA

One-Way ANOVA

One-way ANOVA (analysis of variance) is a statistical method of comparing or testing the equality of group means. This technique deals with a continuous dependent variable and nominal independent variables.

In the study, the subjects were categorized into five groups: 1)those survivors not admitted into hospital (no admit), 2)those survivors with a length of stay in hospital of one to seven days (1-7 days), 3)those survivors with a length of stay in hospital of eight to thirty days (8-30 days), 4)those survivors with a length of stay in hospital of greater than thirty days (31+ days) and 5)fatalities. The equality of the mean ISS's was then tested across these five groups.

The BMDP P1V program was used to carry out the analysis. P1V tests the equality of group means using one-way analysis of variance (F statistic). It then uses T statistics to test the equality of means between each pair of groups.

Results

Table 6-1 illustrates the number of cases per group and the estimates of the mean ISS for each group. The F-test tests the null hypothesis of equal population means. With a calculated F-value of 131.3 ($p<0.0001$), it was concluded that at least two of the group means were significantly different.

TABLE 6-1

Number of Cases and Mean ISS for the Groups Included in the One-Way ANOVA

Group	No. of Cases	Mean ISS
No Admit	110	1.65
1-7 days	28	4.75
8-30 days	4	14.75
31+ days	3	20.00
Fatal	31	47.65

T-statistics determined where the main differences in group means were. Figure 6-1 illustrates these differences. The probabilities for the significant T-tests are presented in Table 6-2. As shown in Figure 6-1, the groups with significantly different mean ISS's were:

a)No admit and 1)8-30 days, 2)31+ days, 3)fatal.

b)1-7 days and 1)31+ days, 2)fatal.

c)8-30 days and 1)fatal.

d)31+ days and 1)fatal.

The pairs of groups that did not have significantly different mean ISS's were 1)no admit and 1-7 days, 2)1-7 days and 8-30 days and 3)8-30 days and 31+ days.

TABLE 6-2

Probabilities for the Significant T-Tests on Group Means

	No Admit	1-7 Days	8-30 Days	31+ Days
8-30 Days	0.0110	--	--	--
31+ Days	0.0020	0.0131	--	--
Fatal	0.0000	0.0000	0.0000	0.0000

FIGURE 6-1

Equality of Group Mean ISS's

```
*-------*
        *-------*
                *-------*

x       x       x       x       x
No Admit 1-7    8-30    31+     Fatal
        Days    Days    Days
```

Note. *-------* connects groups without significantly different mean ISS'S.

Chapter Seven

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN THE INJURY SEVERITY SCORE AND MORTALITY USING PROBIT ANALYSIS

The relationship between the Injury Severity Score and mortality in the pediatric (0-14 years) group was examined using the statistical technique of probit analysis. Prior to this study, Bull (1975; 1978) had employed probit analysis to investigate the same relationship in the young adult (15-44 years), middle aged (45-64 years) and elderly (65+ years) groups. Through the use of this method, Bull was also able to determine the level of injury severity that was fatal for 50% of the victims, denoted as the L.D.50 (lethal dose). The use of probit analysis in the current study permitted a comparison to be made between the findings in the pediatric population and Bull's findings in the adult population, which are documented in the literature. The effect of age on the relationship between ISS and mortality was then determined.

Probit Analysis

Probit analysis is similar to logistic regression in that it investigates the effects of one or more independent variables on a dichotomous outcome variable. Probit analysis concerns itself with proportions or probabilities (P) which, in this study, was the proportion of deaths at varying levels of the ISS.

The probit of any P is defined as: $Y = Y' + 5$, where Y' is the standard normal random variable Zp, such that the proportion P of the standard normal distribution falls to the left of Zp. The value 5 is added to the transformation to make all the new values of Y positive (Armitage, 1971). The following are two examples of probit transformation:

a)if $P=0.50$, $Y= Z_{.50} + 5 = 0.00 + 5 = 5.00$

b)if $P=0.95$, $Y= Z_{.95} + 5 = 1.64 + 5 = 6.64$

The probit, or transformed P, can then be predicted as a linear function of the independent variables.

