

The National Football Head and Neck Injury Registry

14-Year Report on Cervical Quadriplegia, 1971 Through 1984

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• Data on cervical spine injuries resulting from participation in football have been compiled by a national registry. Analysis of epidemiologic data and cinematographic documentation clearly demonstrated that the majority of cervical fractures and dislocations were due to axial loading. On the basis of this observation, rule changes banning both deliberate "spearing" and the use of the top of the helmet as the initial point of contact in making a tackle were implemented at the high school and college level. Subsequently, a marked decrease in cervical spine injury rates has occurred. The occurrence of permanent cervical quadriplegia decreased from 34 in 1976 to five in the 1984 season. It is suggested that axial loading of the cervical spine is also responsible for the catastrophic injuries in diving, rugby, ice hockey, and gymnastics. Implementation of appropriate changes in playing techniques and/or equipment modifications could possibly reduce the incidence of cervical spine injuries in these activities.

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THE SPECTER of catastrophic cervical neurotrauma resulting from athletic participation, although infrequent, has been consistently associated with water sports,^{1,5} football,⁶⁻¹³ gymnastics,¹⁴⁻²⁰ rugby,²¹⁻²³ and ice hockey.²⁴⁻²⁷ A review of the available literature reveals changing injury patterns as well as current concepts regarding the mechanism responsible for most athletic injuries to these structures.^{13,28} Accurate descriptions of the mechanism or mechanisms responsible for a particular injury transcend simple academic interest. In order that preventive measures be implemented, the manner in which injury occurs must be accurately defined. The purpose of this article is to describe how the application of this principle resulted in the significant reduction of cervical spine injuries associated with quadriplegia that occurred in tackle football since 1976.

BACKGROUND

During the 1975 football season, 12 severe cervical spine injuries occurred

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in Pennsylvania and New Jersey.⁸ Determination of the mechanism of injury responsible for the cervical spine fractures and dislocations resulting in quadriplegia was revealing. Six of the eight players were rendered quadriplegic while playing defensive back and making a tackle. In each instance, the head was used as a battering ram in tackling by striking an opponent with the top of the helmet.⁸

In order to document the extent of head and neck injuries, the National Football Head and Neck Injury Registry was established in 1975.^{10,11} Reportable injuries included cervical spine and head injuries that required hospitalization for a minimum of 72 hours, involved a fracture, dislocation, or subluxation, or resulted in paralysis or death.

Initially, the registry collected information retrospectively from 1971 through the 1975 season.¹⁰ Consideration of severe head and neck injuries included four parameters: (1) intracranial hemorrhage; (2) intracranial injuries resulting in death; (3) cervical fractures, subluxations, and dislocations; and (4) cervical spine fracture-dislocations with permanent quadriplegia. Available data allow a

comparison of these four entities for two five-year periods: 1959 through 1963, and 1971 through 1975.^{7,10}

During the five-year period from 1959 through 1963 Schneider⁷ reported 139 (3.4/100,000 [all injury rates are expressed as injuries per 100,000 participants]) lesions in which intracranial hemorrhage was a component and 65 (1.6/100,000) deaths from intracranial injuries.⁷ During this period, 820,000 athletes were exposed annually (Table 1).

The registry reported 72 (1.2/100,000) intracranial lesions and 58 (0.9/100,000) intracranial deaths occurring between 1971 and 1975, with 1,250,000 individuals exposed annually (Table 1).¹⁰

Regarding cervical spine injuries, Schneider⁷ reported 56 (1.4/100,000) injuries that involved a fracture and/or dislocation and 30 (0.7/100,000) with associated permanent cervical quadriplegia occurring during the five-year period 1959 through 1963 (Table 1).

The registry documented 259 (4.1/100,000) injuries involving a fracture and/or dislocation of the cervical spine and 99 (1.58/100,000) with associated permanent quadriplegia during the 1971 through 1975 seasons.¹⁰ When compared on an exposure basis, these data indicate a decrease in intracranial lesions and deaths and, conversely, an increase in the number of individuals who were rendered quadriplegic while playing football during the latter five-year period (Table 1).

