NBSIR 77-1218

Risks Associated with Certain Sports Activites

William B. Beine

Performance and Safety Analysis Section
Product Systems Analysis Division
Center for Consumer Product Technology
Institute for Applied Technology

January 1977

Final Report

Prepared for
Bureau of Engineering Sciences
Consumer Product Safety Commission
5401 Westbard Avenue
Bethesda, Maryland

NBSIR 77-1218

RISKS ASSOCIATED WITH CERTAIN SPORTS ACTIVITIES

William B. Beine

Performance and Safety Analysis Section
Product Systems Analysis Division
Center for Consumer Product Technology
Institute for Applied Technology

January 1977

Final Report

Prepared for
Bureau of Engineering Sciences
Consumer Product Safety Commission
5401 Westbard Avenue
Bethesda, Maryland 20207

U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, ***Secretary***

Dr. Betsy Ancker-Johnson, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Acting Director***

SUMMARY

There are substantial risks associated with many sports activities. This conclusion is supported by the U.S. Consumer Product Safety Commission's Consumer Product Hazard Index which ranks 367 product categories. Many sports rank high on this index, for example, football activity and related equipment is ranked #4, baseball #5, basketball #12, snow skiing #17, hockey #34, and gymnastics #47.

The purpose of this study is to provide the Commission with recommendations for assigning priorities to tasks associated with reducing the incidence and severity of sports related injuries.

This study was limited to sports activities related to football, baseball, basketball, snow skiing, ice hockey, gymnastics, and trampolines. Tasks of identifying hazards associated with these activities and formulating subsequent recommendations were accomplished primarily as a result of reviewing the published literature. Data provided by the National Electronic Injury Surveillance System (NEISS) are also utilized.

The availability of literature regarding hazards in many sports is not consistent with their ranking on the Commission's Hazard Index. Further, the utility of many reports is limited because of the fragmented approach and compartmentalized views of athletic injury research. This precludes a comprehensive statistical assessment of risks associated with sports activities.

An analysis of the literature and NEISS data resulted in the following recommendations:

- Expand data collection activities based upon a systems concept.
- Encourage development of standardized terminology applicable to sports research.
- Determine the feasibility of an institute to initiate and coordinate sport injury research and to disseminate results to the athletic community.
- Improve the surveillance capabilities of NEISS.
- Stimulate research to resolve the controversy and problems associated with helmet test procedures.

- Determine the potential and alternatives for promulgating hockey face guard standards.

- Stimulate research to reinforce theories pertaining to knee injury prevention and provide for disseminating results to the athletic community.

- Allocate resources to areas of ski-boot-binding testing, adjusting, maintenance, and establish equipment performance criteria.

- Determine the feasibility of establishing a ski-boot-binding safety performance standard.

Formulation of these recommendations incorporated an assessment of the frequency and severity of specific injuries and the literatures capacity to identify essential factors for determining appropriate remedial action.

Table of Contents

List of Tables

List of Tables (continued)

RISKS ASSOCIATED WITH CERTAIN SPORTS ACTIVITIES

William B. Beine

This study provides the Consumer Product Safety Commission with recommendations for assigning priorities to tasks associated with reducing the incidence and severity of sports related injuries. Recommendations were derived from an analysis of published literature and NEISS data. They emphasize the need for collecting additional data, improving surveillance capabilities, stimulating research, and developing and promulgating equipment safety standards.

Key words: Accident; associated factors; injuries; literature; NEISS, recommendations; review; sports; safety.

1. INTRODUCTION

The evolution of sport has primarily been the result of advances in technology. Technology has opened the way for new activities such as snowmobiling and has changed the complexion of more firmly rooted sports. Often, these changes place new demands on the athlete. The rigid hard-shelled helmet was introduced to increase head protection. However, it gave the football athlete a sense of added security and permitted the involvement of head and helmet in blocking and tackling. This practice increases the risk of serious injury.

Communications have popularized sport. As a result, greater numbers of youths are participating in sports activities. Many of these persons may be unaware of the risk they are taking as a result of inadequate or poorly fitted and maintained equipment and playing surfaces, or inadequate training and supervision.

The athlete is the core of the person-equipment-sport mix and it is the athlete's physical welfare that is of concern. That risks in sports are not at a minimum is apparent by the high ranking of many sports activities on the U.S. Consumer Product Safety Commission's (CPSC) most recent Consumer Product Hazard Index (314). For example, the

Hazard Index[1] ranks the product categories of football activity and related equipment #4, and similar classifications of baseball[2] #5, basketball #12, snow skiing #17, hockey #34, and gymnastics #47.

Viewed in its entirety, the subject of risk in sports is complex, involving equipment, facilities, supervision, physical maturity, ability, attitude, conditioning, and the environment as contributing factors. Within the context of sports as systems and given the nature of associated accidents and injuries, it is necessary for the Consumer Product Safety Commission (CPSC) to identify those issues and conditions in the person-equipment-sport mix which can be effectively regulated through voluntary or mandatory standards.

This report is the third and final report to the Consumer Product Safety Commission (CPSC). It provides recommendations for assigning priorities to tasks associated with reducing the incidence and severity of sports related injuries, and recommendations to improve data acquisition and analysis. These recommendations are primarily the result of an analysis of previous athletic injury studies appearing in the published literature. Data obtained through the Commission's National Electronic Injury Surveillance System (NEISS) were also utilized.

The usual resource limitation precluded a comprehensive review of all sports activities. Furthermore, it would have been pointless to include activities which were not included in the literature. This criterion resulted in the selection of several product categories: football, baseball, basketball, snow skiing, ice hockey, gymnastics, and trampolines. Specific safety issues related to these activities were not delineated at the outset of the study. Rather, the issues presented in this report, as well as the depth which these were researched, developed as a consequence of the available literature.

---

[1]The "Hazard Index" lists 367 product categories. These product categories were derived by consolidating the National Electronic Injury Surveillance System (NEISS) listing of approximately 1000 categories. Categories are ranked by multiplying the estimate number of injuries treated in emergency rooms by weights for severity and age, then dividing by one million and truncating.

[2]For convenience, the name of the sport associated with each product classification is used throughout the report to identify the actual classification; e.g., football will be used in lieu of football activity and related equipment.

Two earlier memorandum reports were submitted to the Commission. The first report (May 1976) provided a "first cut" assessment of risks associated with these sports and subsequent recommendations. The second report (September 1976) provided an analysis of three years (July 1972 through June 1975) of NEISS data. This report draws from these earlier reports and includes a more thorough analysis of specific issues.

This report is divided into several sections. The next section includes a number of pertinent comments about the data sources. Analyses are provided in the following section. This is followed by a discussion of rules and standards activities, and finally, the conclusions and recommendations. A list of nearly 400 references and tables of injuries projected by NEISS are included at the end of this report.

2. COMMENTS ON THE DATA SOURCES

2.1 Published Literature

In 1967, Haddon (269) authored a paper discussing principles in sports research. He comments, "good basic data on incidence and prevalence (i.e., the numbers of cases existing at a given time per unit population) have not yet been obtained for the effects of most organized and unorganized sports, whether beneficial or injurious." Shortly thereafter, Clarke (258) commented that, "research activity in sports may be prevalent, but there is little evidence to support or deny respective opinions on most legitimate arguments." More recently, Blyth and Mueller (9) in a unique attempt to apply methods of epidemiology to problems of football injuries observed that, "There is relatively little data available on the extent of problems of football injuries, or other sports injuries, particularly at the high school level and below--even though football accounts for most of the sports injury research." As recently as 1974, Hayes (274) pointed out, "Because of the approach to recording the incidence, nature, and severity of sports injuries, it is very difficult to assess statistically the risk factors of individual activities. Without this knowledge, one cannot isolate the many variables, both overt and covert, which contribute to injurious situations."

Sports injury research has yet to assess the extent, severity, and nature of athletic injuries. Consequently, basic input to decision processes affecting safety in athletics has been and will be based upon perceived need rather than valid statistical measures. Past studies have addressed a subset of these problems but their utility is limited, because they lack commonality of purpose and design. Traditionally such studies are limited to a geographical sector, to a specific population, and to demonstrating the extent and severity of injuries resulting from a specific set of factors. Further they lack universally accepted basic definitions, such as, reportable injury, injury classifications, injury rate, severity rating, etc.

As with the injurious aspects of sports, research has not provided evidence to demonstrate the beneficial aspects of sports (283, 284) making it impossible to assess the risk of participation, particularly, if a definition of risk is adopted as proposed by Clarke (16): "Calculated risk is an assessment of the hazards in the sports being offered relative to the sports' purported benefits."

Given that an equation in terms of benefits and injuries can be developed, it would be impossible, according to Hayes (274), to apply the results universally to a population of participants with multifaceted motivations and participating in sports at all levels of competition. The approach suggested by Hayes may be more appropriate: "A risk factor may be defined as the susceptibility of a participant to injury. The susceptibility is determined by the state of the man, machine, and environment, and the interactions among them."

By any definition, an assessment of the risks in sports implies the availability of data. In particular, the latter definition implies statistical knowledge of the system.

A system is characterized by a set of objects, their descriptive attributes, and relationships between these objects and attributes. In general, these objects or entities may be physical or abstract. In sport, these entities might be the athlete, protective equipment, playing surface, coach, etc. The attributes are properties of each entity, for example, the athlete's age, weight, aggressiveness, motivation, muscular strength, or a ski binding's release tolerance, corrosive resistance, tolerance to friction, etc. Relationships between entities and attributes tie the system together. Small changes in one parameter may alter the system dramatically.

Application of the systems concept to sport injury research is a topic discussed by Fraser (266). He writes, "...consideration of the interactions that occur within a man-machine-environment complex that cause or contribute to the occurrence of accidents, allows a clearer analysis,..., of the different components that make up the system,.... Until this approach becomes more widespread among all those involved, we cannot even verge on the optimal in recreational system safety."

In sport injury research, the systems concept has had infrequent application. Most studies isolate one or two variables and assume the effects of others to be negligible. The efficacy of this "piecemeal approach" is obviously limited.

The literature provides very little information on sports injuries related to activities of basketball, trampolines, gymnastics, and to some extent, baseball. Conversely, football and snow skiing activities account for most of the literature. This disproportionate treatment by the literature could properly reflect hazards encountered in these sports. However, this would probably be an erroneous assumption in view of the numbers of basketball and baseball injuries projected by NEISS. Unfortunately, it is beyond the scope of this study to fill the void where data are lacking.

2.2 NEISS

The National Electronic Injury Surveillance System (NEISS) was implemented to collect injury surveillance data on a wide range of products and activities from a sample of 119 participating hospital emergency rooms. These 119 hospitals are a sample of all hospital emergency rooms in the contiguous United States. (The 96th Edition of the Statistical Abstract of the United States indicates that there were almost 6000 nonfederal "short-term" hospitals in the United States in 1973.)

NEISS broadens the scope of this study since it provides data on the general population, whereas the literature principally addresses a subset of this population--those engaged in organized activities. The structure of the NEISS precludes distinguishing between the many activities loosely referred to as sport related activities and those activities defined as sport. Only that activity which pulls together elements of personnel, supervision, officiating, equipment, and rules best characterizes sport. On the other hand, sport related activities are not well defined and are potentially related to sport only in a most obscure sense. NEISS treats these two classes of activities as one when they are, from the standpoint of this study, essentially dissimilar.

The need for distinction is also evident when approaches are considered for reducing the risks associated with these activities. Obviously, elements unique to organized activities (rules, supervision, equipment, etc.) can serve as vehicles for mitigating the incidence and severity of injuries. On the other hand, problems of reducing the incidence and severity of injuries resulting from unorganized activities, where these common elements are missing, must be addressed in other ways. Reducing the risks encountered by this population could be accomplished through information and education programs, or possibly through improving the safety characteristics of essential equipment.

The utility of NEISS, in view of the project objective, is limited for other reasons.

First, it is impossible to establish statistically valid injury rates from NEISS data, because the number of exposures experienced by those in the NEISS sample is not known. Typical measures of exposure are the number of participants (injured and noninjured), games, ski-man-days, hours, etc. Without exposure data any comparative analysis of the NEISS data assumes that each product category is equally represented in the NEISS sample.

It should not be inferred that rates (injuries per exposure) alone are sufficient for establishing priorities. The magnitude of a problem, in terms of numbers of injuries is equally important. Both statistics must be incorporated into the analysis of risks. NEISS provides an estimate of the number of emergency room treated injuries. Whether or not 1000 injuries are incurred by a population of 1000 participants or 1 million participants is unknown.

Second, the system does not include provisions for identifying any of the elements of the accident sequence. Hence, inferences concerning the relative importance of various elements in accident causation cannot be made.

Third, any rationale for establishing an optimum set of priorities for mitigating the hazards of sports must include measures of severity. Sufficiently detailed measures are lacking because severity ratings are not an integral part of the recording format. As a result, measures of severity must be based on arbitrary ratings and derived in secondary analysis. Such measures may be misleading if used for establishing priorities. Furthermore, these data are limited to immediate consequences. Data on long term or late effects of trauma, critical to an accurate assessment of severity (202), are not recorded.

Because it is impossible to identify circumstances related to injuries and the relative risks incurred by various groups, the utility of the NEISS data is limited.

3. DISCUSSION

This section begins with an analysis of data collected by NEISS. Injuries and major injuries are discussed. A discussion of sports fatalities follows. This section closes with a discussion and analysis of material obtained from the published literature.

3.1 NEISS

NEISS[3] provides data over a four year period, from July 1972 through June 1976, providing a multi-year and relatively consistent base of surveillance data about the distribution of injuries treated in the sample of hospital emergency rooms by type of injury, affected body part, age, sex, and disposition. The numbers of injuries presented in this report are in terms of national projections of hospital emergency room treated injuries.[4] These projections are derived by multiplying the number of injuries reported by each hospital and summing the results for all hospitals. The weight factor assigned to each hospital is determined by the nature and number of similar hospitals in the country. These are standard weights developed and used by CPSC in their analyses.[5]

3.1.1 Projected National Emergency Room Injuries

As indicated by table 1, 85% of the injuries are related to football, baseball, and basketball activities. The percentages of injuries distributed between these activities differs only slightly. However, when only those injuries incurred by youths 20 years or less are considered, these differences become more pronounced. Football activities clearly account for the greatest number of injuries. Although the number of injuries related to gymnastics and trampoline activities are low, practically all injuries are incurred by youths 20 years old or less. In general, this age group accounts for 73% of all injuries.

---

[3] NEISS data presented in this report were extracted from data tapes prepared for NBS by CPSC.

[4] See appendix A for data pertaining to specific injury types.

[5] Obtained from the Bureau of Epidemiology, CPSC.

Table 1. NEISS emergency room injury projections for FY 76 by product category and age group

Product Category	All Ages: Projected injuries June '75 - July '76	All Ages: % of all injuries	Age Group < 20 Years: Projected injuries June '75 - July '76	Age Group < 20 Years: % of corresponding injury projections for all ages
Football	386 944	31%	331 748	86%
Baseball	351 073	28	207 575	59
Basketball	329 637	26	235 965	72
Snow skiing	85 807	7	54 292	63
Ice hockey	25 919	2	18 441	71
Gymnastic	54 105	4	50 814	94
Trampoline	18 465	1	17 642	96
	1 251 940	100%	916 477	73%

For the most part, this predominance of football, basketball, and baseball injuries is the result of greater numbers participating in these activities. This conclusion is supported by data presented in table 2 on sports participation in institutions of the National Collegiate Athletic Association (NCAA) (321) and the National Federation of State High School Associations (NFSHSA) (322). The participation pattern for various activities parallels the results indicated by table 1. To extend this analysis further would be misleading

Table 2. Numbers[a] of participants in recreational programs of member institutions of the National Federation of State High School Association (322) and the National Collegiate Athletic Association (321)

Sport	Interscholastic high school	Intercollegiate athletics	Intramural sports (college)	Total All levels
Tackle football	1 113 106	42 187	4 341	1 493 101
Other football activities	19 066	----	314 401	
Baseball	426 424	19 487	8 198	973 537
Softball	155 552	3 185	360 691	
Basketball	1 127 797	22 937	412 246	1 562 980
Skiing	19 510	1 324	2 855	23 689
Ice hockey	30 065	2 851	15 074	47 990
Gymnastics	116 764	4 202	3 763	124 729

a) These data do not account for all sports participants.

since the participation data provide only partial estimates. Participation data for pre-secondary school and non-scholastic sports are not included. In addition, the unknown numbers participating in sports related activities would increase participation estimates tremendously, particularly, for sports such as football, basketball, and baseball.

In view of the project objective, it would be desirable to express injuries in terms of rates for comparative analysis. Risks of participation might be expressed in terms of injuries per unit of exposure. Obviously, NEISS provides input for estimating numbers of injuries, but exposure estimates for the broad base of participants sampled by NEISS are unmeasurable. A more realistic measure of the risks incurred in sports activities may be in terms of injuries per unit of participation. However, satisfactory estimates of participation for all groups have not been obtained. Even if these data were available, it may be inappropriate to establish rates without further adjustments for geographic factors. Establishing priorities on the basis of numbers of injuries alone suggests that football, basketball, and baseball should receive the greatest priority for further investigation.

Relative to other NEISS product categories, only two, "Stairs, Ramps and Landings" and "Bicycles and Bicycle Equipment," account for more emergency room injuries (324) during this period, than football, baseball, or basketball.

3.1.2 Major Injuries

All injuries reported through the NEISS are classified according to one of four disposition codes:

1. Treated and released or examined and not treated;
2. Treated and transferred for hospitalization;
3. Admitted for hospitalization;
4. DOA or expired in emergency room.

Major injuries will be defined as those injuries classified according to code 2, 3, or 4.

As indicated in table 3, football accounts for the greatest number of major injuries, followed by baseball and snow skiing. Snow skiing[6] accounts for the highest ratio of

---

[6]Ski injuries may be misrepresented by the NEISS. See discussion, page 19.

major to all injuries--1 out of every 13 injuries is a major injury. Conversely, basketball suggests the lowest ratio. The incidence of major injuries incurred by youths less than 20 years old is similar to that indicated by table 1--72% of all major injuries compared to 73% of all injuries are incurred by this age group.

Table 3. NEISS major injury projections for FY 76 by product category

Product Category	All Ages: Major injury projections June '75 - July '76	All Ages: % of all major injuries	All Ages: Ratio of major injuries to all injuries	Age Group < 20: Major injuries June '75 - July '76	Age Group < 20: % of corresponding major injury projections for all ages
Football	11 938	37%	1/32	10 613	89%
Baseball	8 063	25	1/44	4 639	58
Basketball	2 919	9	1/113	1 921	66
Snow skiing	6 608	21	1/13	3 622	55
Ice hockey	343	1	1/76	211	62
Gymnastics	1 417	4	1/38	1 361	96
Trampoline	911	3	1/20	805	88
Total	32 199	100%		23 172	72%

3.1.3 Projected Injury Trends

Table 4 provides the average annual percent changes in the projected number of injuries treated in hospital emergency rooms. As indicated, only activities related to ice hockey show a decline in the projected number of injuries.

Table 4. Average annual percentage change in projected injuries by sport--July 1972 through June 1976.

Activity	Average Annual % change
Football	19.1
Baseball	22.7
Basketball	20.4
Snow skiing	4.0
Ice hockey	-3.4[a]
Gymnastics	51.1
Trampoline	3.9

[a]Based on two years of data July 1974 through June 1976.

Injuries resulting from gymnastic activities have increased at the greatest rate. However, given the greater numbers of injuries in activities related to football, baseball, and basketball, the increases corresponding to these activities are of greater consequence.

3.2 Fatalities

Data pertaining to fatalities in sports come from two sources--the CPSC's Death Certificate Project and the Annual Survey of Football Fatalities.

3.2.1 Death Certificate Project

The Death Certificate Project was initiated by the CPSC to "provide additional information concerning hazard patterns." (324) The project is designed to collect certificates from 54 health jurisdictions, New York City, the District of Columbia, Puerto Rico, and the Virgin Islands. At this time, not all jurisdictions have reported. Thus, these data do not reflect the totality of sports fatalities. It should also be noted that these fatalities are the result of a broad range of sports activities (from recreational to competitive activities) and no inferences can be made regarding the role of protective equipment.

The seven product categories emphasized in this study have accumulated 126 certificates of death since 1973. Table 5 provides a summary of these certificates. They are primarily distributed in the categories related to football, baseball, and snow skiing activities. These fatalities are associated primarily with head injuries.

3.2.2 Annual Survey of Football Fatalities

Another source of information on fatalities in sports has been the Annual Survey of Football Fatalities initiated in 1931 by the American Football Coaches Association. Since then, a study has been conducted each year with the exception of 1942. The 1975 report (5) indicates 1221 fatalities have been recorded during the past 43 years as a result of football activities. Of these, 821 have been classified as "direct" and 400 as "indirect."

The criteria for making these classifications are as follows: Direct--"Those deaths which resulted directly from participation in football"; Indirect--"Those which are caused by systematic failure as a result of exertion while participating in football activity or by a complication which was secondary to a non-fatal injury."

Table 5. Summary of death certificates collected by CPSC as of October 1976 by sport, year of death, and location of related injury

(These data were extracted from the certificates by CPSC staff.)

	Yr.	Head injury	Neck/ spine	Trunk internal	Other	Total	
Football (Prod. Code 1211)	73	10	1	2		13	51 (40%)
	74	13	2	2	3	20	
	75	9	3	1	4	17	
	76				1	1	
Baseball (1204)	73	4		2		6	35 (28%)
	74	11		2	3	16	
	75	5			2	7	
	76	4			2	6	
Basketball (1205)	73	1				1	8 (6%)
	74	2			1	3	
	75		1	1	1	3	
	76	1				1	
Snow skiing (1216)	73	1		1		2	23 (18%)
	74	4	2		1	7	
	75	5			2	7	
	76	4	1	1	1	7	
Ice hockey (1279)	73					0	1 (1%)
	74					0	
	75					0	
	76			1		1	
Gymnastics (1272)	73					0	2 (2%)
	74	1				1	
	75		1			1	
	76					0	
Trampoline (1233)	73					0	6 (5%)
	74	2	2			4	
	75		1	1		2	
	76					0	
Total (%)		77 (61%)	14 (11%)	14 (11%)	21 (17%)		126 (100%)

The majority of all football-related fatalities have occurred in high school football (60.5%), followed by sandlot (20.9%), college (11.1%) and pro and semipro football (7.5%).

Direct fatalities were primarily the result of head injuries (60.6%), followed by injuries to the spine (18.3%) and injuries to the abdominal or internal organs (17.0%).

In 1975, there were 15 direct fatalities, 13 involving the head and 2 involving the spinal cord. There have been 57 direct fatalities recorded in the four seasons between 1971 and 1975 (2-5). Fifty-three of these fatalities resulted from injuries to the head, neck, and spinal cord.

The incidence of fatalities in sports appears to be low. For example, Blyth and Arnold (5) calculate the average number of fatalities directly related to football to be 1.09 per 100 000 players annually.

3.3 Published Literature

There are no comprehensive studies that examine injury patterns across all sports. Most of the literature concerns specific problems within individual sports. A direct comparison of these reports is usually impossible because each employs a different definition of reportable injury, different definitions of severity, and focuses on different problems and populations. The literature can be grouped into that material concerning the distribution of injuries within a sport and reports emphasizing specific issues. Specific issues are discussed in the latter portion of this section. However, to place these issues in proper perspective a review of the distribution of injuries is presented first.

3.3.1 Distribution of Injuries by Sport

a. Football

Football has been the principal target of most athletic injury research. As a result, reports on football injuries are numerous. Those presented were chosen because they are the more recent reports available or they illustrate a particular approach to research and reflect the literature regarding the overall distribution of injuries encountered within this sport.

Garrahan (21), in a study of the 1960-65 high school football seasons in Rhode Island, obtained injury data from insurance claim forms. Of 11 020 football athletes participating in this 6-year period, 2191 were injured. This injury rate (19.9 injuries per 100 participants) is one of the lowest reported for football and is typical of rates based upon insurance claims.

Most injuries involved the

knee,	- 13.4%
hand,	- 12.7%
ankle,	- 8.4%
shoulder, and	- 7.4%
back.	- 7.2%

The types of injuries were

strains and sprains,	- 61.0%
fractions,	- 15.2%
concussions, and	- 4.9%
lacerations.	- 4.7%

A study by Allen (1) of 465 football players, constituting 5 teams participating in league play during the 1965 and 1966 season at Clarke Air Force Base, recorded 200 injuries for a rate of 62.4 injuries per 100 participants. This is the highest reported injury rate for any population of football players. Also, the severity of these injuries exceeds that usually reported.

One hundred and eleven (38%) injuries were graded as major injuries; 22% "resulted in the player being out for the season"; and 13% resulted in hospitalization. There was a total of 711 days of hospitalization resulting in an average of 2.45 hospitalized days per injury. The body parts most frequently injured were the

knee,	- 21.4%
ankle,	- 15.9%
forearm-wrist-hand,	- 12.4%
shoulder girdle,	- 11.4%
upper arm-elbow,	- 5.5%
thigh,	- 5.2%
spine-back-neck, and	- 4.1%
foot.	- 4.1%

The knee also accounted for 30% of the 111 major injuries.