The SPSSx (2'nd edition) PROBIT procedure was used to carry out the analysis. When there is only one independent variable in the analysis, as was the case for the study, PROBIT computes maximum likelihood estimates of the parameters of the model which, in this case, are the intercept and slope of the regression equation. Included in PROBIT's output are the estimates of the intercept and regression coefficient, or slope, and a table of estimated values of the independent variable which produce selected response rates. For the study, these were estimated values of the ISS which produced selected proportions of deaths.

It is from this table which also provides 95% confidence intervals for the estimates, that the ISS L.D.50 can be determined.

Results

Probit analyses were carried out on three groups, the pediatric group (0-14 years), the 0-6 age group and the 7-14 age group. Table 7-1 lists the number of fatalities at different levels of the ISS for the three groups. These data were used as input for the analyses.

The results of the probit analyses are summarized in Table 7-2. The slope of the fitted probit line relating ISS to percent mortality for the 0-14 age group was 0.0994. The slopes for the 0-6 group and the 7-14 group, 0.1217 and 0.0853 respectively, were not significantly different. The calculated ISS L.D.50 of 22.2 for the 0-6 group was lower than the L.D.50 of 27.3 for the 7-14 group, signifying that at a given level of injury the younger group was more susceptible to death from their injuries than the older group. The overall L.D.50 for the 0-14 group was 24.5.

TABLE 7-1

Number of Cases and Fatalities at Different Levels of ISS for the Three Age Groups: 0-14 Years, 0-6 Years and 7-14 Years

ISS Level	Mean ISS	No. of Cases	No. of Fatalities
		0-14 Years (n=186)	
1-9	2.1	144	1
10-24	13.1	11	3
25-34	28.7	10	7
35-50	40.3	7	6
51-75	70.1	14	14
		0-6 Years (n=68)	
1-9	1.7	49	0
10-24	11.3	3	1
25-34	28.1	7	5
35-50	40.3	3	3
51-75	70.8	6	6
		7-14 Years (n=118)	
1-9	2.3	95	1
10-24	13.8	8	2
25-34	30.0	3	2
35-50	40.3	4	3
51-75	69.6	8	8

TABLE 7-2

Relationship Between ISS and Mortality: Results of Probit Analysis for Different Age Groups

Age (Years)	No.	Fatalities	Intercept	Slope	ISS L.D.50
0-14	186	31	2.566	0.0994	24.5
0-6	68	15	2.302	0.1217	22.2
7-14	118	16	2.667	0.0853	27.3
15-44*	721	17	1.748	0.0820	39.7
45-64*	207	17	1.558	0.1173	29.4
65+ *	110	29	2.031	0.1469	20.2

*Bull, 1975.