These changes were attributed to the improved protective capabilities of the helmet-face mask unit that was developed during the 1960s and early 1970s, which provided better head and face protection. As a result, the use of the head as the primary point of contact in blocking, tackling, and head butting occurred.⁸ Fifty-two percent of the permanent cervical

quadriplegias occurring between 1971 and 1975 were caused by "spearing" or direct compression, the injured player having made initial contact with the top of his helmet.¹⁰ Seventy-two percent of high school players and 78% of college players were rendered quadriplegic while attempting to make a tackle. When injury by position was evaluated for the same period, at the high school level, 52% of the quadriplegics were defensive backs, 13% were on specialty teams, and 10% were linebackers; at the college level, 73% were defensive backs and 7% were specialty team players.¹⁰

Clearly, defensive backs who make a tackle with their head as the initial point of contact are at greatest risk of sustaining a cervical spine injury resulting in permanent cervical quad-

riplegia.

As a result of the National Football Head and Neck Injury Registry findings, the National Collegiate Athletic Association (NCAA) and the National Federation of State High School Athletic Associations adopted rule changes intended to control the "head first" techniques. The NCAA Football Rules Committee implemented the following rules beginning with the 1976 season: (1) no player shall intentionally strike a runner with the crown or top of the helmet; (2) spearing is the deliberate use of the helmet in an attempt to punish an opponent; and (3) no player shall deliberately use his helmet to butt or ram an opponent (NCAA Football Rule Changes and/or Modifications, Jan 23, 1976, rule 2, section 24; rule 9, section 1, article 2-L, 2-N).

MATERIALS AND METHODS

To ascertain the effect of the new rules at both the college and high school levels, a prospective data-collection mechanism was initiated.¹¹ Data were collected prospectively to identify injuries associated with (1) intracranial hemorrhage, (2) craniocerebral death, (3) fracture/dislocation/subluxation, and (4) cervical spine injuries with associated quadriplegia.

Maintained at the University of Pennsylvania Sports Medicine Center, Philadelphia, as an ongoing registry, information was collected by several methods. At the conclusion of each season, a project description and injury report form were mailed to all members of the National Association of Secondary School Principals and the National Athletic Trainers Association. In addition, a newspaper clipping service was used to identify head and neck injuries reported in the press. Finally, when a catastrophic injury was reported, detailed information was obtained from the responsible physician, school administrator, and coach.

RESULTS

Analysis of these data demonstrated interesting trends with regard to the incidence of head and cervical spine injuries occurring in

Table 1.—Comparison of the Occurrence of Head and Neck Injuries Between 1959 Through 1963 and 1971 Through 1975*

Source, yr	Intracranial Hemorrhages	Intracranial Deaths	Cervical Spine Fractures/Subluxations/Dislocations	Permanent Cervical Quadriplegics
Schneider ⁷ 1959-1963	139 (3.39/100,000)	65 (1.58/100,000)	56 (1.36/100,000)	30 (0.73/100,000)
Football Head and Neck Injury Registry 1971-1975	72 (1.15/100,000)	58 (0.92/100,000)	259 (4.14/100,000)	99 (1.58/100,000)

*Includes intracranial hemorrhage, intracranial deaths, cervical spine fractures/subluxations/dislocations, and permanent cervical quadriplegia. Injury rates per 100,000 participants are shown in parentheses.

Table 2.—Nine-Year Data for Head and Neck Injuries for High School, College, and Recreational-Professional Levels of Participation*