The most common type of injuries were

contusions,	- 29.7%
sprains (injuries to the ligaments),	- 27.6%
strains (injuries to the musculotendinous structures)	- 14.5%
fractures,	- 6.2%
abrasions and lacerations, and	- 5.5%
dislocations.	- 3.4%

Sprains and strains also accounted for 40.5% of the 111 major injuries.

The National Football Injury Report (28) represents a joint effort by the National Collegiate Athletic Association Committee on Medical Aspects and Competitive Safeguards of Sports and the U.S. Public Health Service, to provide nation-wide data at the college level on the incidence and causes of football injuries. The report is plagued by what the authors refer to as "some confusion as to what constituted a reportable injury." Data were drawn from 40 schools participating in National Collegiate Athletic Association (NCAA) football during the 1970 season.

There were 2782 injuries reported and classified according to three degrees of severity: "Active Participation" (those injuries without time lost from participation); "Partial Participation" (injuries with time lost from games or practice); and "Hospitalized." The 2782 injuries involved 1468 players. These were classified as "Active Participation" injuries in 37.5% of the 2782 injuries; "Partial Participation" injuries (56.0%); and "Hospitalized" (6.5%).

The principal types of injuries reported were

sprains,	- 31.1%
contusions,	- 25.4%
strains,	- 17.1%
concussions, and	- 6.5%
fractures.	- 4.7%

The most frequently injured body part was the

knee,	- 18.2%
ankle,	- 12.0%
head and face,	- 10.6%
thigh, and	- 5.7%
shoulder.	- 5.3%

Of the 179 hospitalized cases, 40.8% were the result of knee injuries and 20.7% the result of head and face injuries.

Probably the most comprehensive study of high school football injuries is one conducted in North Carolina between 1968 and 1972 by Blyth and Mueller (9). This study included 43 high schools selected on the basis of size, and for logistic reasons, within a 100-mile proximity of Chapel Hill, North Carolina. As a result, 8776 participants were included in the study. A reported injury was "one occurring as a result of participation in an organized football program at the high school level, for which professional treatment was received, and/or which resulted in restriction or modification of the boy's usual activity for one day beyond the day of injury."

There were 4287 injuries recorded in four years resulting in an average injury rate of 488 injuries per 1000 players. Data on these injuries were the result of interviews with coaches, injured players, and fellow players.

The major types of injuries were

sprains,	- 20.4%
contusions,	- 17.7%
fractures,	- 10.6%
pulled muscles,	- 8.8%
strains,	- 7.4%
lacerations, and	- 5.8%
concussions.	- 5.4%

Injuries were distributed in the following manner:

lower leg, knee, and ankle,	- 38.0%
trunk,	- 13.2%
head and neck,	- 12.9%
shoulder,	- 8.3%
hand, fingers, and thumb,	- 8.0%
lower arm, including wrist and elbow,	- 6.7%
upper leg,	- 5.4%
back,	- 4.7%
foot and toe, and	- 2.9%
upper arm.	- 1.4%

The most frequently injured body part was the lower leg (including knee and ankle) with 38.0% of the reported injuries. Over one half (50.8%) the lower leg injuries involved the knee, followed closely by the ankle (40.3%).

A severity classification for specific groupings of injuries was not given. However, the overall severity of the 4287 injuries was assessed. Of these injuries, 34.7% resulted in "seven or more days lost from participation by injured participants."

The frequency of injuries resulting from a "blow from object" accounted for 31.2% of all injuries. The "objects" were recorded as helmets causing 38.8% of these injuries, shoes (23.1%), shoulder pads (15.2%), and knees (11.9%). Injuries involving helmets and shoulder pads as the "objects," accounted for 16.8% of the total number of injuries.

Other major classifications of causes include:

collision with another person,	- 20.1%
torsion or twisting,	- 10.8%
collision with object,	- 8.6%
contact with sharp, hard, or rough object,	- 4.0%
illegal act,	- 3.7%
stepped in or on object,	- 2.6%
improper technique, and	- 1.9%
ill fitting, broken, or defective equipment	- 1.7%

Summary

Injuries occurring in football are primarily distributed about the

knee and ankle,
hand and arm, trunk, and
shoulder.

The principal types of injuries are

sprains and strains,
contusions, and
fractures.

Since football is a contact sport, it is not surprising that most injuries result from impacts with objects and collisions with other persons.

b. Ice Hockey

Ice hockey, like football, is a contact sport involving forces which are potentially injurious. These forces are transmitted through body checks, stick, puck, skate blades and contact with boards, surface, or goal posts.

An early survey (1963-64 season) by Toogood and Love (111), collected injury data from insurance claims on 85 reported injuries from a population of 2469 participants (ages 7-18 years) in the Toronto Township Hockey League. Although the report implies mouthpieces and headgear were worn (the extent to which these were worn is not mentioned), 65.9% of the injuries were injuries to the head or face. The mouth and teeth accounted for 24.7% of these injuries. The majority of head and face injuries were due to being hit by the hockey stick (18.8%), puck (12.9%), or skate (7.1%).

A survey (109) of hockey injuries during the 1969-70 season "within the greater Edmonton metropolitan area," collected data on 446 injuries involving 345 players. The survey included 6890 players, ages 9 through "18 plus," from 461 teams. Again, the majority of injuries were to the head and face (55.5%). Injuries were distributed to the

head and face,	- 55.5%
shoulder,	- 7.4%
knee,	- 7.4%
hand,	- 4.9%
ankle, and	- 4.7%
wrist.	- 3.6%

The typical injuries were

lacerations,	- 34.8%
bone/muscle bruise,	- 19.5%
fractures,	- 12.8%
sprains/strains,	- 12.6%
teeth,	- 8.7%
concussions, and	- 4.3%
dislocations.	- 3.6%

The "causes of injury" were attributed to the

stick,	- 32.7%
puck,	- 17.7%
boards,	- 15.9%
body check,	- 12.1%
accidental collisions between players,	- 7.4%
fall or trip,	- 5.8%
skates,	- 3.6%
fights, and	- 2.5%
goal posts.	- 1.8%

Inadequate or faulty equipment was named in 0.2% of the total injuries. The extent to which helmets and intra-oral mouth protectors were worn by all players cannot be determined.

However in 90% of the injuries involving teeth, the players were not wearing a mouth protector. Ninety-three percent of the lacerations were to the facial area. Of the 19 players suffering concussions, 17 were wearing hockey helmets.

Hayes (102) collected ice hockey injury data during the 1970-71 season from 21 Canadian and 9 American universities conducting intercollegiate hockey programs. The 328 injuries were distributed about the

head and face,	- 45.1%
knee,	- 10.4%
neck and shoulders,	- 9.2%
trunk,	- 8.8%
ankles and feet,	- 8.2%
arms and hands, and	- 7.9%
upper leg.	- 5.5%

The distribution of these injuries "relative to the cause" included

body contact,	- 38.3%
stick,	- 29.1%
puck,	- 15.2%
ice surface, and	- 13.9%
skates.	- 3.5%

Hayes also noted that most injuries were contusions or lacerations.

c. Snow Skiing

Unlike hockey and football, ski-accident research has emphasized noncompetitive populations engaged in recreational activities. Associated with this population are wide differences in participant age, physical condition, ability, experience, exposure, training, among other factors.

Shealy (75), in reviewing the literature, estimates that there are between 3 and 5 million skiers in the U.S. and 165 000 to 600 000 injuries annually. Most of these injuries involved the lower extremity.

The incidence of skiing injuries estimated by Shealy is much greater than that suggested by the NEISS data. A possible explanation is that ski areas frequently provide emergency medical facilities or first-aid stations at the base of the slopes. As a result, many injured skiers are treated locally and may not require emergency room treatment. Since NEISS reflects only those cases treated in the emergency rooms of participating hospitals, these injuries are not recorded.

Arnold and Ackman (45) in a study of ski injuries in Canada, indicate approximately 39.0% of all injuries are sprains followed in frequency by

fractures,	- 32.0%
cuts,	- 15.0%
dislocations, and	- 4.0%
frostbite.	- 1.0%

The lower extremity was injured in approximately 70% of the cases. In commenting on the effectiveness of release bindings the authors indicate, "approximately half the injured skiers felt that their bindings failed to function properly at the time of their injuries."

Snow conditions were indicated as factors contributing to the "causes of accidents" in 30% of the cases, closely followed by "carelessness" (27.5%); "faulty equipment" was indicated in 10% of the cases.

In an analysis of ski injuries encountered during the 1972-73 season at a Vermont ski area and treated at the emergency medical care facility at the base of the slope, Gutman (59), et al., recorded 792 injuries. Sprains were the most frequently reported injuries, accounting for 43% of the total. Fractures were second with 31% of the total. Thus sprains, strains, and fractures represented 74% of all injuries in that survey. These 584 injuries involved the upper extremity (including trunk) in 33.9% of the cases and lower extremity in 65.8% of the cases.

These statistics compared with a similar and earlier study of the 1960-61 season by the same authors, show little change in the overall injury rate and similar distributions of specific types of injuries. However, this comparison shows the number of upper extremity sprains and fractures have increased from 49 in 1960-61 to 198 in 1972-73 while lower extremity sprains and fractures have decreased from 476 in 1960-61 to 384 in 1972-73. Total sprains and fractures increased from 539 to 584 for the same period. The authors hypothesize that modern equipment, "hard-plastic boots," and "improved release binding" may be the reason for this slight shift in the injury pattern.

The changing patterns of ski injuries was the subject of a report by Tapper and Moritz (78). They compare data collected at one ski area during the 1969-72 skiing seasons with injury records of earlier seasons. The rate of ski injuries, according to the authors, has declined from 7.4 per 1000 skiing days in 1960-61 to 3.2 injuries per 1000 skiing days in 1971-72. The most "significant factors" in the declining injury rate, according to the authors, have been "the slope grooming and continued expansion" of the skiing area.

The most pronounced change in injuries has been a decline in ankle sprains and fractures and foot injuries and an increase in tibial shaft fractures. Of the tibial shaft fractures occurring during the 1971-72, 30% were in children under the age of 10. Injuries involving the knee, tibia, ankle, and foot accounted for 45% of the injuries during the 1969-72 seasons.

In most accidents, injured skiers blamed slope conditions, bindings, collisions, or ski poles as the "cause" of their injury--37% directly blamed malfunction of their bindings.

Garrick and Kurland (58), in a study assessing the methods of collecting ski injury data, suggest that "data from ski patrol reports may not represent accurately the number of injured skiers or the characteristics of all the injured as a group."

In a controlled experiment to determine the extent that injuries are not reported, they found that characteristics of sex, age, and skill level were significant in determining who would and who would not report injuries. Of the injured seen in this experiment, 45% had not reported their injuries to the local ski patrol. The importance of this result should be emphasized. First, reports using data collected by the ski patrol or at the ski-area first-aid station apparently underestimate the extent of the injury problem. Second, such studies may be misleading since young, inexperienced, or female skiers are most likely to report their injuries while their counterparts are least likely.

A study by Shealy, et al. (75) supports this finding. Their study population consisted of 2071 members (primarily students - 90%) of a ski club in Buffalo, New York. Data were collected through questionnaires sent to members. When comparing results with those of the ski patrol for the same period, the authors found that 58% of all fractures and 84% of all non-fractures and 80% of all injuries had not been reported to the ski patrol. In addition, the same reporting biases in age, sex, and experience were observed as in the study by Garrick and Kurland.

d. Baseball

The published literature offers very little regarding injuries related to baseball activities. A report by Polk (96) was published in 1968 and provides data on the frequency and causes of baseball injuries incurred by professional and college baseball players. The principal types of injuries reported in this survey were

sprains,	- 27.3%
strains,	- 18.7%
contusions,	- 16.9%
pulled muscles, and	- 11.3%
fractures.	- 8.3%

These injuries accounted for 82.5% of all injuries.

Sprains were primarily due to sliding and running between bases. Strains were predominantly the result of throwing, followed in frequency by running between the bases. Contusions were primarily the result of a batter being hit by the pitched ball or as a result of collisions between players. Pulled muscles were predominantly due to running between bases or throwing. The causes of fractures were distributed evenly between sliding and the batter being hit by the pitched ball.

e. Basketball

Few reports were obtained describing injuries and related factors associated with basketball. There is a paucity of published literature regarding this sport.

Basketball injuries, according to the authors of a University of Toronto study (288), are primarily sprains and strains. This type of injury accounted for 58.3% of all intercollegiate and intramural athletic injuries. The most frequently occurring injuries were

sprains and strains,	- 58.3%
contusions,	- 14.0%
fractures, and	- 5.1%
abrasions/lacerations.	- 4.6%

Injuries were distributed about the

ankles,	- 31.6%
hands/wrists/fingers/ thumbs,	- 20.1%
knees,	- 11.4%
head/face, and	- 6.7%
elbows/shoulders.	- 4.3%

f. Gymnastics

Gymnastics includes a variety of activities. The sport encompasses the events of floor exercise, vaulting, rings, horizontal bar, parallel bars, pommel (side) horse, and includes activities of trampolining and tumbling.

Bozdech (361, pp. 541-542), in surveying the literature of European countries, indicates the relative injury rate (number of injuries in 100 athletes per year) is between 0.8 and 2.07 percent. According to Bozdech "the greatest number of injuries occur on the parallel bars; then follow the horizontal bar, rings, and horse. But the most dangerous apparatus is the horizontal bar: Of all fatal injuries, 36 percent occur on this apparatus as opposed to only 18 percent on the rings." Most of the injuries in gymnastics, he claims, are the result of a wrong execution of the exercise. Defects in the apparatus is second in causing injuries, but he adds "this is far less common."

The reasons why the horizontal bar is the more hazardous apparatus are not given by Bozdech. However, the increased risk is probably due to the height of the apparatus (102 3/8 in (40.31 cm) from floor to bar) (125, p. GY10, Rule 1) and the requirement for executing maneuvers. In the latter case the performer must release and regrasp the bar, providing opportunity for falls.

The published literature provides no additional injury statistics regarding trampoline activities. However, according to Piscopo (121, p. 34-37) "the element of risk sharply increases when somersault turns are introduced."

3.3.2 Specific Issues

Several of the more frequently occurring or severe sports injuries are emphasized by the literature. These include head and facial injuries, lower leg, spinal injuries, lower extremity equipment related ski injuries, and injuries related to playing surfaces. These are discussed in the following sections.

a. Head Injuries - Concussions

Injuries involving the head have created greater concern than injuries to any other parts of the body. It is not because these injuries occur more frequently, but because of their potential severity. Although there are limited data available to quantify the extent of serious head injuries in sports, many studies have been published which provide insight into this problem. Probably the most notable of these studies are the annual surveys of football fatalities (2-5). According to the Forty-Fourth Survey (5) 819 deaths resulted directly from participation in football over the past 44 years. Sixty-one percent of the recorded deaths resulted from head injuries (66% as a result of high school football, 20% from "sandlot" football, 7% from college and 7% from "pro and semipro" football activities). Unfortunately, similar studies for other sports have not developed.

Recently the CPSC began collecting death certificates. These data do not reflect the totality of sports fatalities nor at this time are they relevant to statistical analysis. However, the certificates provide additional information on the severity of head injuries in sports. As indicated in table 5 (page 12), head injuries account for 61% of the certificates on record for the seven sports. It should be noted that these fatalities are the result of a broad range of sports activities (from recreational to competitive activities) and no inferences can be made regarding the role of protective equipment. They do emphasize, however, the importance and need for adequate head protection in sports.

Concussions, according to NEISS,[7] account for approximately 1% or less of all injuries reported for each sport. However, when only major injuries (those requiring hospitalization) are considered, concussions become more apparent accounting for

11.8% of major football injuries,
8.7% of major basketball injuries,
11.6% of major baseball injuries,
2.5% of major snow skiing injuries,
9.5% of major gymnastic injuries, and
5.4% of major trampoline injuries.

Again, it must be noted that these data are drawn from the general population and the specific role of protective equipment is unknown.

Many studies have emphasized particular populations and show the incidence of head injury in relation to other injuries. The study of North Carolina High School football injuries discussed earlier (9), surveyed 45 schools over a 4-year

---

[7]See appendix A.

period--1969-1972. Two hundred and thirty-one concussions were recorded for 8776 football participants in the sample schools. Assuming other regions of the country experienced similar rates (2.6 concussions per 100 athletes), the resulting projection is substantial--28 941 concussions annually occurring in interscholastic high school football alone.

In relation to other injuries, the North Carolina study showed concussions accounted for 5.4% of all reported injuries. This is comparable to rates reported in other studies conducted by Garrahan (21), Martin, et al. (28), and Grippo (25).

Table 6. Comparison of head injury (concussions) reported by various studies.

Source	% of all injuries	Population
Garrahan	4.9	High School Football 1960-1965
Martin, et al.	6.5	College Football 1970
Grippo (SRI)	4.5	Professional Football 1974
Blyth, et al. N.C. Study	5.4	High School Football 1969-72

There is no argument as to the etiology of head injuries. As Snook (175) suggests, "...the etiology is a blow to the head,..." The injuries that follow may be "...cerebral concussion, intracerebral hemorrhage, craniocerebral hematoma, either epidural and subdural, and cerebral hemorrhage." Thus, the prime objective of a helmet is to provide a "smooth ride for the brain" (163) by attenuating the forces of impact (158). But the characteristics of these impacts depends upon the sport (143, 156). In hockey and baseball these impacts are characterized by high velocity low mass impacts (puck, ball, stick), whereas the reverse holds true for football.

The head injury problem has attracted the attention of two groups currently developing standards in athletic equipment--the National Operating Committee on Standards for Athletic Equipment (NOCSAE) and the ASTM Committee F-8. NOCSAE has prepared and implemented a "Standard Method of Impact Test and Performance Requirements for Football Helmets" (348) based on work done at Wayne State University. As of August 1976, a total of 93 helmet models have passed the

NOCSAE standard (327). ASTM will soon follow with a football helmet test procedure. Both are preparing and considering standards for ice hockey helmets and NOCSAE will soon present a baseball batting helmet standard (330).

The NOCSAE standard is a significant document in that it has established the minimum level of performance helmet manufacturers must attain if their helmets are to be used in high school and college football programs throughout the nation. This is the result of recent decisions by the rules committees making the wearing of NOCSAE approved helmets mandatory for college football players in 1978 and high schools in 1980 (174, 37).

Considerable controversy has surrounded the differences between the NOCSAE test methods and the ASTM method of testing helmets, particularly with respect to the headform--NOCSAE using a resilient headform and ASTM favoring a rigid metal headform.[8] The extent of these differences, particularly regarding the ability to reflect safety performance characteristics, is not known. Some proclaim a distinct difference exists. Hodgson (147) commenting on this difference notes, "...some comparative drop tests were made using human cadavers. The data revealed that the MHF (metal headform) was not only unrealistic in response characteristics, but also distorted the comparison between helmets, thus making a more realistic head model essential to progress." On the other hand, Newman (158) cites recent work "with both cast magnesium and soft headforms" where results indicated that "the physical properties of the headform have little influence on helmet response."

Recent tests, in which NBS participated (129, 130, 131), indicate the existence of "substantial differences in the measured values of maximum accelerations transmitted to the headform when using the NOCSAE and ASTM test systems" and "poor correlation between the two test methods." If in fact the results differ substantially between two relatively simple drop tests, what differences prevail when playing field conditions are substituted for laboratory conditions?

Of further concern has been the failure to demonstrate interlaboratory reproducibility of test results. This was indicated by Andrews (129, 130) and more recently suggested by the results of the "NOCSAE Round Robin" presented at the ASTM meeting of January 1977.

---

[8]Several reports are available that examine in considerable detail the difficulties of evaluating protective headgear, for example, reports by Berger (134) and Newman (158).

Another controversial point concerns the criteria for determining failure, i.e., "at what point the output exceeds that, which, from a biomechanical point of view, would be injurious to the wearer of the helmet" (158). Data needed to confirm or dispute this argument do not exist.

The criteria used in the NOCSAE test is based on an approximation of the Wayne State Tolerance (WST) curve:[9]

$$SI = \int_{0}^{T} a^{2.5} dt.$$

Portions of the WST curve were derived from tests using human cadavers, animals, human volunteer studies and accidental free falls (158). This curve has never been verified for living humans (158), nor is there convincing evidence in the published literature showing correlation between the severity index and tolerance to impact conditions encountered on the playing field.

Studies to determine the characteristics of impacts encountered under playing conditions are practically non-existent. Radio telemetry has been attempted (163) but the results are questionable. That differences in the two environments exist is obvious. In the laboratory the helmet absorbs most of the impact. On the field the helmet becomes an element of the system absorbing part of the impact and the physiologic response of the athlete dissipating the rest (163). Further, current test methods for helmets simulate only the translational component of acceleration. Obviously, head impacts in sports result in both translational and rotational motions. The importance of the rotational component relative to the translational component has not been conclusively demonstrated.

Still to be resolved is the question as to how long a certified helmet maintains its certified condition. This is a complicated problem that depends on several factors including type of helmet, age, usage pattern, and if it will be reconditioned periodically.

Research in helmet testing is in its first generation and it is apparent in reviewing the published literature that current testing methods are embedded in considerable controversy. These problems can only be resolved by stimulating and encouraging research.

---

[9]See appendix B.

b. Facial Injuries

Facial injuries have also attracted the interest of those concerned with sport safety. These injuries occur with greatest frequency as a result of ice hockey activities.

Of the ice hockey data collected through NEISS over the past two years,[10] almost 56% involve an injury to the head, ear, eye, face, or mouth. The face alone accounts for 38.9% of all injuries.

The survey of ice hockey injuries (1963-64 season) by Toogood and Love (111), of the Toronto Township Hockey League support these data. Of the 85 injuries, 65.9% were injuries to the head or face. The mouth and teeth accounted for 24.7% of these injuries. The majority of head and face injuries resulted from being hit by the hockey stick, puck, or skate.

The survey (108) of hockey injuries during the 1969-70 season "within the greater Edmonton metropolitan area," also indicates that the majority of injuries involve the head and face (55.5%). Injuries involving the head were distributed about the

mouth,	- 16.4%
eyes,	- 13.7%
nose,	- 8.1%
head (not face),	- 4.7%
forehead,	- 4.5%
cheek, and	- 4.3%
jaw.	- 3.8%

Typical injuries were

lacerations,	- 34.8%
bone/muscle bruises,	- 19.5%
fractures,	- 12.8%
sprain/strains,	- 12.6%
teeth,	- 8.7%
concussions, and	- 4.3%
dislocations.	- 3.6%

The study of ice hockey injuries during the 1970-71 season by Hayes (102) shows similar findings. Of 328 injuries encountered in 280 collegiate games, slightly more than 45% involved the head and face.

---

[10] See appendix A, table A.6.

It is apparent from the available literature that over 45% of hockey injuries involve some part of the face. This is substantiated by the Massachusetts Medical Society's recent findings and recommendations.

> "A Committee of the Massachusetts Medical Society finds a startling increase in eye and facial injuries in hockey at all levels and recommends every player--not just goalies--wear full masks." (113)

Face shields are becoming increasingly popular in hockey and will be mandatory for all Ameteur Hockey Association (AHA) players up to age 16 starting this season and for Massachusetts secondary school players in 1978 (115).

Goalie masks are worn by practically all goalies. The performance of these masks was the subject of a clinical test by Sze, et al. (110) Their test apparatus consisted of a rigid headform. The location, magnitude, and direction of puck impact was controlled by a puck suspended on three guy wires. A heavier than normal puck was used to enable the investigators "to extrapolate the findings to higher velocities for which the momentum of the modified puck is comparable to the momentum of an actual puck traveling between 80 and 100 miles per hour." The results indicate, "...two serious design weaknesses in all of the masks tested. None were able to distribute a blow which impacted on a support point. Secondly, blows away from support points caused the mask to 'bottom out' in critical regions at forces well below those commonly developed in a game."

ASTM is developing a standard for eye and face protection for hockey players. This standard which will be completed in the near future does not include contour masks for goalies. NOCSAE is in the preliminary stage of developing a face mask standard (330). The potential and alternatives for promulgating these standards should be evaluated.

c. Neck Injuries

Spinal injuries, particularly those to the cervical region also have resulted in sports. A recent study of spinal cord injuries in high school and college programs by Clarke (139), estimates that 68 permanent cases[11] occur annually (54 in high school programs, 4 in 2-year college and 10 in 4-year college programs).

---

[11]Defined as hemiplegia-monoplegia, paraplegia, quadriplegia, or death.

Of the 86 permanent cases reported in that 3-year study, football accounted for 46 (or 54%), gymnastic activities for 22 (26%), baseball for 3, and basketball for 1. Trampoline activity accounted for 36% of the permanent cases resulting from participating in gymnastic activities.

Most of the spinal injuries in gymnastics were attributed to "improper landings on the apparatus" leading that investigator to emphasize the need for "...competent supervision more to protect the participant from premature attempts to execute advanced maneuvers than to serve as a spotter for off-apparatus landings."