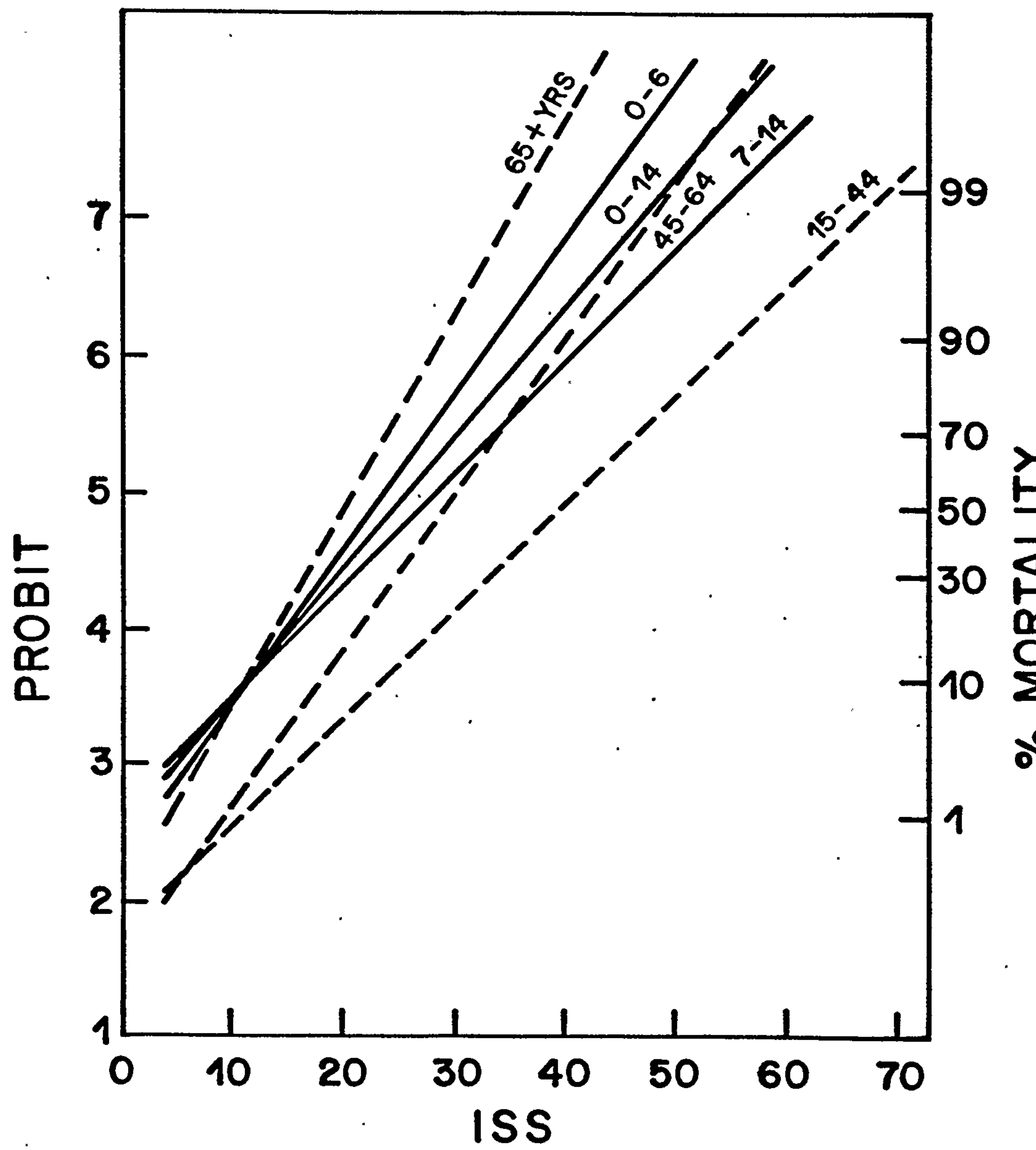
A Comparison of the Pattern of Mortality in Children and Adults

The pattern of mortality in children was compared to the patterns of mortality in young adult (15-44 years), middle aged (45-64 years) and elderly (65+ years) groups, as described by Bull (1975; 1978) (Table 7-2). A definite age effect was evident in the relationship between the level of injury severity (ISS) and the proportion of victims dying, and is seen in Figure 7-1 which illustrates the fitted probit lines for the different age groups.

The pediatric group's pattern of mortality most closely resembled that of the middle aged and elderly groups. The L.D.50 of the 0-14 group, 24.5, was markedly lower than the young adult group's L.D.50 of 39.7, and lay in between that of the middle aged (L.D.50=29.4) and elderly (L.D.50=20.2) groups. The low L.D.50 and the orientation of the fitted probit line of the 0-14 group are indicative of a higher susceptibility in the pediatric group to death from injuries at any level of severity than in the young adult group. In other words, for any given level of ISS the proportion of children dying was greater than the proportion of young adults dying.

FIGURE 7-1

Relationship Between ISS and Percent Mortality for Different Age Groups (Fitted Probit Lines)



Note. Fitted probit lines for the 15-44, 45-64 and 65+ age groups taken from Bull, 1975.

The effect of age was also evident when the pediatric group was separated into younger (0-6 years) and older (7-14 years) children, despite the smaller numbers in the two samples. The higher proportion of deaths exhibited by both groups at any level of ISS, in comparison to young adults, was most marked at the less severe levels of injury where the percent mortality was even higher than that of the middle aged group (Figure 7-1). This pattern of poorer resistance to injury than the adult group, particularly at the lower levels of the ISS, was similar to the pattern found in the elderly group.

The L.D.50 of the 0-6 group, ISS 22.2, was very similar to the L.D.50, 20.2, of the elderly group. On the other hand, the 7-14 group had an L.D.50 of 27.3 which was very similar to that of the middle aged group (L.D.50=29.4), suggesting inherent differences in the response to injury even within the pediatric group as a whole.