Injury	Year								
	1976	1977	1978	1979	1980	1981	1982	1983	1984
Intracranial hemorrhage									
High school	10 (0.89)	6 (0.55)	10 (0.93)	8 (0.85)	8 (0.85)	11 (1.15)	17 (1.88)	12 (1.30)	16 (1.73)
College	1 (1.33)	1 (1.33)	1 (1.33)	1 (1.33)	0	3 (4.00)	1 (1.33)	1 (1.33)	4 (4.00)
Other	1	0	0	2	4	3	1	0	1
Total	12	7	11	11	12	17	19	13	21
Craniocerebral deaths									
High school	11 (0.98)	5 (0.46)	5 (0.46)	1 (0.10)	7 (0.74)	6 (0.63)	8 (0.88)	6 (0.65)	6 (0.65)
College	0	0	0	1 (1.33)	1 (1.33)	2 (2.66)	1 (1.33)	1 (1.33)	1 (1.33)
Other	1	0	0	2	3	1	1	0	2
Total	12	5	5	4	11	9	10	7	9
Cervical spine fracture/dislocation/subluxation									
High school	86 (7.72)	76 (7.06)	40 (3.72)	42 (4.47)	52 (5.54)	49 (5.16)	46 (5.10)	60 (6.50)	36 (3.91)
College	23 (30.66)	15 (20.00)	8 (10.66)	7 (9.33)	9 (12.00)	8 (10.66)	6 (8.00)	7 (9.33)	5 (6.66)
Other	1	5	3	2	1	0	5	2	1
Total	110	96	51	51	62	57	57	69	42
Permanent quadriplegia									
High school	25 (2.24)	14 (1.30)	14 (1.30)	8 (0.85)	13 (1.38)	7 (0.73)	7 (0.77)	9 (0.97)	4 (0.43)
College	8 (10.66)	2 (2.66)	0	4 (4.00)	2 (2.66)	2 (2.66)	1 (1.33)	1 (1.33)	0
Other	1	2	2	1	1	2	2	1	1
Total	34	18	16	13	16	11	10	11	5

*Includes intracranial hemorrhages, intracranial deaths, cervical spine fractures/subluxations/dislocations, and permanent cervical quadriplegia. Injury rates per 100,000 participants are presented in parentheses.

high school and college football.

When expressed as injuries per 100,000 participants, head injuries associated with intracranial hemorrhage demonstrated a general increase over the nine-year period (1976 through 1984). At the high school level, these injuries ranged from a low of 0.55/100,000 participants in 1977, to a high of 1.88/100,000 participants in 1982. At the college level, the low was 1.33/100,000 participants in 1976, increasing to a maximum of 4.00/100,000 in 1984 (Table 2). Graphic representation of combined intracranial hemorrhages of all groups demonstrated an increase in the incidence from seven injuries in 1977 to 21 intracranial hemorrhages in 1984 (Fig 1). This apparent increase is due to the advent of widespread use of computed tomography and the resulting increase in the accuracy with which these lesions are diagnosed. This interpretation is substantiated by the relatively constant craniocerebral death rate over the same nine-year period (Table 2). Graphic representation of combined craniocerebral deaths over the period from 1975 through 1984 also reveals a relatively constant occurrence rate (Fig 2).

Whether expressed as occurrences or injuries per 100,000 participants, fractures, dislocations, and subluxations of the cervical spine decreased at both the high school and college levels. In 1975, the season prior to the initiation of the rule changes, there were 6.5 injuries per 100,000 participants and 29.3 per 100,000 at the high school and college levels, respectively. In 1976, the first year of the rules change, a slight increase occurred, 7.7 per 100,000 and 30.7 per 100,000 at the high school and college levels, respectively. Subsequently, a gradual decrease in cervical spine injury rates occurred over the following eight years, resulting in injury rates of 3.9/100,000 and 6.7/100,000 at the high school and college levels, respectively, in 1984 (Table 2). Graphic representation of the total number of cervical spine fractures, dislocations, and subluxations over the ten-year period demonstrates a dramatic decrease from 110 in 1976 to 51 in 1978, the third season after spearing was prohibited, with maintenance of the decrease at this level throughout sub-