Annual surveys of football fatalities (2-5) have collected data over a 43-year period. The most recent survey (5) provides data on 819 fatalities directly related to football activities--18.3% of these were the result of spinal injuries, primarily injuries involving the cervical spine. Since 1970, spinal injuries have accounted for 17.9% of all direct football fatalities.

The incidence of neck injuries, however, appears to be low. The North Carolina Study (9) of high school injuries showed 2.6% of all injuries were neck injuries. The "National Football League 1974 Injury Study" found 2.8% of all injuries involved the neck. The NEISS data provides rates for the general population. These are shown in table 7. The incidence of neck injury is less than 5% for any category.

Table 7. NEISS data--average annual number of projected emergency room injuries involving the neck by sport (FY 1973-76)

	Average annual projected number %	Injuries requiring hospitalization %
Football	3779 (1.2)	4.6
Basketball	791 (0.3)	3.4
Baseball	1661 (0.6)	0.8
Snow skiing	537 (0.6)	7.4
Gymnastic	1086 (3.0)	11.3
Trampoline	813 (4.4)	4.0
Ice hockey	202 (0.8)	0.0

Although gymnastic and trampoline activities produce more neck injuries per 100 reported injuries, football activities provide the greatest number of neck injuries. Gymnastic activities also produce the greatest rate of major injuries.

The principal factor in the production of neck injuries "...is a forceful displacement of the neck in one direction or, less commonly, in a twisting action." (175)

Liedholt (154) suggested that the "forces that produce injuries of the spine can be divided into compression, flexion, extension, lateral flexion, rotation and horizontal shear." Of these, flexion, extension, and lateral flexion are primarily associated with severe neck injuries in sports.

In an early study of head and neck injuries published in 1961, Schneider (171) reviewed 14 football fatalities. He noted that, "Often the unyielding plastic face guard was found to have been forced upward, throwing the neck into hyper-extension. ...The posterior rim of the helmet,..., was driven against the back of the neck and frequently caused severe injury to the cervical vertebrae and spinal cord."

Alley (128), a few years later, in a study of head and neck injuries in high school football reached the opposite conclusion and noted that, "the vast majority of neck injuries were sustained in flexion, and the faceguard was found not culpable in the production of those injuries." He further indicated that many of these injuries were the result of a technique known as "spearing."

More recently, Snook (175) commented, "...that such hyper-flexion injury is relatively rare," and noted that, "By far, the most common type of neck injury that we have seen is the lateral-flexion neck injury in which the head is sharply laterally flexed to one side." He also suggests that "high shoulder-pads" or "neck collars" protect against these injuries.

The face mask probably contributes to neck injury. Considering the observed mechanisms of neck injury, the protruding face mask serves as a lever for increasing the effective load applied to the cervical spine. In recognition of this fact, some have encouraged the removal of the mask. However, as Torg has been quoted (187), "due to playing techniques and attitudes inculcated in players today, I think to remove the face mask would be sheer folly." The face mask and helmet have become integral parts of techniques employed in blocking and tackling. As one investigator notes, "...improved headgear makes it possible for a good tackler to stop a runner cold with a head-on tackle." (184)

Recently, the National Football Alliance, realizing the hazards of using the head in blocking and tackling, implemented rules making illegal the techniques of butt blocking and face tackling. Butt blocking is defined as "a technique involving a blow with the face mask, frontal area, or top of the helmet, driven directly into an opponent as the primary point of contact, either in close line play or in the open field." (186) Face tackling is defined as "driving the face mask, frontal area, or top of the helmet directly into the runner." (186) The NCAA made similar rule changes, making it illegal for a player to "deliberately use his helmet to butt or ram an opponent" and to "intentionally strike a runner with the crown or the top of his helmet." (37)

Because of these changes the hazards of serious neck injuries in football may be substantially reduced. However, rules have little effect unless they are enforced. According to a recent publication published by the NFSHSA "it would be difficult to remove head contact from all blocking and tackling because such a rule would be so difficult to administer that it would be unenforceable." (40)

Of greater consequence may be the positions adopted by the American Football Coaches Association and the National Athletic Trainers' Association "...opposing the use of tackling and blocking techniques with the helmet and/or face mask as the initial point of contact." (181, 30)

The effectiveness of these recent changes will have to be demonstrated. Unfortunately, good historical baseline data to aid such an analysis are limited.

d. Lower Leg Injuries (Knee)

The knee in sports is most susceptible to injury. To some "the knee was not well designed"--its strength dependent upon surrounding "large and strong muscles and strong ligaments." (203) To others the "knee is remarkable in its ability to encompass the two seemingly incompatible properties of stability and mobility and in order to accomplish this many subtle anatomic mechanisms are necessary." (367, p. 52) Therefore, it is not surprising that knee injuries account for the greatest proportion of sports injuries.

That the injuries involving the knee pose a substantial problem was suggested by Torg, et al. (230): "Each season there are an estimated 100 000 to 130 000 (football) knee injuries among professional, collegiate, scholastic, and sandlot players, with 30 000 to 50 000 of these requiring surgery."

Table 8 presents a summary of findings of recent reports with respect to knee and ankle injuries. As indicated, the knee in football is the most frequently injured body part,

Table 8. Extent of knee and ankle injuries reported by different studies.

Author	Study Period	Source	Sport	Knee		Ankle	
				% of injuries	Most frequently injured	% of injuries	Most frequently injured
Allen (1)	1965-66	U.S. Air Force Personnel Clark Football League 290 injuries	Football	21.4%	Yes	15.9%	No
Martin, et al. (28)	1970	40 schools engaged in NCAA college play 2782 injuries	Football	18.2%	Yes	11.8%	No
Blyth and Mueller (9)	1969-72	High school football players in 43 North Carolina schools 4287 injuries	Football	19.3%	Yes	15.3%	No
Grippo (23)	1969-72	Professional-National Football League	Football	25.3%	Yes	11.8%	No
Grippo (24)	1973	" "	Football	23.7%	Yes	9.4%	No
Grippo (25)	1974	" "	Football	20.0%	Yes	10.4%	No
MacIntosh, et al. (288)	1951-69	Male athletic injury records at the Univ. of Toronto 10,216 records	Football	18.0%	Yes	12.5%	No
MacIntosh	" "	" "	Basketball	11.4%	No	31.6%	Yes
MacIntosh	" "	" "	Ice Hockey	18.1%	Yes	7.0%	No
Hayes (102)	1970-71	Canadian and American institutions (20) conducting intercollegiate hockey programs 228 injuries	Ice Hockey	10.4%	No	8.2% (ankles & feet)	No
Reeves and Mendryk (108)	1969-70	Hockey players "within the greater Edmonton metropolitan area" 328 injuries	Ice Hockey	7.4%	No	4.7%	No
Polk (96)	1968	Professional and college baseball teams "all over the country" 407 injuries	Baseball	8.8%	No	16.5%	Yes
Tapper and Moritz (78)	1969-72	Sun Valley, Idaho 1502 injuries	Snow Skiing	18.0%	Yes	17.6%	No
Arnold and Ackman (45)	1970-71	Canadian ski patrol accident records 8000 accidents	Snow Skiing	20.6%	No	24.4%	Yes

accounting for approximately one out of every five injuries. Basketball, ice hockey, and baseball account for fewer knee injuries. The inconsistency reported in the incidence of ice hockey knee injuries shown by the Toronto study (18.1%) compared to the results of studies by Reeves and Hayes is probably due to the nature of that study. The Toronto study is based on injury records and emphasizes a dynamic activity over an extended period of time (1951-1969).

Knee and ankle injuries are both frequently occurring injuries in skiing (lower leg injuries related to skiing activities will be discussed in the next section). Interestingly, in instances where the knee does not account for the greatest number of injuries, the ankle predominates. (The exception is the ice hockey studies.)

A summary of lower leg injuries reported through NEISS[12] is shown in table 9. The knee and ankle are included in one classification--lower leg. The results are comparable to table 8. The lower leg is the most frequently injured body part in sports. Ice hockey is the exception, here head and facial injuries predominate.

Table 9. Projected number of lower leg injuries annually incurred by the general populace based on the NEISS sample

Sport activity	Average number of lower leg injuries per year[a]	% of Total	Most frequent body part injured
Football	74 321	23.9%	yes
Basketball	105 427	41.2%	yes
Baseball	66 653	24.5%	yes
Snow skiing	47 754	58.5%	yes
Gymnastics	8 587	23.6%	yes
Trampoline	4 433	24.4%	yes
Ice hockey	3 472	13.2%	no
Total	310 647	31.5%	

a) Derived by summing projections for each of four fiscal years and dividing by four.

[12]See appendix A.

According to the "National Football Injury Report--1970" (28), knee injuries appear to be among the most severe injuries "with a hospitalization rate of 14.5%" The overall hospitalization rate for that study was 6.5% of all injuries reported.

In Allen's study (1) of Air Force football injuries, 30% of the 111 major injuries involved the knee. Thirteen of these players required surgery.

In the "1976 Spring Football Injury Study," (15) Clarke notes: "The knee definitely was the body part most frequently receiving a significant injury." Significant injuries are defined as "those causing absence for at least one week and/or dental injuries."

Because the knee in sports is the most vulnerable joint in the body, it has been studied by many researchers. Their findings regarding factors contributing to knee injuries can be divided into four groups:

i) susceptibility to injury,
ii) physical conditioning,
iii) previous injury, and
iv) shoe-turf interface.

i. Susceptibility to Injury. In a study of 139 professional football players, Nicholas (199), suggests there are differences between athletes which account for various injuries. He devised procedures to determine the looseness or tightness of the body. These tests comprise the following indices:

- palms to floor, knees extended,
- knee recurvatum,
- rotation of the knee and ankle,
- rotation of the hip, and
- upper extremity laxity.

Thirty-nine professional football players out of 139 examined had at least three indices of looseness, and of these 72% ruptured their knee ligaments. Of the remaining 100 players with two or less indices of looseness, 9% ruptured their ligaments. In view of these findings, he concluded that, "independent of many factors responsible for injury in football, an increased likelihood of ligamentous rupture of the knee occurred in loose jointed football players and of muscle tears in tight jointed football players."

In his paper, "Muscular Strength and the Knee" (197), Klein notes that the "ligaments are responsible for maintaining the integrity of the joint structure." He reasons that, if these ligaments are loose "an increased amount of torque results before the stretch reflex response for muscle action, and the knee itself may try to prevent abnormal movement." The high incidence of knee injuries in high school football players he notes, occurs at a time when ligaments are "more flexible because of the normal pubertal growth pattern."

However, the findings of Godshall (268) do not agree with those of Nicholas or Klein. In an 8-year study yielding 2800 examinations of high school athletes the author states that "We certainly could not find any definite correlation between loose-jointedness and major injuries in our patients."

ii. Physical Conditioning. Proper conditioning is recognized by most to be a key factor in injury prevention (206, 197, 367, 248). Allman (248) comments, "The proper utilization of exercise is undoubtedly the single most important factor for the prevention of sports injuries." Sinton (206) agrees, and encourages year-round conditioning of the leg musculature, as "the best method of preventing knee and ankle injuries in athletes."

It is questionable that year-round conditioning programs are adhered to. In their analysis of injuries reported during the first three days of 1975 football practice, Powell, Carey, and Clarke (31) note that "the advent of the special rules for the first three days (of football practice) may have lulled some athletes into neglecting a well rounded preseason conditioning program...." These "special rules" limit the first three days of NCAA preseason football practice to non-contact conditioning drills.

iii. Previous Injury. Studies have shown that players with a history of injury sustain higher rates of re-injury. The North Carolina study, for example, (9) shows injury rates of 624 per 1000 for those with a history of injury while only 437 per 1000 for those without a previous injury. Of course, these rates include all types of injuries, not only those involving the knee. Unfortunately, there are no studies to show the effect of previous injury on the incidence of knee injuries. However, the literature suggests that athletes with a history of injury should concern themselves with proper rehabilitating conditioning (367, Ch. V) (197); that bracing and taping is effective in preventing re-injury (213, 203); that in certain instances individuals with previous damage should be screened from competition (213).

iv. Shoe-Turf Interface. The likelihood of a knee or ankle injury increases as the foot becomes more rigidly attached to the surface (209, 215, 25, 196, 8). In the presence of torque resulting from upper trunk rotation or a force applied to the lower extremity in a "plane other than that of normal joint motion" (209), an injury may occur.

This problem has been studied by many and solutions have emphasized cleat design. Hanley, in 1963, (196, 298), introduced shoes with flat cleatless heels and shorter front cleats. This was later modified by Smith and described by Hirata (196) as a cleat "somewhat oval in shape" and "lower in profile." A swivel football shoe is discussed by Cameron and Davis (191). It features a "metallic forefoot turntable within a molded sole which are mounted four football cleats." The turntable is capable of rotating 360°. It also features a cleatless heel "which contains a beveled notch."

Cleat configuration relative to injury rates has been investigated by some studies. Such a study was conducted by Torg and Quendenfeld (209) of two high school leagues (public and Catholic leagues) in the Philadelphia area. All reported injuries were examined by an orthopedic surgeon and graded for severity. The public high school league consisted of 18 teams for a total of 594 players per season. The Catholic league had 18 teams for a total of 704 players per season. Players in both leagues wore conventional football shoes having seven 3/4 inch (1.9 cm) cleats with tips 3/8 inch (0.95 cm) in diameter[13] during the first year of the study (1968 for the public league and 1969 for the Catholic league). For subsequent years (1969, 70, 71), the players in the public school league were required to wear "shoes with molded soles, each containing fourteen 3/8 inch (0.95 cm) cleats for both practice and games." Similarly, players in the Catholic league, for the 1970 and 1971 seasons, were "required to wear the soccer type shoe for both practice and games." All games were played on natural turf and the authors assumed that "any differences in the incidence and severity of knee and ankle injuries were due to differences in shoe type and cleat length."

In the first year, with the conventional shoe, the Catholic league encountered 93 knee injuries and 72 ankle sprains. With the soccer type shoe, the number of injuries declined to 38 knee injuries and 36 ankle sprains in 1970, and 35 knee injuries

---

[13]The NCAA and NFSHSA now require shoes with a maximum cleat length of 1/2 inch (1.27 cm).

and 39 ankle sprains in 1971. In addition, the authors report "a decrease in the number of knee injuries requiring surgery from 32 in 1969, to four in 1970, and five in 1971."

Shoe		Injuries Knee	Injuries Ankle	Requiring Surgery (knee)
Conventional	(1969)	93	72	32
Soccer	(1970)	38	36	4
Soccer	(1971)	35	39	5

During 1968, 51 knee injuries were reported for the public school league using the conventional shoe. During the following years, with the required shoe the number of injuries dropped to 24 in 1969, 30 in 1970, and 29 in 1971. The number of cases where surgery was performed or indicated was 24 in 1968, 4 in 1969, 7 in 1970, and 2 in 1971.

Shoe		Knee injuries	Requiring Surgery
Conventional	(1968)	51	24
Soccer	(1969)	24	4
Soccer	(1970)	30	7
Soccer	(1971)	29	2

The authors concluded "that the conventional football shoe with seven long cleats is the major factor responsible for the epidemic of knee injuries at all levels of organized football." Further, they recommended the use of a soccer type shoe with:

(1) synthetic molded soles,
(2) minimum of 14 cleats per shoe,
(3) 1/2 inch (1.27 cm) minimum cleat tip diameter, and
(4) 3/8 inch (0.95 cm) maximum cleat length.

A number of laboratory studies emphasize the need for matching shoes with types of surfaces to minimize the risk of lower extremity injuries. These tests attempt to describe the traction typical of various shoe-surface combinations.

Torg, Quendenfeld, and Landau (210) attempted to quantify the "shoe-surface interface release coefficient" for various combinations. Their test device consisted of a prosthetic foot for mounting shoes with different cleat types. Attached to the prosthetic foot was a perpendicular rod with a torque wrench attached to the opposite end. The shoe/surface could be engaged to a prescribed load and torque applied. A measurement could be taken directly from the torque wrench.

On the basis of their "experience," they classified the shoe-turf combinations as "not safe" if the release coefficient exceeded 0.49 and "safe" if the release coefficient was less than 0.31. The midpoint between these extremes was chosen to define the two categories of "probably not safe" and "probably safe."

The results of that study indicate that the conventional football shoe with 1/2 inch (1.27 cm) cleats "required by NCAA and NFSHSA is probably not safe on grass." In addition, all shoes with exception of the 1/2 inch (1.27 cm) by 3/8 inch (0.95 cm) soccer cleats tested on the Astroturf sample were classified as "safe" or "probably safe" when tested on various synthetic turf samples.

Two points should be noted in interpreting these results. The criteria for classifying different types of shoe surface combinations was established on the basis of their "experience." It was assumed that conditions of the test, e.g., shoe position and weight distributions, adequately simulated the actual conditions when injuries occur.

A study by Bonstingel, Morehouse, and Niebel (215) investigated the effects of shoe types and playing surfaces. Their findings are in agreement with Torg's knee injury statistics. However, their conclusions are tempered by observations that the study was "only a simulation of what occurs under actual playing conditions," and "that many knee injuries are a result of positional vulnerability and could occur regardless of the shoe or playing surface."

Unfortunately, until relationships between the shoe-turf interface and the occurrence of injuries are more thoroughly researched and injury threshold criteria are established, the utility of such laboratory studies is limited.

From the preceding discussions the basis for mitigating lower leg injuries is apparent or in some instances within grasp through additional research. However, the real obstacle may not lie in obtaining the solutions but in disseminating the results to coaches, athletes, and administrators so that the solutions will become routine practice. For example, attempts to gain acceptance of specifications for "safe" cleated or cleatless shoes will be met with resistance if performance appears to be affected.

e. Lower Extremity Equipment Related Skiing Injuries

Shealy (75) estimates that between 165 000 and 600 000 skiing injuries occur annually. The lower extremity is involved in 60% to 70% of these injuries (62, 45, 59). Typically ski injuries are sprains and fractures (62. 45, 59). Factors of age, sex, skill, ability, physical condition, slope conditions, crowds, equipment, equipment adjustment and maintenance, and prior injury have been associated with the occurrence of skiing injuries. Their ralative importance is disputed. However, the role of equipment, specifically the ski-boot-binding system, is considered to be one of the most significant factors associated with the occurrence of skiing injuries. Johnson, et al. (62) classified 44% of the injuries investigated in their study as "lower extremity equipment related" (LEER) injuries. Tapper and Moritz (78) note of the injuries investigated during the 1971-72 season, that "37% of those injured directly blamed malfunction (release failure or premature release) of their bindings."

The ski bindings function is twofold: (1) it serves to couple the skier to his skis, and (2) in the event of an accident, allows the skier and skis to separate before the forces "exceed the failure loads of the leg." (48, 56)

Ski bindings according to Shealy, et al. (75) employ the same basic mechanical design--"a spring loaded cam or lever detent. The cam or lever requires some predetermined force to be displaced; once the displacement exceeds the detent value, the spring ceases to exert any retentive force." The differences in bindings lie in the application of this principle.

Should the binding fail in its first function, the phenomenon is known as "inadvertent release." Shealy, et al. (75) found the advanced skier was encountering a large number of upper extremity injuries relative to the intermediate and beginner classes. These injuries, they suggest, "are typical of what one would expect from what is known as an inadvertent release," and estimate perhaps as much as one-third of the skiing population is at risk.

Should the binding not release in the event of a fall, the ski acts as a "lever in twist," "as a lever in bending," or as both "a lever in twist and bending." (62) The result may be a knee or ankle sprain, or a fracture of the tibia, ankle, or fibula (62, 47, 65).

Some binding types are apparently more effective than others in protecting the lower leg. This was pointed out by Shealy, et al. (75) They classified bindings as:

(1) cable bindings (used by approximately 9% of the study population),

(2) bindings with "two release modes" (54% of the population),

(3) bindings with "more than two release modes" (14% of the population).

The cable release binding consists of a "forward throw-handle" which pulls the cable snug over the heel of the boot, forcing the boot forward into the "toe piece" of the binding. The two release modes bindings enable the release of the toe in a "twisting fall" preventing "torsion at the tibia," and an upper release in a forward fall preventing a "levered break of the tibia." The third category of bindings is simply described as bindings that release in other ways, e.g., an upward or rolling release at the toe.

The resulting overall accident rates per 1000 man-ski-days were 13.07 for cable bindings, 8.60 for two-release modes bindings, and 6.75 for those with more than two release modes.

Their analyses suggested that "the more-than-two release mode binding is superior, for every skill level except beginner, where there is no apparent advantage over the two-release mode binding."

That bindings perform to their theoretical potential is dependent upon many factors. These factors can be grouped as follows:

i) binding release settings,
ii) friction, and
iii) environmental factors.

i. Binding Release Settings. Ski binding release settings are based upon skier parameters of age, weight, sex, ability, and proximal tibia width (352, p. 221) (56). In practice, weight and ability are the two principal parameters. A study by Johnson, et al. (62) examined binding release settings of injured and non-injured skiers. They found the average setting exceeded the recommended value by 45% for the uninjured group. The average setting of the injured groups exceeded the recommended value by as much as

85%--85% for the LEER injuries of a flexural nature, 75% for the LEER injuries produced by torque, and 55% for all other injuries.

A release setting too high negates the release protection afforded by the binding. Conversely, a low release setting could permit the binding to release prematurely. However, it is questionable whether release settings adequately indicate the value at which release occurs. Bahniuk, et al., (47) in laboratory conditions, tested seven bindings previously "set in the pure torsion mode (toe release) at approximately 58 newton meters." When a load was applied to the ski, the torques required for release varied up to 104 newton-meters.

It is interesting to note that Johnson, et al. (62) found that the skier "who more recently has adjusted and tested his bindings for release and who has more recently had his equipment set up for release by a ski shop professional" was more often found in the group with lower extremity injuries than in the control group of uninjured skiers. Similar findings were reported by Young, et al. (83)

ii. Friction. The binding's ability to function properly can be affected by friction between the top of the ski and boot sole (68, 62, 74). This force depends on the weight of the skier and effective coefficient of friction between the boot sole and ski surface. Friction can be reduced by placing a pad or lubricant between the ski top and boot sole. Material for this pad, called an anti-friction device (AFD), can be metal, plastic, polyethylene, teflon, or a mechanical device.

The efficacy of these devices has been demonstrated by Johnson, et al. (62) Particularly effective were the teflon and mechanical devices. Laboratory studies by Bahniuk, et al. (48, 64) support these findings.

iii. Environment. The effects of environmental factors on "the efficacy of modern ski bindings" was the subject of a clinical study by Bahniuk and Izant (47). That study was designed to measure changes in release values after the bindings were exposed to different simulated environmental conditions. These conditions included an initial test to determine the baseline release value followed by exposure to vibration, use, salt, ice, and dirt.

A number of weaknesses in the test procedures limit conclusions based on the results. For example, although each of the seven bindings was set to release at 58 newton-meters (toe-release) in the "pure torsion mode," the baseline release value obtained in the initial test varied up to 104 newton-meters. The accumulated effects of exposure were discounted. The simulated tibia, according to the authors, did not possess the same mechanical properties as the human tibia.

However, the results of the study provide some important observations. Each of the seven bindings was affected differently by the tests. For example, the second and most severe "dirt test" caused a 16% decrease in the "maximum torsional moment at release" in one binding and a 30% increase in another.

The ice test adversely affected all bindings. Each binding was tested after exposure to water spray and temperatures of 5°C for 48 hours. When tested, the increase in the "maximum torsional moment at release" varied from 56% in one binding to 270% in another. When compared to the "tibia failure criteria" suggested by the authors, each of the bindings exceeded the failure criteria.

The study of environmental factors under actual conditions has received little attention. However, Johnson, et al. (62) observed that corrosion of the binding mechanism and improper lubrication of the binding was more frequently found in the group encountering "lower extremity equipment related injuries" than in a control population of uninjured skiers.

The "typical fracture" found in skiing injuries has risen from the area of ankle to the lower third of the tibia (52, 78, 56). This shift has been attributed to the modern rigid ski boot.

A ski boot, according to Bahniuk, et al. (49), is a mechanical device coupling the ski-boot-binding system and foot of the skier. The modern boot is a hard, rigid or hinged, plastic boot which functions in two ways to prevent injury. First, the boot enables a skier "to control his skis and thus avoid a fall" and subsequent possibility of injury. Second, if a fall should occur, the boot can absorb energy and thus prevent or reduce injury. In their clinical study of ten boots (one leather and nine versions of the plastic type), they concluded that the ability of a boot to absorb energy is inversely correlated with the boot's stiffness. Hence, the potential for injury appears to be greater for the stiffer boot.

However, the stiffer boot enables the skier to be more closely coupled to his skis, thereby providing the potential for increased controllability and, as a result, decreasing the number of falls. On the basis of that study, it is impossible to "assess the relative importance of energy absorption and boot stiffness."

The population of recreational skiers is not typified by the properly conditioned athlete. As such, recreational skiers rely primarily upon their equipment for protection against lower extremity injuries. This equipment, in laboratory conditions, performs with a great deal of variability. In actual use conditions, reliability is influenced by the interactions of several variables of which little has been documented. Many skiers are skiing with improperly adjusted bindings, evidenced by the number of skiers reported by Johnson (62) and Young (83) who had their bindings adjusted just prior to encountering a lower extremity injury.