Differences in the response to injury between the pediatric and adult groups were also demonstrated by opposite trends in mortality with increasing age. As age increased in the pediatric group the response to injury improved, demonstrated by decreased mortality in the older group of children (7-14 years). The adult population displayed an opposite trend in mortality with increasing age. The response to injury worsened in the older groups, the elderly having the highest proportion of deaths in the adult population.

Hypothesis Testing

The results of the probit analysis enabled the fifth hypothesis stated on page 21 to be tested. The findings did not support the hypothesis which states that "the pattern of mortality in children and youths at different levels of injury severity will be similar to the pattern of mortality in young adults.....and will least resemble the patterns of mortality found in the middle aged and elderly population." In fact, the pattern of mortality of the pediatric group most closely resembled that of the middle aged and elderly groups.

Chapter Eight

CONCLUSION

Summary

Injuries are the number one cause of death amongst children and youths today and a major cause of hospitalization. Injury and pediatric trauma care research are essential for injury prevention and in the battle against mortality and morbidity due to injuries. An important component of this research involves the development of a valid and reliable index of injury severity to serve as a tool in the measurement or classification of overall injury severity.

The Injury Severity Score (ISS), a numerical method of rating the overall severity of multiple injuries, has previously been validated and tested for reliability in the adult population. The objective of the study was to evaluate the ISS in a pediatric population of victims of blunt trauma (motor vehicle crash victims) and thereby determine its applicability in the research, evaluation and planning of pediatric trauma care as well as childhood injury research for blunt trauma. The effect of age on the relationship between the Injury Severity Score and mortality was also determined.

The data utilized in the study were obtained from Transport Canada's Canadian Light Truck and Van Study databank. A sample of 186 children and youths 14 years of age and under who were involved in crashes included in the Light Truck and Van Study and who sustained at least one injury were included in the study.

Five hypotheses were developed, based on a critical review of the literature, and tested. The first two hypotheses dealt with the relationship between the ISS, as well as the other predictor variables age, sex, occupancy, height, weight and QUET, and the outcome variable mortality. The next two hypotheses dealt with the relationship between ISS, as well as the other predictor variables age, sex, occupancy, height, weight and QUET, and the outcome variable length of stay in hospital. The fifth hypothesis dealt with the effect of age on the pattern of mortality at different levels of injury severity.

Through the use of the statistical technique of logistic regression, the ISS was ascertained to be a significant predictor of mortality in the pediatric group. This result supported the first hypothesis. The second hypothesis dealing with the other independent variables was not, however, supported by the findings. None of the other independent variables was a significant predictor of mortality.

The ISS was also determined to be a significant predictor of length of stay in hospital of survivors, thereby supporting the third stated hypothesis. Using multiple regression analysis, the ISS alone was able to explain 56% of the variance in length of stay. The fourth hypothesis dealing with the other independent variables was also upheld by the results. The variables age and occupancy were, as well, found to be significant predictors of length of stay of survivors (at the 0.05 level of significance). However, their contribution to prediction was minor in comparison to that of the ISS. With the ISS already accounted for in the model, age and occupancy each explained approximately 2% more of the variance in the length of hospital stay.

By using probit analysis and comparing the results with findings from Bull's (1975; 1978) studies, age was shown to have an effect on the relationship between levels of the ISS and percent mortality. The pattern of mortality in the pediatric group, for both the younger and older children, was found to be very similar to that of the elderly and middle aged populations. This phenomenon revealed itself in a higher susceptibility to death than the young adult population at all levels of injury severity. This was particularly evident amongst the less severely injured, with the pediatric group having a much higher proportion of deaths than the young adults. Thus, the fifth hypothesis was not supported by the findings. The pattern of mortality in children and youths was not similar to the pattern of mortality in young adults, but was in fact most similar to that of the older population.

In conclusion, the study has shown that the Injury Severity Score is a significant predictor of mortality and hospital length of stay in pediatric motor vehicle crash victims. The addition of other independent variables including age, sex, height, weight, QUET and occupancy did not significantly improve the prediction of the outcome. The study has also confirmed that age has an effect on the relationship between the level of ISS and percent mortality. The pattern of mortality due to trauma in children and youths most closely resembles that of the middle aged and elderly population rather than the young adult population. This finding suggests that the younger population is not as resilient to injury as the young adult population.