In summary, the literature suggests several discrepancies relative to the occurrence of lower extremity ski injuries. Procedures for testing the ski-boot-binding system are not optimal, performance criteria have not been established, guidelines are needed to aid in properly adjusting bindings, and finally, the skier must be educated in equipment maintenance.

f. Natural versus Synthetic Playing Surfaces

The safety issue concerning natural versus synthetic playing surfaces has been controversial since synthetic surfaces were first introduced. It has stirred the interest of manufacturers, players, sport safety researchers and, during 1971 and 1972, was a subject before the Congressional Subcommittee on Commerce and Finance (226). More recently the National Football League Players Association petitioned the Consumer Product Safety Commission to, "...commence a proceeding to issue a consumer product safety rule for synthetic turf used as a surface cover for athletic playing fields." (238, 237) Those petitions were subsequently denied.

Among the first studies to investigate possible differences in injury rates on natural and synthetic surfaces was the "National Football Injury Study--1970" by Martin, et al. (28) The intent of that study was to provide national data at the college level on the incidence and causes of football injuries. Data were drawn from 40 schools participating in National Collegiate Athletic Association (NCAA) football during the 1970 season. However, the report is plagued by what the authors refer to as "some confusion as to what constituted a reportable injury," thereby limiting the reliability of these data.

There were 2782 injuries reported and classified according to three degrees of severity: "Active Participation" (injuries without time lost from participation); "Partial Participation" (injuries with time lost from games or practice); and "Hospitalized." Game injuries accounted for 1178 injuries. Table 10 shows the distribution of these injuries by severity and the type of playing surface associated with each injury.

Table 10. Severity versus type of surface - incidence per game (Martin, et al. (28))

Surface[a]	Hospitalized	Partial Participation	Active Participation	Combined
Grass	0.19	1.58	0.96	2.73
Turf A	0.27	1.70	0.66[c]	2.63
Turf B	0.17	1.24	1.10	2.51
Turf C	0.15	3.15[b]	1.46[d]	4.76[b]

a) Turf designations were taken from Martin's report.
b) Significant: $p < .01$ Chi-square.
c) Significant: $p < .05$ Chi-square.
d) Significant: $p < .10$ Chi-square.

One by two Chi-square analysis to determine the statistical significance of injury rates (injuries per game) associated with synthetic surfaces compared to grass, shows that "Active Participation" injuries associated with Turf A[14] to be significantly lower than the rate associated with grass. The rate of "Active" and "Partial Participation" injuries associated with Turf C significantly exceeded that of grass. The difference in rates between Turf B and grass are not significant. Finally, the rates of "Hospitalized" injuries do not differ significantly between grass and synthetic surfaces. However, only 2 "Hospitalized" injuries were reported for Turf C.

Another study of the 1970 football season was conducted by Bramwell, Requa, and Garrick (223). The principal objective of that study was to determine if any differences existed in injury rates sustained on synthetic and natural surfaces at the high school level. Their study included 26 high schools in the greater Seattle area. These schools participated in 228 games: 80 games played on 1 artificial surface and 148 on 12 different grass fields.

[14]Turf A, B, and C were designations used by Martin (28) for the three brands of synthetic surfaces.

An injury was defined as one "that resulted in not finishing a game and/or missing 2 or more subsequent practices and/or any subsequent game or games." Injuries resulting in 2 or more missed games were considered severe. Table 11 shows the rates of injuries and severe injuries for the two types of surfaces. There were 139 injuries reported, yielding overall injury rates of 0.52 injuries per game on grass fields and 0.76 injuries per game on the synthetic surface. The higher rate on the synthetic surface was statistically significant ($p < .05$ Chi-square).

Table 11. Injuries versus type of surface - incidence per game - 1970 (Bramwell, Requa, and Garrick (223))

Surface	Injury rate	"Severe" Injury rate
Grass	0.52	0.18
Synthetic	0.76[a]	0.24

a) Significant: $p < .05$ Chi-squares.

Of the 139 injuries, 32.4% were classified as serious. The overall serious injury rate for the synthetic surface was 0.24 injuries per game and 0.18 injuries per game for grass fields. This difference was not statistically significant.

The second year of the study by Adkison, Requa, and Garrick (214) was expanded to "include participation on additional brands and generations of synthetic turf as well as additional games played on grass." That portion of the study included 73 high schools in the Seattle and Spokane, Washington, and Portland, Oregon, areas. The playing surfaces studied consisted of "over 50 different grass fields" and four synthetic surfaces--one three-year-old Tartan Turf and "two generations" (3 fields) of Astroturf.

Results for the second year are provided in table 12 and show Astroturf to be associated with a significantly higher injury rate. Tartan Turf, however, is associated with a significantly lower injury rate.

Table 12. Injuries versus type of surface - incidence per game - 1971 (Adkison, Requa, and Garrick (214))

Surface	Injuries per game	Severe injuries per game
Grass	0.51[b]	0.19
Astroturf	0.63	0.25
Tartan Turf	0.28[a]	0.17

a) Significant: $p < .05$ Chi-square.
b) Significant: $p < .10$ Chi-square.

Severe injuries were defined as those resulting in a "player missing two or more subsequent games." The pattern of severe injury rates is similar to that of all injuries. However, these differences are not statistically significant.

If the injury rates for synthetic surfaces are considered in aggregate, the resulting injury rate is 0.55 injuries per game and does not differ significantly from that of grass at 0.51 injuries per game. This difference, as pointed out by authors, "underscores the fallacy of considering all brands of synthetic turf in aggregate when comparing their safety characteristics to grass."

Extending the results of the preceding studies to the population of synthetic and natural surfaces must be based on the assumption that factors other than the type of surface contribute negligibly to the results. That this is a valid assumption is questionable. For example, in the latter study by Adkison, Requa, and Garrick (214), the differences in injury rates between the three Astroturf surfaces were greater than the differences in rates between grass, Tartan Turf, and the aggregate rate for Astroturf (see table 13). Differences in rates between Astroturf's A and B, and B and C are statistically significant ($p < .05$ Chi-square).

Table 13. Injury rates for grass and four synthetic surfaces - incidence per game - 1971 (Adkison, Requa, and Garrick (214))

Surface			Incidence per game
Grass			0.51
Astroturf	A	0.71	0.63
	B	0.37	
	C	0.81	
Tartan Turf			0.28

As another example that the assumption of uniformity among surfaces of a particular type may be invalid, consider the study of high school football injuries by Blyth and Mueller (9). To remove the possibility that field conditions were influencing rates of knee and ankle injuries, 9 of the 43 study schools were randomly selected and "their game and practice fields were completely resurfaced and maintained in good condition for the final two years of the study, 1971-72." Table 14 provides the injury rates (knee and ankle only) for the two groups. As indicated by the differences in these rates, knee and ankle injury rates are, in part, determined by the condition of the playing field.

Table 14. Knee and ankle injury rates for schools with fields resurfaced and maintained and those with no change - 1971-1972 (Blyth and Mueller (9) Table LXXIII)

Schools	Injury rate	Percent of population
Fields resurfaced and maintained	0.142	19.1
Schools with no change	0.213	80.9

Significant: $p < .01$ Chi-square.

That possible differences within a class of surfaces affect the results of comparative studies of synthetic and natural surfaces is apparent, however, the extent of this influence is not so obvious.

One comparative study where variability in field conditions is expected to be at a minimum is the multi-year National Football League Injury Study conducted by the Standard Research Institute (SRI) (23, 24, 25). The most recent of three reports emphasizes the 1974 professional football season. Two earlier reports cover the period from 1969 to 1973.

The analysis of "turf injuries" is "separated into gradients of injury severity":

Frequency -	Gradient 1:	Incidence of injury
Severity -	Gradient 2:	Incidence of re-injury
	Gradient 3:	Injuries causing two or more missed games
	Gradient 4:	Injuries requiring hospitalization
	Gradient 5:	Injuries requiring surgery
	Gradient 6:	Third degree injuries
"Punishment" -	Gradient 0:	Playable injuries

The first of these gradients, the incidence of injury associated with playing on synthetic surfaces and natural turf for 1970-1974, is provided in the 1974 NFL report. A comparison of this result and those of the two previous NFL studies is provided in table 15. As the NFL data indicate, the three types of synthetic surfaces have consistently been associated with higher accumulated rates (incidence per game) of injury than natural turf. After five seasons of data, the differences in rates beween each type of synthetic surface and natural turf is statistically significant.

Table 15. Frequency of injury versus turf as reported in the three NFL studies

Turf[a]		1970-72[b]	1970-73[c]	Turf	1970-74[d]
		Incidence per game			
Natural	A	2.0	2.08	Natural	2.23
Synthetic	B_1	2.2	2.28	Poly	2.53[g]
	B_2	2.8[e]	2.89[f]	Tartan	3.05[f]
	B_3	2.8[e]	2.77[f]	Astro	2.93[f]

a) The first two NFL injury reports designates playing surfaces as A, B_1, B_2, and B_3.
b) Figure 33 of the 1972 NFL study (23).
c) Table 15 of the 1973 NFL study (24).
d) Table 27 of the 1974 NFL study (25).
e) Significant (computed by SRI).
f) Significant at the .001 level (computed by SRI)
g) Significant at the .05 level (computed by SRI).

Gradients 2 through 7 are all measures of major[15] or serious injuries. Gradient 2 is included because the report notes that "reinjuries were more severe than new injuries (in terms of recovery rates)." When minor injuries are excluded, which is the case in table 16, only the incidence of third degree injuries per game (Gradient 6) associated with Tartan Turf is significantly greater than that recorded for natural turf. In fact, only those rates associated with Tartan Turf suggest a pattern of greater rates than those of natural turf.

[15]A major injury is defined "as one causing two or more missed games."

Table 16. Summary of injuries per game for Gradient 2 through 7 versus various surfaces

Turf	Gradient:	Incidence per game 1970-1974 2	3	4	5	1973-1974 6	7
Natural		0.36	1.00	0.37	0.29	0.33	0.37
Poly		0.31	0.97	0.29	0.25	0.35	0.45
Tartan		0.45	1.04	0.40	0.25	0.55[a]	0.49
Astro		0.35	0.94	0.44	0.29	0.40	0.36

---

a) Significant at the .05 level (computed by SRI).

Also included in that study is an analysis of "playable" injuries (gradient zero) which are not considered an injury as defined in the NFL study. Data for these rates "were collected in logs by NFL medical personnel after each of the 20 games played during 1973 and 1974." The rates for each type of playing surface are presented in table 17. As indicated, synthetic surfaces were associated with significantly greater rates of playable injuries than those recorded on natural surfaces.

Table 17. NFL "Playable" injuries versus turf 1973-74

Turf	Incidence per game
Natural	5.60
Poly	7.56[a]
Tartan	6.46[b]
Astro	7.75[a]

---

a) Significant at the .001 level (computed by SRI).
b) Significant at the .01 level (computed by SRI).

Previously it was mentioned that basic differences in generic classes of surfaces limit the reliability of many comparative studies of playing surfaces and that these differences may be at a minimum with fields used by the NFL. However, in the NFL study the question also arises concerning the appropriateness of comparing each generic class of synthetic surface with natural turf. Synthetic surfaces of a particular brand will have different characteristics if some are football fields and some are converted baseball fields, because, as stated in the 1974 NFL study, "a football field is crowned or peaked in the center and supposedly, has better drainage, converted baseball fields have more obstructions in that pitchers mounds, base paths, and the like, must be converted; the synthetic baseball fields also have different shock pads (to make the ball livelier) than those on football fields." These differences were only superficially analyzed in the report. However, differences are apparent as shown in table 18. When converted baseball fields are excluded, the differences between natural and synthetic surfaces do not appear to be great, but no mention is made of statistical significance.[16]

Table 18. NFL injuries on turf versus field types 1973-74 (incidence per game)

Turf	Football fields	Converted baseball fields
1973		
Natural	1.73	1.65
Synthetic	1.84	2.43
1974		
Natural	2.23	1.97
Synthetic	2.57	3.00

The results of the NFL studies show significantly more NFL injuries have been recorded per game played on each of three synthetic surfaces over the five seasons between 1970 and 1974. The differences in injury rates are primarily due to the incidence of minor injuries, since each measure of severity (Gradient 2 through 7) shows no significant differences exist, with exception of third degree injuries (Gradient 6 versus Tartan Turf), between natural turf and each of the three synthetic surfaces. The significant differences in "playable" injuries tends to support the predominance of minor injuries occurring on synthetic surfaces.

In general, the findings of natural/synthetic surface studies suggest that synthetic surfaces are associated with higher rates of injury when compared to rates associated with natural surfaces. However, these results cannot be

---

[16]It is impossible to compute the statistical significance of these differences using the data presented in the study.

extended to show that a particular type of turf is a cause of injury. At most, they indicate that the type of turf is a parameter in an unspecified set of elements which may be responsible for different rates of injury. It may well be that one turf brings together elements of equipment, personnel, environmental factors, styles of play, and other unknowns, which ultimately contribute to different rates of injury (e.g., football versus converted baseball fields, cleat selection versus type of turf, physical changes due to aging of surfaces and underpads, etc.).

If questions concerning safety implications of playing surfaces are to be answered on the basis of turf related studies, additional data are required. These studies must incorporate controls to account for the many factors influencing the incidence and severity of turf related injuries.

3.4 Rules and Standards Activity

The recent decisions by the National Federation of State High School Associations (NFSHSA) and the National Collegiate Athletic Association (NCAA) to incorporate a rule change intended to eliminate the use of the head as the initial point of contact in blocking and tackling promises to be a significant step in reducing the number of serious football injuries. More important may be the positions taken by the National Athletic Trainer's Association (181) "opposing the use of tackling and blocking techniques with the helmet and/or face mask as the initial point of contact," and that taken by the American Football Coaches Association to discourage the teaching of head tackling and blocking (186).

The incorporation, enforcement, and effectiveness of rules and rule changes targeted for enhancing participant safety is an area that could be explored further. As a study entity, it has not been emphasized. However, there are indications that organized competition at the college level and below is becoming more regulated in the use of specific items of protective equipment. The NCAA Football Rules (37, p. FR-16) require all players to wear knee pads, head protectors, shoulder pads, and mouth protectors. Four point chin straps were mandatory in 1976 and all helmets used in 1978 must comply with the National Operating Committee on Standards for Athletic Equipment (NOCSAE) standard. Further, the rules prohibit the use of certain equipment such as shoe cleats more than 1/2 inch (1.27 cm) in length or exceeding a specified minimum cleat diameter.

The NCAA Baseball Rules (101, p. BA-14) require players to wear protective helmets (double ear flap helmet preferably) while batting and running the bases.

The NCAA Hockey Rules (114, pp. IH-9-10) require goalkeepers to wear protective face masks. All players must wear dental guards and head guards with chin straps fastened. Skates must be equipped with approved safety heel tips.

The NCAA Basketball Rules (126, p. BR-56) include recommendations for court specifications, padding for back boards, and lighting.

The NCAA Gymnastic Rules (125, pp. CY-5-14) contain dimensions and safety specifications for the pommel horse, rings, vaulting board, parallel bars, horizontal bar, and mat dimensions and placement.

Some schools have minimum medical qualifications for participation (140, 66) or incorporate other safety procedures in attempting to reduce the risk of participating in sports. One such experiment (306) was conducted in New York State where "junior high football rules were changed to eliminate the kickoff, deflate the ball to a lower pressure, and allow coaches to point out dangerous practices to officials at any time." They claim to have reduced their injury rate by almost 100%.

Also in New York, there is an ongoing experiment based upon what is called the Selection Classification Age Maturity Program (SCAM) "aimed at grouping athletes (ages 12-19) on the basis of physical fitness, skills and physical maturity" (267) in hopes of reducing injury to participants in sports. The usual mechanism for grouping athletes is by chronological age and sometimes also by weight.

There are two principal groups in the U.S. currently involved with developing standards for athletic equipment: NOCSAE and the American Society for Testing and Materials (ASTM) Committee F-8 on Protective Equipment for Sports.

NOCSAE, formed in 1969 "for the purpose of making competitive sports (147), as free from injury as possible through protective equipment standards" has developed a method and requirements for testing football helmets (348). As of August 10, 1976, "93 helmet models have passed the NOCSAE football helmet standard." (327) A preliminary baseball batting helmet standard may be the second NOCSAE standard (329). In addition this group is conducting preliminary studies on ice hockey protective headgear and soft-shell football helmets (330).

In June 1969, ASTM entered the sports field, according to Hale (270), because of the number of participants seriously injured "owing to the lack or the inadequacy of protective equipment." In the Committee's seven years of existence, they have produced two standards:

1. Designation: F381-74 Standard Consumer Safety Specification for Components, Assembly, and Use of a Trampoline.

2. Designation: F355-72 Standard Method of Test for Shock Absorbing Properties of Playing Surface Systems.

A number of standards are currently in various stages of development. These include proposed standards for football and hockey helmets, knee pads for football, mouth protectors for all contact sports, and eye and face protection for forwards and defensemen in hockey. The Skiing Safety Subcommittee is developing standards for determining the longitudinal and torsional stiffness of Alpine skis, and a standard for measuring the static release moments of adult ski bindings.

The American National Standards Institute (ANSI) has also been engaged in sports standards activities. They approved a standard entitled "American National Standard Safety Requirements for Aerial Passenger Tramways," designated ANSI B77.1-1973. This standard includes provisions for tramways, lifts, and tows used in ski areas. (These devices are under the jurisdiction of the U.S. Forest Service in those instances where the ski site is built on land designated as part of the national forest.. There are 129 such sites in the U.S.)[17]

A number of groups have been involved with developing standards for helmets in general. These standards are the forerunners of standards for helmets in sports and include: The ANSI Z-90.1-1966 and a revision Z-90.1-1971 which address safety helmets; the Snell Memorial Foundation 1968 and 1970 standards; a number of military specifications for aviators helmets; and a number of foreign standards including:

(British)	-	BSI 2011:	1956	(motorcycle helmets)
		BSI 1869:	1960	(motorcycle helmets)
(Canadian)	-	CSA D230:	1970	(motorcycle helmets)
(Australian)	-	AS E33:	1968	(motorcycle helmets)
		AS E43:	1968	(motorcycle helmets)
(New Zealand)	-	NZS 1214:	1969	(motorcycle helmets)

---

[17]Telephone conversation with Mr. P. Wingelman, U.S. Forest Service, March 1976.

The International Organization for Standardization (ISO) has issued a standard on helmets for "road users" designated ISO/R 1511-1970. ISO has also issued standards for gymnastic equipment:

ISO/R 378-1964 (E) - Parallel Bars
ISO/R 379-1964 (E) - Horizontal Bars
ISO/R 380-1964 (E) - Rings
ISO/R 381-1964 (E) - Vaulting Horse and Pommel Horse
ISO/R 382-1964 (E) - Balancing Beam

However, these standards primarily address equipment dimensions and specifications. ISO is also developing a standard on ski boots (75).

4. CONCLUSIONS AND RECOMMENDATIONS

- Expand data collection activities based upon a systems concept.

From the preceding discussion it is evident that risks in sports cannot be quantified on the basis of existing data. The published literature provides an incomplete and inconsistent assessment of the risks associated with sports. Some activities (baseball, basketball, and gymnastics) account for a great number of hospital emergency room injuries, but have rarely been the subject of injury research.

The assessment of risks for a particular sport and population of participants must include more than an analysis of the occurrence of injury. The assessment must also include measures of severity, immediate diagnosis, and long term effects of injuries.

Furthermore, risks can be altered. Consequently, the analysis must include provisions for addressing factors which might potentially influence risks. These factors include supervision, officiating, physiological characteristics of participants, conditioning, experience, ability, skill, facilities, protective equipment, the environment, and use and fit of protective equipment. The relationships among these factors and their specific roles in influencing injury must be quantified. Data collection activities based upon the systems concept must be expanded. Otherwise, as noted by Fraser "...we cannot even verge on the optimal in recreational system safety." (266)

Expansion of data collection activities does not necessarily require development of data collection methods. For example, the National Athletic Injury/Illness Reporting System (NAIRS), when fully implemented, may provide injury data related to a variety of sports activities.

- Encourage development of standardized terminology applicable to sports research.

  The results of most sport injury investigations are not compatible because of the use of nonuniform terminology. For example: What is an injury? Sports injury studies employ a variety of definitions comprising various intervals of lost participation time, need or perceived need for professional treatment, specific kinds of trauma regardless of lost participation time, or incidents resulting in insurance claims. Similar variations are observable in definitions of injury severity. The formulation of standardized terminology applicable to sports research should be encouraged.

- Determine the feasibility of an institute to initiate and coordinate sport injury research and to disseminate results to the athletic community.

  In recognition of the fragmented approaches to football injury research, the lack of injury research in other athletic activities, and the futility of most research efforts, Blyth and Mueller in their report of 1972 (9), recommended the establishment "of a 'Sports Trauma Institute' through which efforts could be made to coordinate research ventures, provide adequate medical specialist consultation, and disseminate research findings to the athletic community." The concept of a "Sports Trauma Institute" was also suggested by Grippo (25). Although Grippo's recommendation is limited to a "safety committee" within the National Football League, it serves to emphasize the desire and need for centralized control to initiate, coordinate, and monitor research activities over a complex base of sports safety issues.

  At the Second National Conference on Sports Safety, October 1976, the need for such an organization was again emphasized. This "Umbrella Organization" would be entrusted with establishing priorities, coordinating research activities, and disseminating information to the athletic community.

Millions of injuries occur annually as a result of recreational and competitive sports activities. Research has been sporadic, producing results of limited value. The concept of a "Sports Trauma Institute" to initiate and coordinate research activities and disseminate the results to the athletic community appears to be a logical alternative to attaining the optimum in sports safety. The CPSC should jointly explore the feasibility of establishing such an institute.

- Improve the surveillance capabilities of NEISS.

The NEISS system is a surveillance tool intended to serve "...as a springboard for action to combat product-related injuries." (325) Currently, the system provides data which are manipulated to form the Age Adjusted Frequency Severity Index (AFSI). Many categories of the general class "Sports and Recreational Equipment" rank high on this index. However, because each sport-related product category includes a broad base of activities (e.g., Basketball Activity and Related Equipment--Product Code (PC-1205), the nature of specific injury problems cannot be identified. Consequently, the ability to plan and implement injury prevention programs is reduced. Efforts to limit the scope of some categories is evident by the inclusion of single product categories (e.g., Ice Skates--PC-1245). However, this results in ambiguous categories (e.g., Ice Hockey and Related Equipment--PC-1279 and Ice Skates--PC-1245).

A second function of NEISS is to provide surveillance data for measuring the success or failure, of programs to reduce the frequency and severity of injuries. Many sport-related categories, because of their broad scope, may be insensitive to changes in injury patterns resulting from injury prevention programs, or it may be impossible to associate effective programs with identifiable changes (e.g., consider the decline in projected number of ice hockey injuries from FY 75 to FY 76. Is this the result of an effective program or due to a decline in the number of participants (or exposures))?

To improve the surveillance capabilities of NEISS, the "Sport and Recreational Equipment" categories should be reviewed and appropriately altered to correct ambiguities and the lack of specificity. Additionally, if NEISS is to provide useful surveillance data a common unit of exposure must be incorporated and measured.

- Stimulate research to resolve the controversy and problems with helmet test procedures.

Documented reports indicate that head injuries are associated with most sports fatalities. Many fatalities could possibly be prevented with adequate head protection. Standards groups are active in developing helmet standards. The NOCSAE standard has been recognized by the two organizations (NCAA and NFSHSA) representing the majority of participants in organized football, in effect making NOCSAE approved helmets compulsory items in the near future. A youth headform has been developed, and these helmet designs are being tested. Further, the NCAA and NFSHSA have passed rule changes which are intended to reduce the potential for serious head and neck injury. The impact that these developments will have on serious head injury remains to be evaluated.

Also, the ASTM standard for testing helmets will soon be available. At that time, both manufacturer and those professionally involved will have to choose the method which better reflects their respective needs. This becomes an inconsequential decision if both methods are equally valid. However, there exists considerable controversy regarding the differences between the two methods. Recent tests, in which NBS participated (129, 130, 131), indicate the existence of "substantial differences in the measured values of maximum accelerations transmitted to the head-form when using the NOCSAE and ASTM test systems" and "poor correlation between the two test methods." The apparent controversy concerning the appropriateness of drop test methods and derived injury tolerance criteria relative to conditions encountered in a playing field environment can be resolved only through additional research. Finally, the useful certification period of certified helmets remains to be determined.

The implication that these issues have on participant safety is a matter of speculation. Historical data are not adequate to serve as baseline data for comparative studies intended to resolve conflicting views. Only by stimulating and encouraging research to assess these issues directly will the optimum in head protection be realized. Such research may have considerable value in developing head protection standards for other sports.

- Determine the potential and alternatives for promulgating hockey face guard standards.

  Over 40% of the projected emergency room injuries (FY 76) related to ice hockey activities involve some part of the face.

  ASTM is developing a standard for eye and face protection for hockey players. NOCSAE has conducted tests on ice hockey protective headgear "in order to establish conclusive data for the formation of a safety standard." (330) The potential and alternatives for promulgating these standards should be considered.

- Stimulate research to reinforce theories pertainig to knee injury prevention and provide for disseminating results to the athletic community.

  The knee is the most frequently injured body part in sports. The most damaging of these is an injury involving the surrounding ligaments. The literature suggest that the extent of knee injuries could be minimized through

  1. proper conditioning programs,

  2. in certain instances screening individuals with a previous injury or those susceptible to injury, and

  3. selecting the best combinations of shoe, cleats, and surface to minimize the chance of injury resulting from cleat/surface "lock-up."

  Research needed to reinforce these concepts and obtain an efficient method of disseminating the results (of other sports injury research as well) to coaches, administrators, athletes, trainers and physicians should be encouraged.

- Allocate resources to areas of ski-boot-binding testing, adjusting, maintenance, and establish equipment performance criteria.

  Fractures, sprains, and strains of the lower leg are typical snow skiing injuries. Such injuries have been associated with release failure of the binding system. Injuries have also been attributed to premature binding releases.

Conditioning programs are usually routine to athletes engaged in competitive activities. Thus, these athletes avoid many injuries. The recreational skier, however, usually does not have access to formal conditioning programs. As such, recreational skiers depend on their equipment for protection against injury. The bindings' ability to afford this protection is influenced by friction, release setting, environmental factors, corrosion and type of binding.

The literature suggests four tasks to reduce the risks associated with recreational skiing.

1. Develop guidelines to aid proper binding adjustments.

2. Educate the skier on the importance and procedures for proper equipment maintenance.

3. Improve procedures for testing the ski-boot-binding system.

4. Establish minimum equipment performance criteria.

- Determine the feasibility of establishing a ski-boot-binding safety performance standard.

The ASTM Subcommittee on Skiing is developing standards for skis and binding mountings. Currently, a binding safety performance standard is not included. The feasibility of developing a safety performance standard on bindings, or possibly the ski-boot-binding system should be evaluated.

The preceding recommendations constitute a set of first priority tasks for reducing the incidence and severity of sports related injuries. These recommendations address only a small set of potential hazards in sports. There are indications that different types of playing surfaces are associated with different rates of football injuries. The trunk, shoulder, and hands were shown to be frequently injured in football. According to NEISS, basketball and baseball activities pose as great a problem, in terms of numbers of injuries, as football. However, in view of study constraints, the absence of information precludes consideration of these and other aspects as priority sports safety issues.

Several organizations are committed to pursuing safer participation in sports. Some are actively engaged in tasks related to the preceding recommendations. Coordinating with these groups would minimize redundant efforts and ally substantial resources.

Appendix A. Projected Number of Hospital Emergency Room Treated Injuries

These projections are based on the National Electronic Injury Surveillance System data collected from 119 hospitals from July 1972 through June 1976. Projections are derived by multiplying the number of injuries reported by each hospital by the weight factor associated with that hospital and summing the results for all hospitals.

Table A-1 provides a listing of diagnostic and body part categories used in NEISS. The remainder of this appendix is divided into seven parts according to the following NEISS Product Categories (PC):

Table A-2: Football Activity and Related Equipment (PC-1211)

Table A-3: Baseball Activity and Related Equipment (PC-1204)

Table A-4: Basketball Activity and Related Equipment (PC-1205)

Table A-5: Snow Skiing and Associated Equipment (PC-1216)

Table A-6: Ice Hockey and Related Equipment (PC-1279)*

Table A-7: Gymnastics and Associated Equipment (PC-1272)

Table A-8: Trampolines (PC-1233).

Within these subdivisions the data are arranged by injury diagnosis and affected body part. These data are also arranged according to the most frequently occurring injuries (e.g., sprain/strain-lower leg).

---

*Ice hockey data are available for FY 75 and 76 only.

Table A-1: Categories for injury diagnosis and body parts used in NEISS

Injury Diagnosis	Body Part
Amputation	Head
Anoxia	Ear
Avulsion	Eyeball
Burns (not specified)	Face (including nose)
Burns (scald from hot liquids)	Mouth (lips, tongue, teeth)
Burns (thermal)	Neck
Burns (chemical, caustics, etc.)	Upper trunk (including shoulders)
Cell damage by radiation, except thermal (radiation burns by ultraviolet, x-rays, radioactive materials, etc.)	Lower trunk (including hips)
	Upper arm
	Lower arm (including wrist and elbow)
Concussion	Hand
Contusions/Abrasions	Finger
Crushing	Upper leg
Dermatitis, Conjuntivitis	Lower leg (including knee and ankle)
Dislocation	Foot
Electric Shock	Toe
Foreign Body	25-50% of Body
Fracture	All parts of body
Hematoma	Other
Internal Organ Injury	Not stated
Laceration	
Nerve Damage	
Poisoning	
Puncture	
Strain or Sprain	
Submersion (including drowning)	
Other	
Not stated	
Ingested foreign object	
Aspirated foreign object	

Table A-2: Football Activity and Related Equipment (PC-1211)
All and Major Injuries FY 73-76

		Projected Number of Injuries per Fiscal Year 73	74	75	76	Average Annual Change %	All % of Total	Major % of Total (Major)	Major % of Injury Category	Average Age All	Average Age Major
Body Parts:	Head	8931	12157	16254	17792	26.4	4.4	17.5	12.4	15.6	15.6
	Ear	486	742	531	819	26.2	.2	.0	.0	17.3	—
	Eye	1708	1719	1982	1581	-1.4	.6	.6	3.3	16.3	16.2
	Face	16927	21833	24749	27235	17.5	7.3	2.7	1.2	16.7	18.5
	Mouth	4957.	5531	5210	6475	10.0	1.8	.2	.4	16.1	16.9
	Neck	2453	3739	3685	5235	31.0	1.2	1.8	4.6	15.6	16.3
	Upper Trunk	34794	47931	51389	60709	21.0	15.7	15.7	3.2	16.9	16.6
	Lower Trunk	5549	10056	7180	12909	44.1	2.9	6.4	7.1	16.1	16.1
	Upper Arm	1554	2439	2675	4481	44.7	.9	3.5	12.2	14.4	13.6
	Lower Arm	30134	40250	42093	52056	20.6	13.3	13.6	3.2	14.9	15.0
	Hand	11943	15549	16200	20268	19.8	5.2	.6	.4	15.4	15.3
	Finger	35735	46908	51115	61222	20.0	15.7	3.0	.6	15.2	13.9
	Upper Leg	2770	3651	3538	4848	21.9	1.2	4.1	10.9	15.7	11.5
	Lower Leg	56419	72812	75886	92160	18.2	23.9	28.4	3.7	16.8	16.1
	Foot	12919	13205	13409	14851	4.8	4.4	1.5	1.1	17.1	18.2
	Toe	3677	4102	3485	3870	2.5	1.2	.0	.1	16.9	14.5
	Other	595	263	452	435	4.1	.1	.3	6.6	17.3	17.6
Diagnoses:	Concussion	2662	4478	6397	5451	32.1	1.5	12.7	26.2	16.1	16.1
	Cont./Abra.	57319	83360	92902	114679	26.8	28.1	10.1	1.1	16.0	15.2
	Dislocation	6891	9889	10635	11595	20.0	3.1	6.1	6.1	17.5	18.1
	Fracture	56520	67536	67462	81366	13.3	22.0	55.8	8.0	15.5	15.0
	Hematoma	2786	3555	3113	4317	17.9	1.1	1.1	3.2	15.9	17.1
	Laceration	27456	31994	32875	36507	10.1	10.4	1.2	.4	16.1	15.0
	Sprain/Strn	70657	97298	98935	127084	22.6	31.7	7.1	.7	16.5	18.1
	Other	7260	4777	7514	5947	.7	2.1	5.9	9.0	16.7	17.4
All Injuries:		231551	302887	319833	386946	19.1	100.0	100.0	3.2	16.1	15.7
Most Frequent Occurring Injuries:											
Sprain/Strn	Lower Leg	29568	41133	43928	54508	23.3	13.6	3.7	.9	17.3	18.7
Cont./Abra.	Upper Trunk	13924	19182	23123	27993	26.5	6.8	2.5	1.2	17.3	16.1
Fracture	Finger	14147	15852	19098	22453	16.7	5.8	2.1	1.2	15.4	13.2
Sprain/Strn	Finger	11021	16506	14848	20332	25.6	5.1	.2	.1	14.9	14.0
Cont./Abra.	Lower Leg	11163	15150	15317	20468	23.5	5.0	.5	.3	16.3	19.1
Fracture	Lower Arm	10742	14623	13295	16159	16.2	4.4	12.6	9.0	14.3	14.9
Laceration	Face	9764	12437	14170	14689	15.0	4.1	.3	.2	16.8	16.0
Fracture	Upper Trunk	9748	13257	11413	14659	16.8	4.0	8.7	6.9	15.2	15.3
Sprain/Strn	Lower Arm	8849	12116	11653	17501	27.8	4.0	.2	.1	15.2	16.5
Cont./Abra.	Lower Arm	7609	10063	12072	14009	22.8	3.5	.1	.1	15.0	14.1
Sprain/Strn	Upper Trunk	7062	10448	11443	12162	21.3	3.3	.9	.8	17.6	20.1
Fracture	Lower Leg	8980	9966	8581	9836	3.9	3.0	19.8	20.8	16.1	15.2
Cont./Abra.	Finger	5430	8475	10981	11220	29.3	2.9	.0	.0	14.5	14.0
Cont./Abra.	Head	3462	3786	5827	7095	28.3	1.6	4.2	8.2	15.3	14.1
Concussion	Head	2662	4478	6397	5451	32.1	1.5	12.7	26.2	16.1	16.1
Fracture	Face	3216	3783	4347	5324	18.3	1.3	2.0	4.7	18.2	19.1
Dislocation	Upper Trunk	2849	4168	4039	4315	16.7	1.2	2.8	7.2	18.5	19.5
	Total %						71.1%	73.3%			

Table A-3: Baseball Activity and Related Equipment (PC-1204)

All and Major Injuries Fy 73-76

		Projected Number of Injuries per Fiscal Year 73	74	75	76	Average Annual Change %	All % of Total	Major % of Total (Major)	Major % of Injury Category	Average Age All	Average Age Major
Body Parts:	Head	16082	15116	19113	23545	14.5	6.8	19.2	6.8	14.3	17.8
	Ear	804	794	1668	1590	34.7	.4	.1	.3	17.6	22.0
	Eye	5100	5702	5005	4692	-2.2	1.9	8.7	11.1	16.4	15.9
	Face	34829	38494	45929	52132	14.4	15.8	14.2	2.2	15.0	17.1
	Mouth	7872	7727	8962	10898	11.9	3.3	1.0	.7	14.2	20.3
	Neck	1090	2137	1510	1905	31.0	.6	.2	.8	16.8	27.3
	Upper Trunk	9349	11763	20816	22759	37.4	6.0	2.7	1.1	22.0	23.6
	Lower Trunk	2835	3704	5286	6314	30.9	1.7	4.0	5.8	21.5	24.3
	Upper Arm	1403	830	1728	1389	15.9	.5	.3	1.3	19.3	20.0
	Lower Arm	17301	22276	27074	31150	21.8	9.0	9.6	2.6	18.7	23.3
	Hand	8936	9465	14351	14916	20.5	4.4	.4	.2	19.4	18.3
	Finger	33380	43437	63602	65527	26.5	19.0	2.2	.3	18.9	22.4
	Upper Leg	2012	2485	3247	4984	35.9	1.2	.8	1.6	22.6	22.4
	Lower Leg	40510	55646	79452	91003	31.6	24.5	34.4	3.4	21.8	23.0
	Foot	8241	8935	11611	14358	20.7	4.0	1.8	1.1	21.9	23.2
	Toe	1551	2509	2801	3677	34.9	1.0	.1	.2	21.2	15.2
	Other	576	160	251	235	-7.2	.1	.5	11.1	24.6	16.0
Diagnoses:	Concussion	2152	2319	2715	3279	15.2	1.0	10.1	25.1	17.7	19.3
	Cont./Abra.	58063	71628	96567	117871	26.7	31.7	10.9	.8	17.7	18.8
	Dislocation	4414	6665	8371	9018	28.1	2.6	3.1	2.9	23.3	23.5
	Fracture	33149	40624	53816	60077	22.2	17.3	47.9	6.7	19.7	21.2
	Hematoma	5672	5942	6155	10682	27.3	2.6	5.7	5.2	17.2	15.7
	Laceration	37101	38796	45320	46746	8.2	15.5	6.9	1.1	16.4	18.4
	Sprain/Strn	44791	59577	89530	98137	31.0	26.9	11.2	1.0	21.0	24.6
	Other	6529	5629	9932	5264	5.2	2.5	4.2	4.0	19.1	18.7
All Injuries		191871	231190	312406	351074	22.7	100.0	100.0	2.4	18.9	20.6
Most Frequent Occurring Injuries:											
Sprain/Strn	Lower Leg	21062	28592	44210	50499	34.9	13.3	5.3	1.0	22.5	22.6
Fracture	Finger	10755	14069	21582	23219	30.6	6.4	1.6	.6	19.4	22.2
Cont./Abra.	Face	13596	14110	18956	21358	16.9	6.3	3.3	1.3	14.3	19.4
Laceration	Face	13287	15307	15499	17104	8.9	5.6	2.7	1.2	14.9	15.5
Sprain/Strn	Finger	10317	11875	18239	18564	23.5	5.4	.0	.0	17.4	—
Cont./Abra.	Lower Leg	7216	12053	17484	20627	43.4	5.3	.4	.2	21.0	21.5
Cont./Abra.	Finger	6792	9077	12373	14583	29.3	3.9	.0	.0	17.6	14.0
Cont./Abra.	Lower Arm	6451	7305	8989	12383	24.7	3.2	.4	.3	17.3	20.9
Cont./Abra.	Head	6014	6741	8461	11670	25.2	3.0	2.7	2.1	14.6	17.1
Fracture	Face	5823	6914	8315	10319	21.0	2.9	7.6	6.3	16.6	17.1
Cont./Abra.	Upper Trunk	3945	5717	9663	12008	46.1	2.9	.4	.3	20.8	22.5
Fracture	Lower Leg	5173	7598	6930	8687	21.1	2.6	25.4	23.3	22.4	23.4
Sprain/Strn	Lower Arm	4598	6166	8429	9082	26.2	2.6	4.0	3.7	19.4	25.5
Laceration	Mouth	5659	5622	7014	7853	12.0	2.4	.1	.1	14.2	16.6
Fracture	Lower Arm	4818	5915	6916	7155	14.4	2.3	4.5	4.7	19.4	22.4
Laceration	Lower Leg	5067	5037	6946	6485	10.2	2.2	1.4	1.6	18.7	16.0
Laceration	Head	6286	4478	6002	5476	-1.2	2.0	1.4	1.7	13.7	22.8
Cont./Abra.	Eye	2860	3534	3773	3172	4.8	1.2	2.5	4.9	16.3	17.5
Concussion	Head	2152	2319	2715	3279	15.2	1.0	10.1	25.1	17.7	19.3
	Total %						74.5	73.8			

Table A-4: Basketball Activity and Related Equipment (PC-1205)

All and Major Injuries Fy 73-76

		Projected Number of Injuries per Fiscal Year 73	74	75	76	Average Annual Change %	All: % of Total	Major: % of Total (Major)	Major: % of Injury Category	Average Age: All	Average Age: Major
Body Parts:	Head	4762	6547	8329	9738	27.2	2.9	12.7	5.4	16.7	15.4
	Ear	342	106	282	272	31.2	.1	.0	.0	20.1	—
	Eye	2391	2989	2789	3376	13.1	1.1	1.3	1.4	19.1	21.5
	Face	13795	17690	24456	27732	26.6	8.2	9.6	1.4	19.5	18.3
	Mouth	3535	4658	5238	5961	19.3	1.9	.7	.4	18.8	20.5
	Neck	392	491	922	1357	53.4	.3	.9	3.4	16.4	19.5
	Upper Trunk	5990	8533	10023	12043	26.7	3.6	12.7	4.4	20.2	18.5
	Lower Trunk	3324	4864	4158	4946	16.9	1.7	5.8	4.2	18.7	16.7
	Upper Arm	508	424	372	822	30.7	.2	1.0	6.2	17.9	14.5
	Lower Arm	13014	16404	18333	22514	20.2	6.9	13.9	2.5	17.2	15.5
	Hand	8561	8036	9573	12137	13.3	3.7	.2	.1	17.9	18.5
	Finger	39171	43748	51069	61894	16.5	19.1	4.3	.3	16.6	19.3
	Upper Leg	1122	853	828	1605	22.3	.4	1.3	3.7	18.8	14.7
	Lower Leg	75379	91444	118385	136489	22.0	41.2	28.2	.8	19.6	21.7
	Foot	14157	16925	20033	25421	21.6	7.5	7.2	1.2	19.6	20.4
	Toe	2319	3263	2806	3272	14.4	1.1	.3	.4	18.8	14.0
	Other	328	38	353	46	217.9	.1	.0	.0	14.7	—
Diagnoses:	Concussion	568	708	994	1239	29.9	.3	8.8	31.3	15.9	16.4
	Cont./Abra.	33709	45284	50188	63110	23.6	18.8	12.2	.8	18.0	16.0
	Dislocation	5006	6002	7716	8726	20.5	2.7	4.0	1.8	20.2	20.8
	Fracture	28480	35364	42412	47147	18.4	15.0	45.3	3.7	17.9	17.6
	Hematoma	1994	1840	2345	2913	14.6	.9	2.1	2.9	18.3	18.5
	Laceration	18725	22599	31680	33409	22.1	10.4	6.5	.8	19.2	19.5
	Sprain/Strn	94196	112357	138330	169915	21.7	50.3	10.7	.3	18.9	24.0
	Other	6412	2859	4284	3166	-10.6	1.6	10.3	7.8	19.8	20.7
All Injuries:		189090	227013	277949	329625	20.4	100.0	100.0	1.2	18.7	18.6
Most Frequent Occurring Injuries:											
Sprain/Strn	Lower Leg	59915	72728	95269	110142	22.7	33.0	8.1	.3	19.6	24.6
Sprain/Strn	Finger	14730	15319	17520	23543	17.6	6.9	.0	.0	16.0	—
Fracture	Finger	11793	12687	16309	19033	17.6	5.8	2.9	.6	16.5	21.0
Laceration	Face	8857	10968	16607	17600	27.1	5.3	5.9	1.4	20.0	19.4
Cont./Abra.	Lower Leg	6901	9366	11160	14476	28.2	4.1	.6	.2	19.0	21.9
Cont./Abra.	Finger	7452	10340	10392	12019	18.3	3.9	.3	.1	16.4	13.0
Sprain/Strn	Foot	7544	10255	8767	13309	24.4	3.9	.5	.2	19.3	28.2
Sprain/Strn	Lower Arm	4888	5676	6590	9830	27.1	2.6	.4	.2	17.1	11.4
Fracture	Lower Leg	3780	6385	7469	7791	30.1	2.5	13.2	6.5	19.8	19.2
Fracture	Lower Arm	3458	5422	4962	5614	20.5	1.9	13.0	8.4	17.0	15.6
Fracture	Foot	3473	3387	5121	5446	18.4	1.7	5.6	4.1	19.9	17.9
Cont./Abra.	Upper Trunk	2445	3467	3758	4484	23.2	1.4	4.5	4.0	20.6	19.5
Fracture	Face	1773	2115	3206	3744	29.2	1.1	3.2	3.7	20.0	16.7
Cont./Abra.	Head	1560	2236	2057	3493	35.0	.9	3.4	4.5	15.4	12.4
Cont./Abra.	Lower Trunk	1524	2148	1857	1979	11.3	.7	2.2	3.6	17.2	11.3
Other	Lower Leg	2912	547	1692	915	27.4	.6	3.5	7.1	21.5	24.6
Concussion	Head	568	708	994	1239	29.9	.3	8.8	31.3	15.9	16.4
	Total %						76.6	76.1			

Table A-5: Snow Skiing and Associated Equipment (PC-1216)

		All and Major Injuries Fy 73-76									
		Projected Number of Injuries per Fiscal Year				Average Annual Change	All	Major		Average Age	
		73	74	75	76	%	% of Total	% of Total (Major)	% of Injury Category	All	Major
Body Parts:	Head	3407	2781	3468	3660	4.0	4.1	2.1	4.2	18.5	14.4
	Ear	40	16	35	134	113.9	.1	.0	.0	20.2	—
	Eye	622	70	433	65	114.9	.4	.0	.0	17.6	—
	Face	5689	2136	4277	4103	11.2	5.0	2.2	3.7	18.2	18.6
	Mouth	612	1035	393	236	-11.0	.7	.0	.0	19.2	—
	Neck	409	509	519	707	20.9	.7	.6	7.4	22.5	17.7
	Upper Trunk	.6582	6601	7712	8815	10.5	9.1	6.5	5.9	25.6	27.1
	Lower Trunk	1697	1857	2414	2010	7.6	2.4	6.6	22.2	21.8	25.1
	Upper Arm	276	278	571	546	33.9	.5	.7	12.0	26.1	23.1
	Lower Arm	5373	3701	4262	4966	.2	5.6	3.8	5.6	22.4	20.5
	Hand	1760	1355	1612	2073	8.2	2.1	.0	.0	21.7	—
	Finger	3326	4952	5512	6945	28.7	6.4	.3	.4	19.8	20.7
	Upper Leg	2074	1716	1079	2740	33.2	2.3	4.8	16.8	18.3	22.5
	Lower Leg	49425	36485	57051	48061	4.8	58.5	70.2	9.8	18.8	19.0
	Foot	2129	1234	1559	611	-25.5	1.7	.3	1.5	23.3	25.0
	Toe	183	17	185	95	283.0	.1	.0	.0	20.8	—
	Other	436	233	533	42	-3.3	.4	1.7	37.5	20.4	25.5
Diagnoses:	Concussion	815	722	895	431	-13.7	.9	1.4	12.7	20.1	14.6
	Cont./Abra.	10821	15010	15534	13023	8.7	16.7	4.8	2.3	19.8	16.1
	Dislocation	908	2209	2660	1514	40.2	2.2	3.9	14.5	28.3	28.5
	Fracture	24123	17829	28045	20435	1.4	27.7	79.4	23.4	19.3	20.1
	Hematoma	994	184	981	501	100.9	.8	.0	.5	20.5	13.3
	Laceration	9769	5923	8584	7432	-2.6	9.7	1.5	1.2	20.0	23.2
	Sprain/Strn	34452	22420	33138	41834	13.0	40.4	7.9	1.6	19.9	20.4
	Other	2158	629	1778	639	15.9	1.6	1.1	5.6	20.9	21.6
All Injuries:		84040	64976	91615	85809	4.0	100.0	100.0	8.2	19.9	20.2
Most Frequent Occurring Injuries:											
Sprain/Strn	Lower Leg	24669	15516	25452	29300	14.0	29.1	6.5	1.8	18.9	17.1
Fracture	Lower Leg	18038	12877	20592	13306	-1.4	19.9	61.7	25.4	18.2	19.3
Cont./Abra.	Lower Leg	4687	6786	7020	3990	1.7	6.9	1.1	1.3	18.3	12.6
Laceration	Face	3960	1629	2925	2643	3.7	3.4	1.1	2.7	18.1	24.0
Sprain/Strn	Upper Trunk	2845	1732	1545	3705	30.0	3.0	.2	.7	25.1	29.0
Sprain/Strn	Finger	996	2085	2305	3663	59.6	2.8	.0	.0	19.6	—
Cont./Abra.	Upper Trunk	1384	2295	2527	2719	27.8	2.7	.2	.7	25.2	30.4
Laceration	Head	1725	1285	1808	1768	4.3	2.0	.0	.0	18.2	—
Fracture	Lower Arm	1716	1349	1523	1272	-8.3	1.8	3.8	17.5	24.6	20.5
Dislocation	Upper Trunk	788	1734	1796	1221	30.5	1.7	3.7	17.9	29.0	28.2
Fracture	Upper Trunk	1168	794	1761	1118	17.8	1.5	2.1	11.8	23.3	25.3
Fracture	Upper Leg	231	942	462	1552	164.3	1.0	4.6	38.8	17.7	22.7
	Total %						75.8	85.0			

Table A-6: Ice Hockey and Related Equipment (PC-1279)