Discussion

The study has replicated the findings of prior studies of the ISS, this time in a pediatric population. As previously shown by Baker et al (1974), Bull (1975; 1978) and Semmlow and Cone (1976), the ISS is a good predictor of mortality and hospital length of stay. The phenomenon of the effect of age on the relationship between the ISS and mortality described by Baker et al and Bull in the adult population is also demonstrated in this study. For the first time, the pattern of mortality in children has been shown to be similar to the pattern found in the older population and not, as had been previously suggested, similar to that of the young adult population.

This finding regarding the comparison of the patterns of mortality in the pediatric and adult populations must, however, be interpreted cautiously at this stage until further studies substantiate it. When comparing the pediatric sample obtained from the LTV Study with Bull's (1975) adult sample, it is necessary to recognize that: 1)these two populations are not identical and 2)to identify the differences between them which may be potential sources of bias. One major difference is the hospital care received by the two groups. The adult sample was treated at the Birmingham Accident Hospital, England, a hospital with a heavy caseload of motor vehicle crash victims and expertise in treating trauma victims. The subjects were, however, admitted to this hospital during the year 1961 and many changes in the medical care of trauma victims have occurred since then. The pediatric sample obtained from the LTV Study was, on the other hand, treated in a variety of health care settings across Canada during the years of 1981 to 1983.

Another important difference between the two groups is the version of the AIS used for injury severity coding. Injury severity of the pediatric sample was coded using the AIS-80, while Bull's study utilized an earlier version of the AIS which did not include all the coding changes and improvements found in the 1980 version. The reliability in the assignment of AIS codes and ISS calculations also remains an important issue when comparing the pediatric and adult samples. The reliability of the coding may not be comparable due to the possibility of the existence of differences between the two samples in the experience and background of the coders and the quality of the injury descriptions in the sources of data available to them.

All of the above differences between the pediatric and adult samples may have resulted in the age effect observed in the study. Further studies comparing pediatric and adult samples that are similar in terms of emergency and hospital care received and reliability in AIS and ISS coding are necessary to verify the existence of the age effect demonstrated in the study. It is suggested that a sample of the adult subjects included in the LTV Study be analysed using probit analysis and the results be compared to the pattern of mortality found in the pediatric sample, documented in Chapter Seven, since the pediatric sample also originates from the LTV Study.

The implications of the study are two-fold. Firstly, the Injury Severity Score is a valid method of categorizing injury severity in pediatric motor vehicle trauma victims. It can be used to quantify the input, or injury severity of pediatric patients entering, into any system of care. The ISS can therefore be employed as a tool in the research, planning and evaluation of pediatric trauma care, in childhood injury research and in the evaluation of the needs of pediatric trauma victims.

Secondly, the study demonstrates the importance of adjusting for age when utilizing the Injury Severity Score to classify injury severity, particularly when dealing with mortality as the outcome measure. Distinct differences in the pattern of mortality have been demonstrated in the pediatric population as compared to findings in the older population, particularly the young adult group, documented in the literature (Bull, 1975; 1978). The results of the study suggest that even within the pediatric group, some differences exist between the younger and older children, although this needs to be further researched. Not adjusting for age in studies employing the ISS may result in misleading findings and incorrect conclusions regarding the quality of the medical care and services being evaluated.

Further studies on the use of the ISS in the pediatric population need to be done in order to be able to generalize the results of this study to all young trauma victims. The applicability of the ISS in the classification of blunt trauma other than motor vehicle-related trauma (falls, child abuse) and penetrating injuries still needs to be examined. As well, the ISS's ability to predict outcome measures other than mortality and hospital length of stay, such as disability, must be evaluated. Further research of this type will help to determine the clinical and research situations in which the use of the ISS is most appropriate.

As discussed in detail above, further research to verify the existence of the age effect on the pattern of mortality demonstrated in the study is necessary and must be done on pediatric and adult samples that are comparable in terms of hospital care and AIS reliability.

This study has mainly concentrated on the pediatric group (0-14 years) as a whole. As mentioned above, the results suggest that even within this age group differences in response to injury exist between the younger and older pediatric population. In the future, studies involving larger sample sizes of different age categories within the pediatric population need to be done in order to examine more closely the effects of age on outcome.

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