		Projected Number of Injuries per Fiscal Year				All and Major Injuries Fy 73-76					
		73	74	75	76	Average Annual Change %	All: % of Total	Major: % of Total (Major)	Major: % of Injury Category	Average Age: All	Average Age: Major
Body Parts:	Head			2890	2281	-21.1	9.8	46.5	7.6	17.4	14.8
	Ear			382	187	-51.0	1.1	.0	.0	23.9	—
	Eye			449	81	-82.0	1.0	8.4	13.5	16.8	20.0
	Face			11207	8811	-21.4	38.0	3.4	.1	18.8	29.0
	Mouth			1602	1633	1.9	6.1	.6	.2	19.2	15.0
	Neck			213	193	-9.4	.8	.0	.0	19.9	—
	Upper Trunk			1932	3218	66.6	9.8	7.6	1.2	19.8	26.7
	Lower Trunk			763	692	-9.3	2.8	3.4	2.0	17.6	12.3
	Upper Arm			39	53	35.9	.2	.0	.0	13.8	—
	Lower Arm			1866	1670	-10.5	6.7	.6	.1	18.8	16.0
	Hand			700	725	3.6	2.7	.0	.0	16.3	—
	Finger			771	1338	73.5	4.0	.0	.0	16.5	—
	Upper Leg			254	292	15.0	1.0	1.5	2.4	16.9	15.0
	Lower Leg			3049	3900	27.9	13.2	27.8	3.4	18.8	19.7
	Foot			698	765	9.6	2.8	.0	.0	17.8	—
	Toe			13	74	469.2	.2	.0	.0	19.5	—
	Other			0	5	—	.0	.0	.0	31.0	—
Diagnoses:	Concussion			614	353	-42.5	1.8	37.9	33.0	16.1	13.7
	Cont./Abra.			6116	7500	22.6	25.8	5.4	.3	18.0	16.0
	Dislocation			226	534	136.3	1.4	3.1	3.4	20.8	14.0
	Fracture			2360	2497	5.8	9.2	46.4	8.0	18.9	21.7
	Hematoma			354	347	-2.0	1.3	.0	.0	17.8	—
	Laceration			13890	10909	-21.5	47.0	3.7	.1	18.8	25.1
	Sprain/Strn			3160	3635	15.0	12.9	1.9	.2	18.7	11.0
	Other			108	143	32.4	.5	1.7	5.6	19.6	14.4
All Injuries:				26828	25918	-3.4	100.0	100.0	1.6	18.6	17.9
Most Frequent Occurring Injuries:											
Laceration	Face			9604	7309	-23.9	32.1	.0	.0	19.0	—
Laceration	Mouth			1517	1455	-4.1	5.6	.6	.2	19.4	15.0
Sprain/Strn	Lower Leg			1281	1695	32.3	5.6	.0	.0	19.0	—
Cont./Abra.	Upper Trunk			1042	1703	63.4	5.2	.0	.0	19.3	—
Laceration	Head			1611	1110	-31.1	5.2	.0	.0	16.0	—
Cont./Abra.	Lower Leg			1192	1337	12.2	4.8	.0	.0	17.4	—
Cont./Abra.	Lower Arm			915	797	-12.9	3.3	.0	.0	18.4	—
Cont./Abra.	Face			727	894	23.0	3.1	.0	.0	16.0	—
Fracture	Face			809	516	-36.2	2.5	3.4	2.2	19.8	29.0
Cont./Abra.	Head			530	689	30.0	2.3	.0	.0	21.3	—
Cont./Abra.	Foot			510	573	12.4	2.1	.0	.0	17.6	—
Concussion	Head			614	353	-42.5	1.8	37.9	33.0	16.1	13.7
Fracture	Lower Leg			363	503	38.6	1.6	24.6	23.9	21.6	20.4
Fracture	Upper Trunk			327	472	44.3	1.5	7.6	8.0	17.9	26.7
	Total %						76.7	74.1			

Table A-7: Gymnastics and Associated Equipment (PC-1272)

		Projected Number of Injuries per Fiscal Year 73	74	75	76	Average Annual Change %	All and Major Injuries Fy 73-76: All, % of Total	Major, % of Total (Major)	Major, % of Injury Category	Average Age: All	Average Age: Major
Body Parts:	Head	925	1551	2393	2513	42.3	5.1	9.0	6.8	12.1	13.0
	Ear	0	116	51	0	—	.1	.0	.0	11.6	—
	Eye	61	47	172	49	57.2	.2	.4	7.7	25.6	19.0
	Face	980	763	3133	1877	82.8	4.6	1.0	.8	12.2	45.2
	Mouth	89	308	655	890	131.5	1.3	.0	.0	10.2	—
	Neck	573	1014	1431	1325	36.9	3.0	8.8	11.4	14.4	15.0
	Upper Trunk	1091	3591	4010	5967	96.5	10.0	7.0	2.7	14.8	13.6
	Lower Trunk	861	1565	2079	2796	49.7	5.0	7.4	5.7	15.0	13.9
	Upper Arm	74	221	264	457	97.1	.7	1.0	5.4	13.4	13.1
	Lower Arm	3652	6254	9386	11339	47.4	21.0	41.3	7.6	12.6	11.7
	Hand	1105	946	1839	1574	21.9	3.7	.0	.0	14.8	—
	Finger	1221	2751	3841	5440	68.9	9.1	1.5	.6	13.9	10.0
	Upper Leg	52	62	423	559	211.2	.8	.9	4.8	16.6	38.6
	Lower Leg	3342	7152	10670	13182	62.2	23.6	20.4	3.3	14.6	14.0
	Foot	1472	2578	3439	4225	43.8	8.0	.0	.0	14.9	—
	Toe	909	818	1587	1849	33.5	3.5	1.1	1.2	13.2	18.0
	Other	0	146	74	61	—	.2	.2	5.0	8.9	17.0
Diagnoses:	Concussion	282	315	283	769	57.8	1.1	6.4	21.7	13.2	13.8
	Cont./Abra.	3486	6751	12818	14951	66.7	26.1	7.4	1.1	13.6	16.9
	Dislocation	196	724	1080	1061	105.6	2.1	6.6	12.2	15.7	13.5
	Fracture	4280	5639	7612	10503	34.9	19.2	63.4	12.7	12.8	12.9
	Hematoma	226	187	443	350	32.9	.8	.1	.5	13.9	15.0
	Laceration	1960	2131	5597	3857	46.8	9.3	1.2	.5	12.4	9.9
	Sprain/Strn	5454	13250	16718	22141	67.2	39.5	10.3	1.0	14.8	15.0
	Other	523	886	896	471	7.7	1.9	4.6	9.3	13.9	15.3
All Injuries:		16407	29883	45447	54103	51.1	100.0	100.1	3.9	13.9	13.6
Most Frequent Occurring Injuries:											
Sprain/Strn.	Lower Leg	2149	5185	6132	8951	68.5	15.4	1.1	.3	15.3	16.6
Fracture	Lower Arm	1802	2677	3135	4669	38.2	8.4	38.0	17.4	11.2	11.6
Sprain/Strn.	Lower Arm	1117	1818	3372	3909	54.7	7.0	.0	.0	13.8	—
Cont./Abra.	Lower Leg	384	1054	2521	2596	105.5	4.5	.0	.0	13.8	—
Cont./Abra.	Lower Arm	628	1424	2260	2183	60.7	4.5	.3	.2	13.0	16.0
Sprain/Strn.	Foot	392	1775	1816	2040	122.5	4.1	.0	.0	14.1	—
Sprain/Strn.	Upper Trunk	402	2000	1259	2126	143.1	4.0	.9	.9	15.4	13.8
Cont./Abra.	Upper Trunk	336	914	1889	2587	105.2	3.9	.8	.8	14.0	12.4
Laceration	Face	627	560	2255	1004	78.8	3.0	.0	.0	11.7	—
Fracture	Finger	570	829	1125	1743	45.4	2.9	.8	1.1	13.2	10.6
Sprain/Strn.	Finger	225	676	1039	1675	105.1	2.5	.0	.0	13.4	—
Sprain/Strn.	Neck	481	827	1154	1124	36.3	2.5	7.6	12.0	14.5	15.0
Cont./Abra.	Foot	586	593	1063	1302	34.3	2.4	.0	.0	15.0	—
Sprain/Strn.	Lower Trunk	575	697	1108	1111	26.8	2.4	.7	1.1	16.9	13.9
Fracture	Lower Leg	591	585	1031	989	23.7	2.2	13.4	23.5	13.1	13.8
Cont./Abra.	Lower Trunk	211	705	611	1501	122.2	2.1	3.2	6.0	13.7	11.3
Fracture	Upper Trunk	225	441	461	765	55.5	1.3	4.6	13.7	13.3	13.7
	Total %						74.2	77.8			

Table A-8: Trampolines (PC-1233)

		Projected Number of Injuries per Fiscal Year 73	74	75	76	Average Annual Change %	All: % of Total	Major: % of Total (Major)	Major: % of Injury Category	Average Age: All	Average Age: Major
Body Parts:	Head	2200	1510	2244	1897	.6	10.8	4.3	1.9	12.1	14.3
	Ear	0	64	72	75	—	.3	.0	.0	7.2	—
	Eye	0	0	30	17	—	.1	.0	.0	17.4	—
	Face	1223	1633	1983	1615	12.1	8.9	3.2	1.7	12.5	15.9
	Mouth	332	380	766	593	31.2	2.9	.0	.0	10.8	—
	Neck	646	792	883	934	13.3	4.5	3.8	4.0	13.5	14.7
	Upper Trunk	984	1078	1292	2040	29.1	7.4	10.2	6.5	14.2	15.8
	Lower Trunk	798	917	1485	751	9.1	5.4	9.2	8.0	16.2	15.9
	Upper Arm	89	401	121	189	112.3	1.1	10.9	47.4	9.0	7.5
	Lower Arm	3184	4397	2899	2629	-1.8	18.0	31.5	8.3	12.0	11.9
	Hand	289	315	315	256	-3.2	1.6	.0	.0	12.8	—
	Finger	858	956	860	935	3.4	5.0	.0	.0	14.6	—
	Upper Leg	123	135	22	458	636.0	1.0	8.9	41.7	10.1	9.7
	Lower Leg	4070	4578	4015	5065	8.8	24.4	17.2	3.3	14.1	15.7
	Foot	1174	1373	1057	792	-10.4	6.1	.9	.7	14.0	14.0
	Toe	511	614	333	214	-20.4	2.3	.0	.0	15.1	—
	Other	130	0	0	8	—	.2	.0	.0	13.0	—
Diagnoses:	Concussion	143	25	61	40	9.0	.4	2.2	28.1	14.0	16.8
	Cont./Abra.	2882	3556	3531	3562	7.9	18.7	2.7	.7	12.8	11.5
	Dislocation	171	72	217	276	56.9	1.0	4.1	19.5	14.5	15.0
	Fracture	4102	3846	3452	4185	1.6	21.5	67.9	15.1	12.3	12.2
	Hematoma	158	11	412	335	1177.9	1.3	.0	.0	13.1	—
	Laceration	3205	3122	4290	3347	4.3	19.2	.1	.0	12.5	19.0
	Sprain/Strn	5568	8169	5946	6438	9.3	36.0	13.3	1.8	14.5	13.6
	Other	382	342	468	285	-4.2	2.0	9.6	22.4	13.0	16.5
All Injuries:		16611	19143	18377	18468	3.9	100.0	100.0	4.8	13.3	13.0
Most Frequent Occurring Injuries:											
Sprain/Strn	Lower Leg	2118	3484	2822	2889	16.0	15.6	1.8	.6	14.3	12.0
Fracture	Lower Arm	1665	1906	1613	1434	-4.0	9.1	25.2	13.2	11.0	11.6
Laceration	Head	1720	1111	1782	1541	3.8	8.5	.0	.0	12.5	—
Laceration	Face	789	1129	1381	886	9.9	5.8	.0	.0	11.5	—
Sprain/Strn	Lower Arm	947	1844	331	356	6.7	4.8	1.9	1.8	13.5	10.0
Fracture	Lower Leg	1262	465	397	979	22.9	4.3	15.2	16.9	12.4	16.3
Sprain/Strn	Neck	547	610	735	744	11.1	3.6	3.3	4.4	13.6	14.4
Sprain/Strn	Upper Trunk	447	718	544	925	35.5	3.6	3.9	5.2	14.6	15.3
Cont./Abra.	Lower Leg	488	546	600	762	16.3	3.3	.2	.3	12.8	9.0
Cont./Abra.	Lower Arm	423	519	797	652	19.4	3.3	.0	.0	11.6	—
Sprain/Strn	Lower Trunk	364	548	742	566	20.7	3.1	.5	.9	17.6	12.0
Cont./Abra.	Foot	452	770	517	118	-13.2	2.6	.0	.0	14.2	—
Cont./Abra.	Upper Trunk	393	289	320	587	22.6	2.2	.0	.0	13.7	—
Laceration	Mouth	203	276	686	406	47.9	2.2	.0	.0	11.7	—
Sprain/Strn	Foot	363	441	305	448	12.5	2.1	.0	.0	13.1	—
Fracture	Face	153	276	328	352	35.5	1.5	3.2	9.9	16.9	15.9
Cont./Abra.	Head	159	351	196	303	43.7	1.4	2.0	6.9	10.7	11.7
Fracture	Upper Trunk	63	22	331	381	451.5	1.1	5.0	21.7	13.4	15.6
	Total %						78.1	62.2			

Appendix B.
Wayne State Tolerance Curve

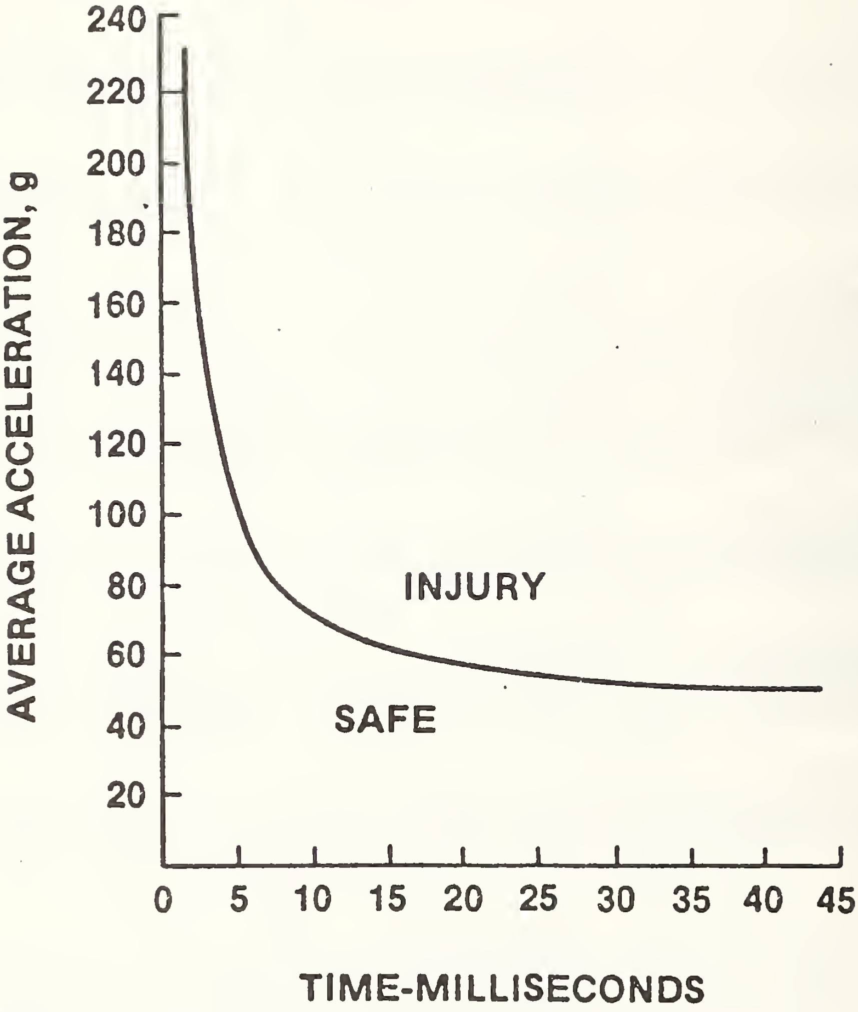

Figure 3. Wayne State Concussion Tolerance Curve.

(Courtesy of R. E. Berger (134, p. 31, figure 3))

List of References

The List of References is arranged alphabetically according to several topics. Because these topics reflect a great deal of overlap, the assignment of each reference to a topic was determined by a simple hierarchial classification scheme--topics grouped as Level 1 were considered first, then Level 2, and finally, Level 3. Each entry appears only once in the list.

LIST OF REFERENCES

Football

1. Allen, M. L., "Air Force Football Injuries," The American Medical Association 206, 5(October 28, 1968) pp. 1053-1058.

2. Blyth, C. S. and Arnold, D. C., The Forty-First Annual Survey of Football Fatalities: 1931-1972, Chapel Hill, North Carolina, February 1973.

3. Blyth, C. S. and Arnold, D. C., The Forty-Second Annual Survey of Football Fatalities: 1931-1973, Chapel Hill, North Carolina, February 1974.

4. Blyth, C. S. and Arnold, D. C., The Forty-Third Annual Survey of Football Fatalities: 1931-1974, Chapel Hill, North Carolina, February 1975.

5. Blyth, C. S. and Arnold, D. C., The Forty-Fourth Annual Survey of Football Fatalities: 1931-1975, Chapel Hill, North Carolina, February 1976.

6. Blyth, C. S. and Mueller, F. O., "Football Injury Survey: Part 1-When and Where Players Get Hurt," The Physician and Sports Medicine 2, 9(September 1974) pp. 45-52.

7. Blyth, C. S. and Mueller, F. O., "Football Injury Survey: Part 2-Indentifying the Causes," The Physician and Sports Medicine 2, 10(October 1974) pp. 71-78.

8. Blyth, C. S. and Mueller, F. O., "Football Injury Survey: Part 3-Injury Rates Vary with Coaching," The Physician and Sports Medicine 2, 11(November 1974) pp. 45-50.

9. Blyth, C. S. and Mueller, F. O., An Epidemiologic Study of High School Football Injuries in North Carolina- 1968-1972, U. S. Consumer Product Safety Commission under Contract CPSC-C-74-18.

10. Bowerman, J. W. and McDonnell, E. S., "Football Injuries Reflect Position Played, Gear Worn," Radiology News Digest October 1975.

11. Bowers, Jr., K. D., "Let's Make High School Football Safer," The West Virginia Medical Journal 70, 8(August 1974) pp. 180-182.

12. Brown, R. B., "Personality Characteristics Related to Injuries in Football," Research Quarterly 42, 2(1971) pp. 133-138.

Football

13. Castellanos, A. and Greer, P., "Tackle Football in Pre-High School Children," Sports Medicine and Physical Fitness 6, 3(September 1966) pp. 187-190.

14. Chandler, J. V.; Langley, T. D.; and Blair, S. N., "Movement Times for Jab and Cross-Over Steps by High School Football Players," Research Quarterly 45, 2(May 1975) pp. 149-152.

15. Clarke, K. S., 1976 Spring Football Injury Study, NCAA Committee on Competitive Safeguards and Medical Aspects of Sports, 1976.

16. Clarke, K. S., "Calculated Risk of Sports Fatalities," The American Medical Association 197, 11(September 12, 1966) pp. 172-174.

17. Conrad, R. W., A Survey of the Pre-Season Football Coaching Techniques, Tri-State Area School Study Council, University of Pittsburgh, June 1966.

18. Diamond, P. E. and McMaster, J. H., "Tackler's Exostosis," Sports Medicine 3, 5(1975) pp. 238-242.

19. Eastwood, F. R., "Hazards to Health," New England Journal of Medicine 271, 8(August 20, 1964) pp. 411-413.

20. Edmunds, G. B., "Football: The Last Hurrah?", Sports Merchandiser (March 1976) pp. 41-42.

21. Garrahan, W. F., "The Incidence of High School Football Injuries," Rhode Island Medical Journal (August 17, 1967) pp. 833-835.

22. Godshall, R. W. "Junior League Football: Risks vs. Benefits," Sports Medicine 3, 3(May/June 1975) pp. 139-144.

23. Grippo, J., National Football League Injury Study 1969-72, Prepared for The National Football League, New York, New York, Stanford Research Institute Project MSD-1961.

24. Grippo, J., National Football League 1973 Injury Study, Prepared for The National Football League, New York, New York, Stanford Research Institute Project MSD-1961.

25. Grippo, J., National Football League 1974 Injury Study, Prepared for The National Football League, New York, New York, Stanford Research Institute Project MSD-1961.

26. Hibbert, Jr., R. W., "High School Football Injuries," The Rocky Mountain Medical Journal 47, (April 1950) pp. 276-279.

Football

27. Himmelwright, G. O., "Field Decisions-Diagnosis In Football," Maryland State Medical Journal (October 1967) pp. 50-58.

28. Martin, G. L. and Costello, D. F., The 1970 Intercollegiate Tackle Football Injury Surveillance Report, The Joint Commission on Competitive Safeguards and Medical Aspects of Sports.

29. Mueller, F. O. and Blyth, C. S., "North Carolina High School Football Injury Study: Equipment and Prevention," Sports Medicine 2, 1(January/February 1974).

30. Murray, B. and Herbert, D., A Coach's Guide to Safe Football, Prepared for the American Football Coaches Association.

31. Powell, J. W.; Carey, R. C.; and Clarke, K. S., "Injury Patterns During the First Three Days of Football Practice Among Big Ten Schools," Athletic Training 11, 1(March 1976) pp. 40-45.

32. Rachun, A. and Kavanagh, F. J., "Protective Football Equipment," American Journal of Surgery 98, (September 1959) pp. 363-367.

33. Robey, J. M.; Blyth, C. S.; and Mueller, F. O., "Athletic Injuries," The American Medical Association 217, 2(July 12, 1971) pp. 184-189.

34. Tomlins, F. I., "The Prevention of Athletic Injury," The Medical Society of New Jersey 63, 9(September 1966) pp. 414-415.

35. Williams, D. J. and Dayries, J. L., A Critical Analysis of the 1969 Little Grizzly Football Program in Missoula, Montana, The Bureau of Research on Physical Activity and Sport, University of Montana (September 1970).

36. "A Modified Junior-High Plan Shows Football Injury Decline," Medical Tribune (January 6, 1964).

37. The Official National Collegiate Athletic Association Football Rules-1976, The NCAA Publishing Service, P. O. Box 1906, Shawnee Mission, Kansas.

38. "The House That Nicholas Built," Physician and Sports Medicine 1, 3(November 1973) pp. 73-79.

39. "Searching for Loose and Tight Joints," The Physician and Sports Medicine 2, 10(October 1974) pp. 80-82.

40. National Federation of State High School Associations: Facts of Football Safety, Elgin, Illinois, National Federation Publications, 1975.

Football/Snow Skiing

41. "October: Football Injuries," Applied Therapeutics (October 1963) pp. 833-841, 920.

42. Hazard Analysis-Football: Activity and Related Equipment, U. S. Consumer Product Safety Commission, July 1974.

43. Fact Sheet-No. 42: Football and Football Equipment, U. S. Consumer Product Safety Commission, October 1974.

44. NEISS News, U. S. Consumer Product Safety Commission 4, 3 (December 1975).

Snow Skiing

45. Arnold, I. M. F. and Ackman, C. F. D., "Skiing Injuries in Canada-A Coast-to-Coast Study," Sports Medicine (January/February 1973) pp. 31-33.

46. Bahniuk, E., "The Right Ski Bindings for Safety," Consumers' Research 60, 1(January 1977).

47. Bahniuk, E. and Izant, T., "The Effects of the Environment on Some Ski Bindings," Safety Research 8, 1(March 1976) pp. 30-37.

48. Bahniuk, E.; Mack, R. P.; Burstein, A. H.; and Frankel, V. H., "The Biomechanics of Contemporary Ski Bindings," Safety Research 4, 4(December 1972) pp. 160-171.

49. Bahniuk, E.; Mack, R. P.; Burstein, A. H.; and Frankel, V. H., "The Biomechanics of Ski Boots," Safety Research 6, 1 (March 1974) pp. 24-33.

50. Bodine, K. G., "Boots and Bindings," The American Podiatry Association 62, 1(January 1972) pp. 33-34.

51. Casewit, C., "Ski Safely," The California Highway Patrolman (December 1975) pp. 14-16, 58, 59.

52. Erskine, L. A., "Recent Changes in the Pattern of Skiing Injuries," Trauma 14, 1(January 1974) pp. 92-93.

53. Ettlinger, C. F., "Five Steps to Skiing Safety," Vermont Ski Safety Equipment, n.d.

54. Ettlinger, C. E., "Bindings Performance Report: The Gertsch Line," Skiing 28, 7(Spring 1976) pp. 82-85.

55. Fagan, C. A. and Tapper, E. M., "The Ski "Safety" Strap: A Misnomer," Sports Medicine 3, 2(March-April 1975) pp. 95-96.

Snow Skiing

56. Garrick, J. G., "The Mythology of Ski Injuries," The Physician and Sports Medicine 1, 3(November 1973) pp. 35-38.

57. Garrick, J. G., "The Epidemiology of Ski Injuries," Minnesota Medicine 54 (January 1971) pp. 17-18.

58. Garrick, J. G. and Kurland, L. T., "The Epidemiologic Significance of Unreported Ski Injuries," Safety Research 3, 4 (December 1971) pp. 182-187.

59. Gutman, J.; Weisbuch, J.; and Wolf, M., "Ski Injuries in 1972-1973," The American Medical Association 230, 10(December 9, 1974) pp. 1423-1425.

60. Harwood, M. R. and Strange, G. L., "Othopedic Aspects and Safety Factors in Snow Skiing," New York State Journal of Medicine (November 1966) pp. 2899-2907.

61. Hoffmann, P., "Take the High Boots from Skiing Children," The Physician and Sports Medicine 2, 12(December 1974) pp. 58-59.

62. Johnson, R. J.; Pope, M. H.; and Ettlinger, C., "Ski Injuries and Equipment Function," Sports Medicine 2, 6(November/December 1974) pp. 299-307.

63. Leach, R. E., "Medicine and Skiing," Skiing 28, 7(Spring 1976) pp. 14-16.

64. Mack, R. P.; Bahniuk, E.; Burstein, A. H.; and Frankel, V., "The Biomechanics of Children's Ski Bindings," Sports Medicine 2, 3(May/June 1974) pp. 154-162.

65. Marshall, J. R.; Warren, R.; and Fleiss, D. J., "Ligamentous Injuries of the Knee in Skiing," Clinical Orthopaedics and Related Research 108(May, 1975) pp. 196-199.

66. McAlister, R.; Brody, J. A.; Hammes, L. M.; Feltz, E. T.; Duncan, D. L.; and Williams, M. L., "Epidemiology of Ski Injuries in the Anchorage Area," Archives of Environmental Health 10, pp. 710-714.

67. Outwater, J. O., "On the Friction of Skis," Medicine and Sports 2, 4(May 1970) pp. 231-235.

68. Outwater, J. O.; Mastro, G. N.; and Ettlinger, C. F., "The Engineering Problem of Ski Safety," Biomechanics 2, 3 (1969) pp. 209-216.

69. Outwater, J. O. and Ettlinger, C. F., "The Engineering of Ski Bindings," Medicine and Science in Sports 1, 4 (December 1969) pp. 200-206.

Snow Skiing

70. Piziali, R. L. and Mote, Jr., C. D., "The Snow Ski as a Dynamic System," Dynamic Systems, Measurement and Control 94(Series G), 2(June 1972) pp. 133-138.

71. Pope, M. H.; Johnson, R. J.; and Ettlinger, C. F., "Ski Binding Settings Based on Anthropometric and Biomechanical Data," Human Factors 18, 1(1976) pp. 27-32.

72. Prokop, L., "Non-traumatic Incidents During Skiing," Sports Medicine and Physical Fitness 12, 4(December 1972) pp. 219-223.

73. Reynolds, P. C., "Safety Strong at Ski Mechanics Seminars," Selling Sporting Goods (November 1975) pp. 52-53.

74. Shealy, J. E., "Effectiveness of Anti-Friction Devices in Snow-Skiing as a Function of Years Use," Human Factors Society, 19th Annual Meeting Proceedings (October 14-16, 1975) pp. 125-129.

75. Shealy, J. E.; Geyer, L. H.; and Hayden, R., "Epidemiology of Ski Injuries: Effect of Method of Skill Acquisition and Release Binding Accident Rate," Human Factors 16, 5, pp. 459-473.

76. Spademan, R., "Lower-Extremity Injuries as Related to the Use of Ski Safety Binding," The American Medical Association 203, 7(February 12, 1968) pp. 103-108.

77. Subotnick, S. I., "The Biomechanical Basis of Skiing (Preliminary Report)," The American Podiatry Association 64, 1(January 1974).

78. Tapper, E. M. and Moritz, J. R., "Changing Patterns in Ski Injuries," The Physician and Sports Medicine 2, 12 (December 1974) pp. 39-47.

79. Tucker, R. C., "Skiing Down Through the Years," Minnesota Medicine 54 (January 1971) pp. 61-69.

80. Ungersma, J. A.; Mason, L. G.; O'Keefe, M. A.; and Walker, O. R., "Helicopter Fracture," Sports Medicine 3, 3(May/June 1975) pp. 122-131.

81. Van Der Linden, W.; Sunzel, H.; and Larsson, K., "Fractures of the Tibial Shaft after Skiing and Other Accidents," The Journal of Bone and Joint Surgery 57-A, 3(April 1975) pp. 321-327.

82. Voorhees, R. L., "Injury Prevention," Minnesota Medicine 54 (January 1971) pp. 19-23.

Snow Skiing/Baseball

83. Young, L. R.; Oman, C. M.; Crane, H.; Emerton, A.; and Heide, R., "The Etiology of Ski Injuries: An Eight Year Study of the Skier and His Equipment," Orthopedic Clinics of North America 7, 1(January 1976) pp. 17-29.

84. Young, L. R. and Crane, H., "The Influence of Equipment and Skier Factors on Ski Injuries: A Nine Year Study," (Unpublished Paper January 1976).

85. Summary Analysis of Snow Skiing and Associated Equipment (1216), U. S. Consumer Product Safety Commission, September 4, 1973.

86. "Ski-ing Safely," New Zealand Road Safety (August-September 1975) pp. 13-15.

Baseball

87. Adams, J. E., "Injury to the Throwing Arm," California Medicine 102, 2(February 1965) pp. 127-129.

88. Brogdon, B. G. and Crow, N. E., "Little Leaguer's Elbow," American Journal of Roentgen 83, 4(April 1960) pp. 671-675.

89. Cahill, B. R.; Tullos, H. S.; and Fain, R. H., "Little League Shoulder," Sports Medicine 2, 3(May/June 1974) pp. 150-153.

90. Diveley, R. L. and Meyer, P. W., "Baseball Shoulder," The American Medical Association 171, 12(November 1959) pp. 135-137.

91. Dworkin, C., "Baseball Fever: An Occupational Hazard," The Canadian Nurse 70, (July 1974) pp. 24-26.

92. Ewing, J. D., "Little League Elbow," Nebraska Medical Journal (March 1972) pp. 73-75.

93. Larson, R. L. and McMahan, R. O., "The Epiphyses and the Childhood Athlete," The American Medical Association 196, 7(May 1966) pp. 99-104.

94. Newell, K. M., "Decision Processes of Baseball Batters," Human Factors 16, 5(October 1974) pp. 520-527.

95. Nirschl, R. P., "Etiology of Tennis Elbow," Sports Medicine 3, 5(September/October 1975) pp. 261-264.

96. Polk, R. G., "The Frequencies and Causes of Baseball Injuries," The Athletic Journal (1968) pp. 18-20.

97. Woods, G. W.; Tullos, H. S.; and King, J. W., "The Throwing Arm: Elbow Joint Injuries," Sports Medicine 1, 4(1973) pp. 43-47.

Baseball /Ice Hockey

98. "Better Baseball Mit Pads Could Avoid Hand Trauma," Medical Tribune and Medical News 17, 18(May 12, 1976) pp. 43.

99. "Catchers Need More than a Mitt," Medical World News (April 5, 1976).

100. Summary Analysis of Baseball Activity and Related Equipment (1204), U. S. Consumer Product Safety Commission, Bureau of Epidemiology, September 4, 1973.

101. The Official National Collegiate Athletic Association Baseball Guide-1976, NCAA Publishing Service, Shawnee Mission, Kansas.

Ice Hockey

102. Hayes, D., "The Nature, Incidence, Location and Causes of Injury in Intercollegiate Ice Hockey," Application of Science and Medicine to Sport, Pub. C. C. Thomas 1975, pp. 292-300.

103. Hornof, Z. and Napravnik, C., "Analysis of Various Accident Rate Factors in Ice Hockey," Medicine and Science in Sports 5, 4(1973) pp. 283-286.

104. Hussey, H. H., "Ice Hockey Injuries," Editorial, The American Medical Association 236, (July 12, 1976) p. 187.

105. Merrifield, H. H. and Cowan, R. F. J., "Groin Strain Injuries in Ice Hockey," Sports Medicine (January/February 1973) pp. 41-42.

106. Nagobads, V. G., "Hockey Injuries: The Pro Is Hit the Hardest," The Physician and Sports Medicine 1, 3 pp. 55-57.

107. Ramey, M. R., "Force Plate Designs and Applications," Exercise and Sport Science Reviews 3, (1975) pp. 303-319.

108. Reeves, J. S. and Mendryk, S. W., "A Study of the Incidence, Nature, and Cause of Hockey Injuries in the Greater Edmonton Metropolitan Area," Application of Science and Medicine to Sport, Pub. C. C. Thomas 1975, pp. 301-308.

109. Reeves, J. S., "Recommendations for the Reduction of Hockey Injuries," The Canadian Association for Health Physical Recreation and Education 38, (March-April 1972) pp. 18-21.

110. Sze, Y.; Thompson, J. C.; Norman, R. W.; and Hayes, D., "Procedures for the Evaluation of Hockey Goaltender's Face Masks," Mechanics and Sport ed. Jeffrey Bleustrin (The American Society of Mechanical Engineers) p. 315.

111. TooGood, T. and Love, W. G. "Jerry", "Hockey Injury Survey," The Canadian Association of Health, Physical Education and Recreation 32, (1966) pp. 20-23.

Ice Hockey /Other Sports

112. Special Analysis of Hockey Equipment (1214), U. S. Consumer Product Safety Commission, Bureau of Epidemiology, April 26, 1973.

113. "Sports," The Washington Post, March 10, 1976, Section D, p. 5.

114. The Official National Collegiate Athletic Association Ice Hockey Guide-1977, NCAA Publishing Service, Shawnee Mission, Kansas.

115. Vinger, Paul F., Letter to ASTM Membership, February 24, 1976.

Other Sports

116. Fink, R. A. and Monge, J. J., "Snowmobiling Injuries," Minnesota Medicine (January 1971) pp. 29-32.

117. Hinrichsen, K. W., "Medical Aspects of Football," The Medical Journal of Australia 1, (April 27, 1963) pp. 608-611.

118. Kraus, J. F. and Gullen, W. H., "An Epidemiologic Investigation of Predictor Variables Associated with Intramural Touch Football Injuries," American Journal of Public Health 59, 12 pp. 2144-2156.

119. Kruger, H., "Playing Safe: Progressive Spotting," Physical Education and Recreation 47, 4(April 1976) pp. 31-33.

120. Lok, V. and Yuceturk, G., "Injuries of Wrestling," Sports Medicine 2, 6(November/December 1974) pp. 324-328.

121. Piscopo, J. and Hennessy, J., "Playing Safe: Trampoline Safety," Physical Education and Recreation 47, 4(April 1976) pp. 33-36.

122. Priest, J. D.; Jones, H. H.; and Nagel, D. A., "Elbow Injuries in Highly Skilled Tennis Players," Sports Medicine 2, 3(1974) pp. 137-149.

123. Fact Sheet No. 85 Trampolines, U. S. Consumer Product Safety Commission, February 1976.

124. Summary Analysis of Trampolines (1233), U. S. Consumer Product Safety Commission, (July 19, 1973) pp. 1-5.

125. The Official National Collegiate Athletic Association Gymnastics Rules-1976, NCAA Publishing Service, P. O. Box 1906, Shannee Mission, Kansas.

126. Official National Collegiate Athletic Association Basketball Rules-1977, NCAA Publishing Service, Shawnee Mission, Kansas, 1976.

Head and Neck

127. Albright, J. P.; Moses, J. M.; Feldick, H. G.; Dolan, K. D., and Burmeister, L. F., "Nonfatal Cervical Spine Injuries in Interscholastic Football," Journal of the American Medical Association 236, 11(September 13, 1976), pp. 1243-1245.

128. Alley, Jr., R. H., "Head and Neck Injuries in High School Football," Journal of American Medical Association 188, 3 (May 4, 1964), pp. 118-122.

129. Andrews, L. M., Football Helmet Tests: Round Robin Using NOCSAE Recommended Test Method, National Bureau of Standards Letter Report to the U. S. Consumer Product Safety Commission, March 3, 1976.

130. Andrews, L. M., Football Helmet Tests: Round Robin Using ASTM Recommended Test Method, National Bureau of Standards Letter Report to the U. S. Consumer Product Safety Commission, March 3, 1976.

131. Andrews, L. M., Football Helmet Tests: Comparison of Data Using Both NOCSAE and ASTM Recommended Test Methods, National Bureau of Standards Letter Report to the U. S. Consumer Product Safety Commission, March 3, 1976.

132. Baldwin, K., "Standards Meeting Focuses on Head Safety," Selling Sporting Goods (March, 1976) pp. 86-87.

133. Bellow, D. G.; Mendryk, S., and Schneider, V., "An Investigation into the Evaluation of Hockey Helmets," Medicine and Science in Sports 2, 1(Spring, 1970) pp. 43-49.

134. Berger, R. E., Considerations in Developing Test Methods For Protective Headgear, National Bureau of Standards Report: NBSIR 76-1107, August 1976.

135. Bishop, P. J., "Head Protection in Sport with Particular Application to Ice Hockey," Ergonomics 19, 4(1976) pp. 451-464.

136. Bolitho, N., "Head Injuries in Ice Hockey at the Amateur Level," Journal of the Canadian Association of Health Physical Education and Recreation 37 (November-December 1970) pp. 29-34.

137. Burstein, F., "Ocular Injuries in Sports," Sports Medicine 3, 1(January-February 1975) pp. 25-34.

138. Chrisman, O. D.; Snook, G. A.; Stanitis, J. M., and Keedy, V. A., "Lateral-Flexion Neck Injuries in Athletic Competition," The American Medical Association 192, 7(May 17, 1965) pp. 117-120.

139. Clarke, K. S., Sport-Related Spinal Cord Injuries in Schools and Colleges, 1973-75, Prepared for the NCAA Committee on Competitive Safeguards and Medical Aspects of Sports, 1976.

Head and Neck

140. Collins, H. R. and Johnson, C., "Heads Up! Protect Neck, Head from Serious Football Injuries," Texas Medicine 63 (November 1967) pp. 40-41.

141. Duff, J. F., "Spearing: Clinical Consequences in the Adolescent," Sports Medicine 2, 3(1974) pp. 175-177.

142. Gibbs, R. W., "Unsafe Headgear Faulted in Critical Hockey Injuries," Physician and Sports Medicine 2, 1(February, 1974) pp. 39-42.

143. Gurdjian, E. S.; Hodgson, V. R.; Hardy, W. G.; Patrick, L. M.; and Lissner, H. R., "Evaluation of the Protective Characteristics of Helmets in Sports," Trauma (1964) pp. 309-324.

144. Hardy, C. H. and Marcal, P. V., "Elastic Analysis of a Skull," Applied Mechanics 27 (December, 1973) pp. 838-842.

145. Heintz, W. D., "Mouth Protectors: A Progress Report," The American Dental Association 77(September 1968) pp. 632-636.

146. Heintz, W. D., "The Case for Mandatory Mouth Protectors," The Physician and Sports Medicine (April 1975) pp. 61-63.

147. Hodgson, V. R., "National Operating Committee on Standards for Athletic Equipment Football Helmet Certification Program," Medicine and Science in Sports (1975) pp. 225-232.

148. Hodgson, V. R. and Thomas, L. M., "Biomechanical Study of Football Head Impacts Using a Human Head Model," Prepared for The National Operating Committee on Standards For Athletic Equipment (April 19, 1973) pp. 3-24.

149. Hughes, J. R. and Hendrix, D. E., "Telemetered EEG from a Football Player in Action," Electroencephalography and Clinical Neurophysiology 24 (1968) pp. 183-186.

150. Jagger, R. G. and Clarke, D. A., "Mouthguards for Contact Sports," Dental Technician 27, 10(October 1974) pp. 88-90.

151. Kindt, G. W.; Schneider, R. C.; and Robinson, J. L., "A Method of Comparing the Impact Absorption Characteristics of Football Helmets," Medicine and Science in Sports 3, 4(1971) pp. 203-209.

152. King, J. H., "Evaluating Head Protecting Devices," Institute of Environmental Sciences 1973 Proceedings, Anaheim, California, April 2-5, 1973.

153. Krans, J. F.; Anderson, B. D.; and Mueller, C. E., "The Effectiveness of a Special Ice Hockey Helmet to Reduce Injuries in College Intramural Hockey," Medicine and Science in Sports 2, 3(1970) pp. 162-164.

Head and Neck

154. Leidholt, J. D., "Spinal Injuries in Sports," Surgical Clinics of North America 43 (April 1963) pp. 351-361.

155. Liu, Y. K. and Chandran, K. B., "Package Cushioning for the Human Head," Applied Mechanics 42, 2(September 1975) pp. 541-546.

156. Mahajan, B. M., Standards for Athletic Helmets--State of the Art and Recommendations, National Bureau of Standards Report: NBSIR 73-276(April, 1974).

157. Melvin, W. J. S.; Dunlop, H. W.; Hetherington, R. F.; and Kerr, J. W., "The Role of the Faceguard in the Production of Flexion Injuries to the Cervical Spine in Football," The Canadian Medical Association Journal 93 (November 20, 1965) pp. 1110-1119.

158. Newman, J. A., On the Use of the Head Injury Criterion (HIC) in Protective Headgear Evaluation, 1974 Stapp Car Conference, (November 17-19) pp. 615-640.

159. Okihiro, M. M.; Taniguchi, R.; and Goebert, H. W., "Football Injuries of the Cervical Spine and Cord," Hawaii Medical Journal 34, 5(May 1975) p. 171-175.

160. Ommaya, A. K., "Surgical Management of Head Injuries in Athletes," The Physician and Sports Medicine 2, 4(April 1976) pp. 56-62.

161. Pashby, T. J.; Pashby, R. C.; Chisholm, L. D. J.; and Crawford, J. S., "Eye Injuries in Canadian Hockey," Canadian Medical Association Journal 113 (October 4, 1975), pp. 663-666.

162. Pizzi, F. J., "Late Effects of Craniospinal Injuries," The Physician and Sports Medicine 2, 4(April, 1976) pp. 74-79.

163. Reid, S. E.; Epstein, H. M.; and Louis, M. W., "Brain Trauma Inside a Football Helmet," The Physician and Sports Medicine 2, 8(August 1974) pp. 32-35.

164. Robey, J. M., "Contribution of Design and Construction of Football Helmets to the Occurrence of Injuries," Medicine and Science in Sports 4, 3(1972) pp. 170-174.

165. Robinson, R. I., "NCAA Football Head and Neck Injuries in Eastern Colleges-1972 and 1974 Seasons," Physical Education and Recreation Journal 46, 6(1975) pp. 45-46.

167. Rontal, E. and Rontal, M., "Maxillofacial Injuries in Football Players. An Evaluation of Current Facial Protection," Sports Medicine and Physical Fitness 11, 4(December 1971) pp. 241-245.

Head and Neck

168. Rose, K. D.; Stone, F.; Fuenning, S. I.; and Williams, J., "Cardiac Contusion Resulting from "Spearing" in Football," Archives of Internal Medicine (August 1966) pp. 129-131.

169. Ryan, A. J., "On-Field Diagnosis of Head Injuries," The Physician and Sports Medicine (April 1976) pp. 82-84.

170. Schmidek, H. H., "Complications May Arise in Seconds-or Months," The Physician and Sports Medicine (April 1976) pp. 68-70.

171. Schneider, R. C.; Reifel, E.; Crisler, H. O.; and Oosterbaan, B. G., "Serious and Fatal Football Injuries Involving the Head and Spinal Cord," The American Medical Association (August 12, 1961) pp. 362-367.

172. Schneider, R. C. and Antine, B. E., "Visual-field Impairment Related to Football Headgear and Face Guards," The American Medical Association 192, 7(May 17, 1965), pp. 616-618.

173. Schneider, V. E., "Protection of the Head in Hockey," The Canadian Association of Health Physical Education and Recreation 37 (May-June 1971) pp. 35-36.

174. Schwank, W. C. and Ryan, A. J., "Stopping Spear Tackling," Physical Sports Medical Journal 3, 9(September 1975) pp. 72-78.

175. Snook, G. A., "Head and Neck Injuries in Contact Sports," Medicine and Science in Sports 1, 3(September 1969) pp. 117-123.

176. Torg, J. S.; Quedenfeld, T. C.; Thieler III, E. R.; and Lignelli, G. J., "Collision with Spring-Loaded Football Tackling and Blocking Dummies," The American Medical Association 236, 11(September 13, 1976) pp. 1270-1271.

177. Vinger, P. F., "Ocular Injuries in Hockey," Archives of Ophthalmology 94, 1(January 1976) pp. 74-76.

178. Wirtz, P. D., "Head and Neck Injuries in Football," Iowa Medical Society 66, 3(March, 1976) pp. 89, 102.

179. Wood, A. W. S., "Search for Safety," The Canadian Dental Association 40, 5(May 1974) p. 338.

180. Yeager, B., "More Experience, More Neck Injury," The Physician and Sports Medicine (April 1975) p. 20.

181. Press Release: Opposing the Use of Certain Tackling and Blocking Techniques, National Athletic Trainers Association, June 11, 1975.

Head and Neck/Lower Extremity

182. "Injuries to the Neck and Upper Extremity in Sports," Special Meeting Report, Sports Medicine 1, 2(January-February 1973) pp. 38-40.

183. "Brain Damage in Sports," The Lancet (February 21, 1976) pp. 401-402.

184. "Helmets, Face Guards, and Better Football," Sportspages, The Physician and Sports Medicine 1, 3(November 1973) p. 32.

185. "Concussion and Head Injuries," The Physician and Sports Medicine 2, 10(October 1974) pp. 46-54.

186. "Football Rules Seek to Curb Head Blocking," Sportspages, The Physician and Sports Medicine 4, 3(March 1976) pp. 23-24.

187. "Head, Neck Injuries Discussed at Meeting," Sportspages, The Physician and Sports Medicine 4, 6(June 1976).

188. "Boxing Produces Most Severe Head Injuries," Discussion, The Physician and Sports Medicine (April 1976) pp. 87-89.

Lower Extremity

189. Abbott, H. G. and Kress, J. B., "Preconditioning in the Prevention of Knee Injuries," Archives of Physical Medicine and Rehabilitation 50, (June 1969) pp. 326-333.

190. Andrish, J. T.; Bergfeld, J. A.; and Walheim, J., "A Prospective Study on the Management of Shin Splints," Journal of Bone and Joint Surgery 56A, 8(December 1974) pp. 1697-1700.

191. Cameron, B. M. and Davis, O., "The Swivel Football Shoe: A Controlled Study," Sports Medicine (January/February 1973) pp. 16-27.

192. Conway, D. H., "An Introduction to Podiatric Sports Medicine," American Podiatry Association 65, 5(May 1975) pp. 495-499.

193. Conway, D. H., "A Modified Athletic Shoe with Adjustable Midfoot Sling," American Podiatry Association 60, 3(March 1970) pp. 118-121.

194. DiStefano, V. J. and Nixon, J. E., "Ruptures of the Achilles Tendon," Sports Medicine (January/February 1973) pp. 34-37.

195. Ferguson, Jr., A. B., "The Case Against Ankle Taping," Sports Medicine (January/February 1973) pp. 46-47.

196. Hirata, Jr., ISAO, "The Hanley Cleat and the Ivy League-A Progress Report," The American College Health Association 17, (April 1969) pp. 369-370.

Lower Extremeity

197. Klein, K. K., "Muscular Strength and the Knee," The Physician and Sports Medicine 2, 12(December 1974) pp. 29-31.

198. McKinney, D.; McKinney, P.; Overman, S.; and Stringfellow, M., "Investigation of a Training Shoe as a Supplemental Conditioning Device," Research Quarterly 46, 4(December 1975) pp. 422-427.

199. Nicholas, J. A., "Injuries to Knee Ligaments Relationship to Looseness and Tightness in Football Players," The American Medical Association 212, 13(June 29, 1970) pp. 2236-2239.

200. Peterson, T. R., "The Cross-Body Block, the Major Cause of Knee Injuries," The American Medical Association 211, 3 (January 19, 1970) pp. 449-452.

201. Peterson, T. R., "Blocking at the Knee, Dangerous and Unnecessary," The Physician and Sports Medicine 1, 2(September 1973) pp. 47-50.

202. Rall, K. L.; McElroy, G. L.; and Keats, T. E., "A Study of Long Term Effects of Football Injury to the Knee," Missouri Medicine 61, 6(June 1964) pp. 435-438.

203. Reahl, Jr., G. E., "Soft Tissue Injuries of the Knee and Ankle," Maryland State Medical Journal (October 1967) pp. 66-71.

204. Rowe, M. L., "Varsity Football Knee and Ankle Injury," New York State Journal of Medicine 69, (December 1, 1969) pp. 3000-3003.

205. Ryan, A. J., "Taping Prevents Acute and Repeated Ankle Sprains," The Physician and Sports Medicine 1, 3(November 1973) pp. 40-46.

206. Sinton, W. A., "Knee Injuries Part II: Prevention," Sports Medicine 1, 2(January/February 1973) pp. 49-52.

207. Slocum, D. B. and Larson, R. L., "Indirect Injuries to the Extensor Mechanism of the Knee in Athletes," American Journal of Orthopedics (November/December 1964) pp. 249-259.

208. Steingard, P. M., "Foot Failures in Basketball," The Physician and Sports Medicine 2, 3(March 1974) pp. 64-69.

209. Torg, J. S. and Quedenfeld, T., "Knee and Ankle Injuries Traced to Shoes and Cleats," The Physican and Sports Medicine 1, 2(September 1973) pp. 39-43.

Lower Extremity/Synthetic Playing Surfaces

210. Torg, J. S.; Quedenfeld, T. C.; and Landau, S., "The Shoe-Surface Interface and Its Relationship to Football Knee Injuries," Sports Medicine 2, 5(September/October 1974) pp. 261-269.

211. Wiechec, F. J., "Examination, Treatment and Conditioning of Athletic Injuries of the Lower Extremities," The American Podiatry Association 57, 11(November 1967) pp. 509-514.

212. Wells, J., "The Incidence of Knee Injuries in Relation to Ankle Taping," The National Athletic Trainer's Association 4, 4(Winter 1969) pp. 10-13.

213. "Prevention of Knee Injuries in Athletes with Knee Joint Laxity," The American Medical Association 231, 2(January 1975) p. 207.

Synthetic Playing Surfaces

214. Adkison, J. W.; Requa, R. K.; and Garrick, J. G., "Injury Rates in High School Football-A Comparison of Synthetic Surfaces and Grass Fields," Clinical Orthopaedics and Related Research 99(March-April 1974) pp. 131-136.

215. Bonstingl, R. W.; Morehouse, C. A.; and Niebel, B. W., "Torques Developed by Different Types of Shoes on Various Playing Surfaces," Medicine and Science in Sports 7, 2 (1975) pp. 127-131.

216. Bowers, Jr., K. D. and Martin, R. B., "Impact Absorption, New and Old Astro-Turf at West Virginia University," Medicine and Science in Sports 6, 3(March 1974) pp. 217-221.

217. Bowers, Jr., K. D. and Martin, R. B., "Aging Astro Turf: A Threat to Safety and Performance?," The Physician and Sports Medicine (October 1975) pp. 65-67.

218. Bowers, Jr., K. D. and Martin, R. B., "Cleat-Surface Friction on New and Old Astroturf," Medicine and Science in Sports 7, 2(1975) pp. 132-135.

219. Carew, J., "Synthetic Grass," Horticulture 48, (January 1970) p. 38.

220. Carry, P., "A Surface Case of Bugs in the Rugs," Sports Illustrated 33, (September 14, 1970) pp. 40-42, 45.

221. Clarke, K. S., Artificial Surface: College Football and Soccer Injuries-1975, Report to the U. S. Consumer Product Safety Commission, (September 8, 1976).

222. Dreiske, P., "Artificial Turf: Pro and Con," Family Safety (Fall 1972) pp. 12-15.

Synthetic Playing Surfaces

223. Garrick, J. G. and Bramwell, S. T., "High School Football Injuries: A Comparison of Playing Surfaces," Medicine and Science in Sports 4, (1972) pp. 166-169.

224. Howard, M. K.; Koon, J. L.; and Rochester, E. W., "Effect of Artificial Turf on Player Environment," The National Athletic Trainer's Association 6, 4(Winter, 1971) pp. 157-159.

225. Kandelin, W. W.; Krahenbuhl, G. S.; and Schacht, C. A., "Athletic Field Microclimates and Heat Stress," Safety Research 8, 3(September 1976) pp. 106-111.

226. McGuire, B. J. and Toner, S. D., Evaluation of Synthetic Turf Safety Test Programs, National Bureau of Standards Technical Report to Subcommittee on Commerce and Finance, January 24, 1972.

227. Morehouse, C. A. and Morrison, W. E., "The Artificial Turf Story," Penn State HPER Series No. 9, The Pennsylvania State University, 1975.

228. Patrick, C. and Barton, B., "Astroturf or Grass as Related to Temperature Relative Humidity," National Athletic Trainer's Association 7, 2(1972) pp. 47-48.

229. Stanitski, C. L.; McMaster, J. H.; and Ferguson, R. J., "Synthetic Turf and Grass: A Comparative Study," Sports Medicine 2, 1(January/February 1974) pp. 22-26.

230. Torg, J. S.; Quedenfeld, T. C.; and Landau, S., "Football Shoes and Playing Surfaces: From Safe to Unsafe," The Physician and Sports Medicine 1, 3(November 1973) pp. 51-54.

231. Whitehurst, J. R., "The Astrodome Turf and Lower Extremeity Injuries," American College Health Association 17, (December 1968) pp. 136-137.

232. "New "Grass" Improves Bowl Playing Surface," Adhesives Age 15, (1972) p. 29.

233. "Artificial Turf: Pros and Cons," Round Table, The Physician and Sports Medicine (February 1975) pp. 41-50.

234. "NFL Players: Give Us Grass (to Play on)," The Physician and Sports Medicine 2, 1(January 1974) pp. 20-21.

235. "Synthetic Turf and Grass," Letters, Sports Medicine 2, 3 (May/June 1974) pp. 178-179.

236. "Researchers Test Shoes Used on Artificial Turf," Parks and Recreation 9, 11(January 1975) pp. 2-3.

Synthetic Playing Surfaces/Environmental Heat/General Topics

237. "National Football League Players Association-Denial of Petition Regarding Artificial Turf Covering," Federal Register 38, 239(December 13, 1973) pp. 34361-34362.

238. "National Football League Players Association Denial of Petition Regarding Artificial Turf Covering," Federal Register 41, 179 (September 14, 1976) pp. 39068-39069.

239. "A Farewell to Grass," Sports, Newsweek 75, (May 11, 1970).

Environmental Heat

240. Blyth, C. S. and Burt, J. J., "Effect of Water Balance on Ability to Perform in High Ambient Temperatures," Research Quarterly (American Association of Health Physical Education and Recreation) 32, 3(October 1961) pp. 301-307.

241. Murphy, R. J., "The Problems of Environmental Heat in Athletics," Ohio State Medical Journal 59, 8(August 1963) pp. 799-804.

242. Murphy, R. J. and Ashe, W. F., "Prevention of Heat Illness in Football Players," The American Medical Association 194, 6(November 8, 1965) pp. 180-184.

243. Spickard, A., "Heat Stroke in College Football and Suggestions for Prevention." Southern Medical Journal 61, (August 1968) pp. 791-796.

244. Westerman, R. L. and Martin, C., "The Case Against Fluid Restriction," The Physician and Sports Medicine 2, 7 (July 1974) pp. 25-28.

245. "Dog Days and Siriasis," Commentary, The American Medical Association 233, 6(August 1975) pp. 513-515.

246. "Water Deprivation and Performance of Athletes," American Journal of Clinical Nutrition 27, 10(October 1974) pp. 1096-1097.

247. "American College of Sports Medicine: Position Statement on Prevention of Heat Injuries During Distance Running," The American Osteopath Association 74, (June 1975) pp. 158-159.

General Topics

248. Allman, F., "Competitive Sports for Boys Under Fifteen Beneficial or Harmful?" The Medical Association of Georgia 55(November 1966) pp. 464-468.

249. Allman, F., "Prevention of Sports Injuries," Athletic Journal 65(March 1976) p. 74.

General Topics

250. Ball, D. W., "Control Versus Complexity-Continuities in the Scaling of Gaming," Pacific Sociological Review 17, 2 (April 1974) pp. 167-183.

251. Blasco, E. A., "Sporting Goods Industry Meeting," Selling Sporting Goods 29, 6(June 1976) pp. 44-45.

252. Blonstein, J. L., "Injuries in Sport," Medical Society of London Transactions 90 (1974) pp. 20-30.

253. Bramwell, S. T.; Masuda, M.; Wagner, N. W.; and Holmes, T. H., "Psychosocial Factors in Athletic Injuries: Development and Application of the Social and Athletic Readjustment Rating Scale," Human Stress 1, 2(June 1975) pp. 6-20.

254. La Cava, G., "Sport and Puberty," Sports Medicine and Physical Fitness 14, 3(September 1974) pp. 163-164.

255. Christophe, K. and Leard, S., "A Follow-Up Study of Athletic Injuries," The American College Health Association 18 (February, 1970) pp. 210-212.

256. Clarke, K. S., "Safeguarding the Health of the Athlete," The West Virginia Medical Journal 60, 10(October 1964) pp. 286-290.

257. Clarke, K. S., "Sports Medicine in Perspective," The West Virginia Medical Journal 66, 2(February 1970) pp. 44-47.

258. Clarke, K. S., "Accident Prevention Research in Sports," Journal of Health, Physical Education and Recreation 45, (1969) pp. 45-48.

259. Clement, Jr., J. D.; Graves, R. A.; Lane, R. M.; and Weisz, H., "Minimum Standards of Physical Fitness Required of Candidates for Collision Sports at the University of Maine," Maine Medical Association Journal 58, 6(June 1967) pp. 121-123.

260. Corbitt, R. W.; Erickson, D. J.; Thornton, M. L.; Kriss, F. C.; Cooper, D. L.; and Crais, T. T., The American Medical Association 228, 10(June 3, 1974) pp. 1266-1277.

261. Cownie, A. R., "An Operational Game for the Study of Decision Making in a Hazardous Activity," Accident Analysis and Prevention 2, (1970) pp. 1-10.

262. DePalma, A. F. and Flannery, G. F., "Acute Anterior Dislocation of the Shoulder," Sports Medicine 1, 2(January/February 1973) pp. 6-15.

General Topics

263. Dotson, C. O. and Stanley, W. J., "Values of Physical Activity Perceived by Male University Students," The Research Quarterly 43, 2(1972) pp. 148-156.

264. Duncan, K. S., "Prevention of Sports Injury," Royal Society of Medicine Proceedings 62, (September 1969) pp. 918-921.

265. Ellison, K. and Freischlag, J., "Pain Tolerance, Arousal, and Personality Relationships of Athletes and Nonathletes," The Research Quarterly Journal 46, 2(May 1975) pp. 250-255.

266. Fraser, T. M., "Recreation, Technology, and System Safety," Human Factors 16, 5(October 1974) pp. 447-453.

267. Gerber, S., "Are Kids Too Yound to Avoid Sports Injuries?", Science Digest 78, (October 1975) pp. 44-52.

268. Godshall, R. W., "The Predictability of Athletic Injuries: An Eight-Year Study," Sports Medicine 3, 1(January/February 1975) pp. 50-54.

269. Haddon, Jr., W., "Principles in Research on the Effects of Sports on Health," The American Medical Association 197, 11(September 12, 1966) pp. 163-166.

270. Hale, C. J., "Significant Trends and Complex Barriers in the Engineering of Protective Sports Equipment," Materials Research and Standards (October 1971) pp. 8-12.

271. Hall, W. K., "A Probabilistic Framework For Accident Data Analysis," Accident Analysis and Prevention 1, (1969) pp. 159-165.

272. Harris, M. B. and Ramsey, S., "Stereotypes of Athletes," Perceptual and Motor Skills 39, 2(October 1974) pp. 705-706.

273. Haycock, C. E. and Gillette, J. U., "Susceptibility of Women Athletes to Injury," The American Medical Association 236, 2(July 12, 1976) pp. 163-165.

274. Hayes, D., "Risk Factors in Sport," Human Factors 16, 5 (October 1974) pp. 454-458.

275. Hendry, L. B., "Human Factors in Sports Systems: Suggested Models for Analyzing Athlete-Coach Interaction," Human Factors 16, 5(1974) pp. 528-544.

276. Hinkamp, J. F., "High School Athletic Injuries," Illinois Medical Journal 148, 2(August 1975) pp. 127-129.

277. Hoffman, S. D., "In Search of Unreasonable Risk of Injury," Lab Data (Fall 1975) pp. 10-16.

278. Hogan, J. C., "Sports in the Courts," Phi Delta Kappan 56, 2(1974) pp. 132-135.

279. Hullemann, K. D.; List, M.; Matthes, D.; Wiese, G.; and Zika, D., "Spiroergometric and Telemetric Investigations During The XXI International Stroke Mandeville Games 1972 In Heidelberg," Journal of Paraplegia 13, 2(August 1975) pp. 109-123.

280. Hurwitz, S., "Medical Aspects of Adolescents," Western Journal of Medicine 121, 5(November 1974) pp. 443-447.

281. Johnson, C. J.; Moran, J. C.; Paine, S. C.; Anderson, H. W.; and Breysse, P. A., "Abatement of Toxic Levels of Carbon Monoxide in Seattle Ice-Skating Rinks," American Journal of Public Health 65, 10(October 1975) pp. 1087-1090.

282. King, R. J., "It's the Law-Seller's Liability," Minnesota Medicine (January 1971) pp. 49-50.

283. Klein, D., "Body-Contact Sports: Catharsis or Reinforcement?" Accident Analysis and Prevention 6, (1974) pp. 85-91.

284. Kniker, C. R., "The Values of Athletics in Schools: A Continuing Debate," Phi Delta Kappan 56, 2(October 1974) pp. 116-120.

285. Lane, R. M., "Uniform Code of Medical Qualifications for Participants in Interscholastic Athletics in Maine," The Maine Medical Association (November 1969) pp. 247-254.

286. Ley, K. "The New York State Experiment," Sports Medicine 1, 3(March-April 1973) pp. 42-44.

287. Lingard, D. A., "The Impact of Sports Injuries in Winter on Medical Services," New Zealand Medical Journal 82, 549(October 1975) pp. 229-232.

288. MacIntosh, D. L.; Skrien, T.; and Shephard, R. J., "Athletic Injuries at the University of Toronto," Medicine and Science in Sports 3, 4(March 1971) pp. 195-199.

289. MacIntosh, D. L.; Skrien, T.; and Shephard, R. J., "Physical Activity and Injury," Sports Medicine and Physical Fitness 12, 4(December 1972) pp. 224-237.

290. Mather, B. S., "Correlations Between Strength and Other Properties of Long Bones," Journal of Trauma 7, 5(1967) pp. 633-638.

General Topics
291. McBryde, A. M., "Stress Fractures in Athletes," Sports Medicine 3, 5(1976) pp. 212-217.

292. McGuigan, R. A., "Sports for Children," The Iowa State Medical Society 50, 10(October 1960 pp. 601-604.

293. Nicholas, J. A., "Risk Factors, Sport Medicine and The Orthopedic System: An Overview," Sports Medicine 3, 5(September/October 1975) pp. 243-259.

294. Ogilvie, B. C. and Tutko, T. A., "If You Want to Build Character, Try Something Else," Psychology Today 5, (October 1971) pp. 61-63.

295. Polednak, A. P., "Secular Trend in Body Size Among College Athletes," American Journal of Physical Anthropology 42, (May 1975) pp. 501-506.

296. Reid, S. E.; Epstein, H. M.; Louis, M. W.; and Reid, Jr., S. E., "Physiologic Response to Impact," Journal of Trauma 15, 2(February 1975) pp. 150-152.

297. Renick, J. A., "The Use and Misuse of College Athletics," Journal of Higher Education XLV, 7(October 1974) pp. 545-552.

298. Ryan, A. J., "Technological Advances in Sports Medicine and in the Reduction of Sports Injuries," Exercise and Sport Sciences Review 1(1973) pp. 285-312.

299. Ryan, A. J., "Medical Aspects of Sports," The American Medical Association 194, 6(November 8, 1965) pp. 173-175.

300. Sayre, B. M., "The Need to Ban Competitive Sports Involving Preadolescent Children," Pediatrics 55, 4(April 1975) pp. 564-565.

301. Sherman, M. A., "Information Retrieval in Sport and Physical Activity," Exercise and Sport Sciences Review 3, (1975) pp. 321-349.

302. Smith, M. D., "Aggression in Sport: Toward a Role Approach," Canadian Association For Health Physical Education and Recreation 37, (January-February 1971) pp. 22-26.

303. Spring, J., "Athletics and the Modern Industrial State," Phi Delta Kappan 56, 2(October 1974) pp. 114-115.

304. Steinhaus, A. H. "Aims and Perspectives," Sports Medicine and Physical Fitness 6, 3(1966) pp. 191-197.

General Topics

305. Thorndike, A., "Prevention of Injuries in College Athletics," The American Medical Association 169, 13(March 28, 1959) pp. 1405-1409.

306. Thornton, M. L., "Pediatric Concerns about Competitive Preadolescent Sports," The American Medical Association 227, 4(January 28, 1974) pp. 418-419.

307. Watt, E. W.; Buskirk, E. R.; and Plotnicki, B. A., "A Comparison of Single vs. Multiple Daily Training Regimens: Some Physiological Considerations," Research Quarterly 44, 1(March 1973) pp. 119-123.

308. White, G., "How to Save Intercollegiate Athletics," Phi Delta Kappan 56, 2(October 1974) pp. 106-109.

309. Zoller, G. W., "Hazards in School Sports," The Physician and Sports Medicine 1, 2(September 1973) pp. 69-71.

310. "Anabolic Steroids: Doctors Denounce Them, but Athletes Aren't Listening," News and Comment, Science 176, (June 1972) pp. 1399-1401.

311. "Problems in Matching Competitors," Clinical Pediatrics 8, 8(August 1969) pp. 434-436.

312. "How to Enjoy Sports-and Avoid Injury," U. S. News & World Report (December 29, 1975) pp. 37-39.

313. "Instant Information on Sports·Injuries," Sportspages, The Physician and Sports Medicine (April 1975) pp. 22.

314. Consumer Product Hazard Index, Fiscal Year 1975, U. S. Consumer Product Safety Commission, December 1975.

315. "The Shoulder in Sports," Report, Sports Medicine 2, 1(January/February 1974).

316. "The Referee and Sports Injuries," The Physician and Sports Medicine 1, 2(September 1973) p. 105.

317. "Medical Care for Young Athletes: 'Pretty Barbaric, But That's the Way It is'," The Physician and Sports Medicine 2, 11 (November 1974) pp. 75-80.

318. "Council Fights for Fitness-and Existence," The Physician and Sports Medicine (April 1976) pp. 106-109.

319. Proceedings of the 3rd Special Convention and 70th Annual Convention, The National Collegiate Athletic Association, St. Louis, Missouri, January 14-17, 1976.

General Topics /Standards and Specifications

320. "What's the Story on Sports Equipment?", The Physician and Sports Medicine (March 1976) pp. 117-125.

321. The Sports and Recreational Programs of the Nation's Universities and Colleges, The National Collegiate Athletic Association, Report Number Four-August 1974.

322. 1975-1976 Sports Participation Survey, The National Federation of State High School Associations, Elgin, Illinois.

323. National Athletic Injury/Illness Reporting System Sport-Related Incidence Charts, 1975-1976, Report to the U.S. Consumer Product Safety Commission, September 4, 1976.

324. NEISS NEWS, U.S. Consumer Product Safety Commission 5, 1 (July/August 1976).

325. NEISS NEWS, Bureau of Product Safety, (October 1972).

326. National Operating Committee on Standards for Athletic Equipment, News Release, June 13, 1976.

327. National Operating Committee on Standards for Athletic Equipment, News Release, August 16, 1976.

328. National Operating Committee on Standards for Athletic Equipment, News Release, September 17, 1976.

329. National Operating Committee on Standards for Athletic Equipment, News Release, October 11, 1976.

330. National Operating Committee on Standards for Athletic Equipment, News Release, November 12, 1976.

331. National Operating Committee on Standards for Athletic Equipment, News Release, December 14, 1976.

332. The Consumer Product Safety Act, Public Law 92-573 92nd Congress, S. 3419, October 27, 1972.

Standards and Specifications

333. American National Standard Safety Requirements for Aerial Passenger Tramways, ANSI B77.1-1973 (New York: American National Standards Institute, Inc. 1973).

334. Canadian Standards Association, Hockey Helmets-Supplement No.1, CSA Standard Z262.1-1975.

335. Canadian Standards Association, Hockey Helmets, CSA Standard Z262.1-1975.

Standards and Specifications

336. ISO Recommendation R378, Gymnastic Equipment-Parallel Bars, ISO/R 378-1964, International Organization for Standardization, (December 1964).

337. ISO Recommendation R379, Gymnastic Equipment-Horizontal Bars, ISO/R 378-1964, International Organization for Standardization, (December 1964).

338. ISO Recommendation R380, Gymnastic Equipment-Rings, ISO/R 380-1964, International Organization for Standardization, (December 1964).

339. ISO Recommendation R381, Gymnastic Equipment-Vaulting Horse and Pommelled Horse, ISO/R 381-1964, International Organization for Standardization, (December 1964).

340. ISO Recommendation R382, Gymnastic Equipment-Balancing Beam, ISO/R 382-1964, International Organization for Standardization, (December, 1964).

341. ISO Recommendation R1511 Protective Helmets for Road Users, ISO/R 1511-1970, International Organization for Standardization, 1970.

342. Japanese Industrial Standard: Protective Helmets for Vehicular Users, JIST 8133-1970, Japanese Standards Association, 1970.

343. Military Specification-Binding, Ski, All Terrain, MIL-B-43504A, U.S. Government Printing Office (February 21, 1972).

344. Military Specification-Ski, Military, All-Terrain, MIL-S-43190B, U. S. Government Printing Office, (December 17, 1974).

345. "Motorcycle Helmets, Federal Motor Vehicle Safety Standard FMVSS No. 218 National Highway Traffic Safety Administration," Federal Register (August 20, 1973) p. 22390.

346. Specifications for Protective Headgear for Vehicular Users, ANZI Z90.1-1971, American National Standards Institute, Inc., New York (1971).

347. Standard Consumer Safety Specification for Components, Assembly, and Use of a Trampoline, ASTM: F 381-74, American Society for Testing and Materials, Philadelphia (1974).

348. Standard Method of Impact Test and Performance Requirements For Football Helmets, National Operating Committee on Standards for Athletic Equipment, September 1973.

349. Standard Method of Test for Shock Attenuation Characteristics of Protective Headgear for Football, ASTM F429-75, American Society for Testing and Materials, Philadelphia (1975).

Standards and Specifications/Books

350. Standard Method of Test for Shock Absorbing Properties of Playing Surface Systems, ASTM F355-72, American Society for Testing and Materials, Philadelphia (1972).

Books

351. Baitsch, H., The Scientific View of Sport (New York: Springer-Verlag Berlin Heidelberg, 1972).

352. Bleustein, J., Mechanics and Sport (New York: The American Society of Mechanical Engineers) AMD- Vol. 4.

353. Boone, W. T., Illustrated Handbook of Gymnastics Tumbling and Trampolining (New York: Parker Publishing Co., Inc., 1976).

354. Brown, B., Complete Guide to Prevention and Treatment of Athletic Injuries (New Jersey: Prentice-Hall, 1972).

355. Craig, T. T., Current Sports Medicine Issues (Ohio: Proceedings of the National Sports Safety Congress, February 15-17, 1973).

356. Dolan, J. P. and Holliday, L. J., Treatment and Prevention of Athletic Injuries (Danville: Interstate Printers and Publishers, Inc., 1976).

357. Grupe, O.; Kurz, D.; and Teipel, J. M., Sport in the Modern World-Chances and Problems (Berlin: Springer-Verlag, 1973).

358. Hay, J. G., The Biomechanics of Sports Techniques (New Jersey: Prentice-Hall, Inc., 1973).

359. Komi, P. V., Biomechanics V-A, Proceedings of the Fifth International Congress of Biomechanics (Finland: University Park Press, 1976).

360. Komi, P. V., Biomechanics V-B, Proceedings of the Fifth International Congress of Biomechanics (Finland: University Park Press, 1976).

361. Encyclopedia of Sport Sciences and Medicine, ed. Leonard A. Larson, (New York: MacMillan Company, 1971).

362. MacMahon, B.; Pugh, T. F.; and Ipsen, J., Epidemiologic Methods (Boston: Little, Brown and Co., 1960).

363. Miller, D. I. and Nelson, R. C., Biomechanics of Sport (Philadelphia: Lea and Febiger, 1973).

364. O'Donoghue, D. H., Treatment of Injuries to Athletes (Philadelphia: W. B. Saunders, Co., 1962).

Books

365. Singer, R. N., Coaching, Athletics, and Psychology (New York: McGraw-Hill, 1972).

366. Taylor, A. W., ed., Application of Science and Medicine to Sport (Illinois: Charles C. Thomas, publisher, 1975).

367. Taylor, A. W., ed., The Scientific Aspects of Sports Training (Illinois: Charles C. Thomas, Publisher, 1975).

368. Yost, C. P., ed., Sports Safety (Prepared under Contract PH 86-67-260, Department of Health, Education, and Welfare).

369. Selected Problems in Sports Safety (Washington, D.C.: AAPHER American Alliance for Health, Physical Education and Recreation Publications, 1975).

370. Athletic Handbook (St. Louis, Missouri: Rawlings Sporting Goods Company, 1974).

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. 77-1218	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE RISKS ASSOCIATED WITH CERTAIN SPORTS ACTIVITIES	5. Publication Date 6. Performing Organization Code
7. AUTHOR(S) William B. Beine	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234	10. Project/Task/Work Unit No. 4411435 11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Bureau of Engineering Sciences Consumer Product Safety Commission 5401 Westbard Avenue Bethesda, Md. 20207	13. Type of Report & Period Covered Final 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This study provides the Consumer Product Safety Commission with recommendations for assigning priorities to tasks associated with reducing the incidence and severity of sports related injuries. Recommendations were derived from an analysis of the published literature and the NEISS data. They emphasize the need for collecting additional data, improving surveillance capabilities, stimulating research, and developing and promulgating equipment safety standards.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Accident; Associated factors; Injuries; Literature; NEISS; Recommendations; Review; Sports; Safety.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[x] Unlimited [ ] For Official Distribution. Do Not Release to NTIS [ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13 [x] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	UNCLASSIFIED	105
	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price $5.50

USCOMM-DC 29042-P74