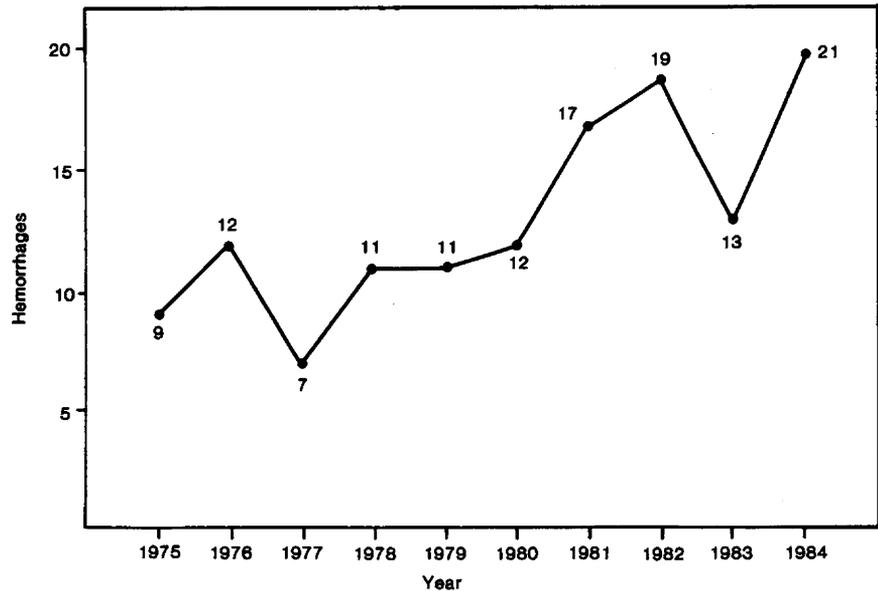


Fig 1.—Yearly incidence of intracranial hemorrhages for all levels of participation demonstrates increase during ten-year period 1975 through 1984.

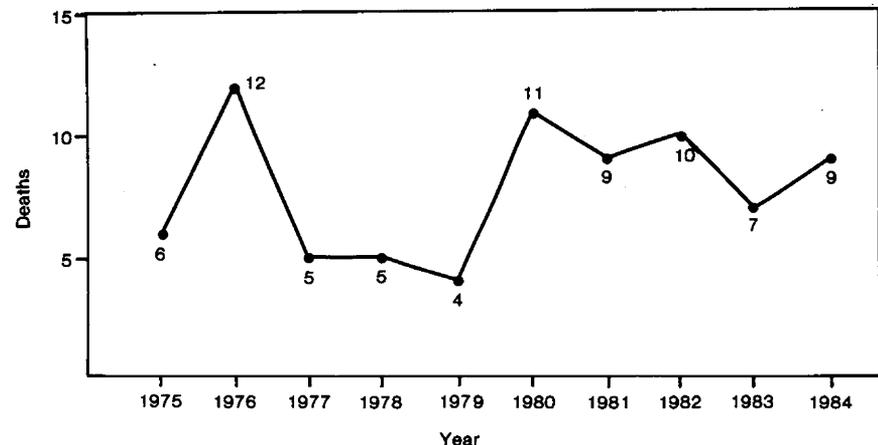


Fig 2.—Yearly incidence of craniocerebral deaths for all levels of participation is relatively constant during ten-year period 1975 through 1984.

sequent years (Fig 3).

Cervical spine injuries resulting in permanent quadriplegia have also undergone a dramatic decrease over this ten-year period. In 1975, the season prior to the rules change, quadriplegia occurred in 2.2 per 100,000 high school players and 8.4 per 100,000 college players. In 1976, the injury rate rose to 3.2 per 100,000 and 10.7 per 100,000, respectively. A marked decrease occurred in 1977, the second year of the antispearing rules, when the rate dropped to 1.3/100,000 at the high school level, and 2.7/100,000 at the college level. This downward trend has continued over the subsequent seven years. In 1984, 0.43 cases of cervical quadriplegia

occurred per 100,000 players at the high school level and none at the college level (Table 2). The total of number of permanent cervical quadriplegias in high school, college, and recreational football over the ten-year period 1975 through 1984 underwent a marked decrease, from 34 in 1976 to 18 in 1977, with a continued decline in subsequent years until a low of five injuries was reached in the 1984 season (Fig 4).

Compression or axial loading continues to be the mechanism causing the highest percentage of quadriplegias and cervical fractures/dislocations/subluxations. In 1971 through 1975, 78% of the quadriplegias were caused by this mechanism.¹⁰ During

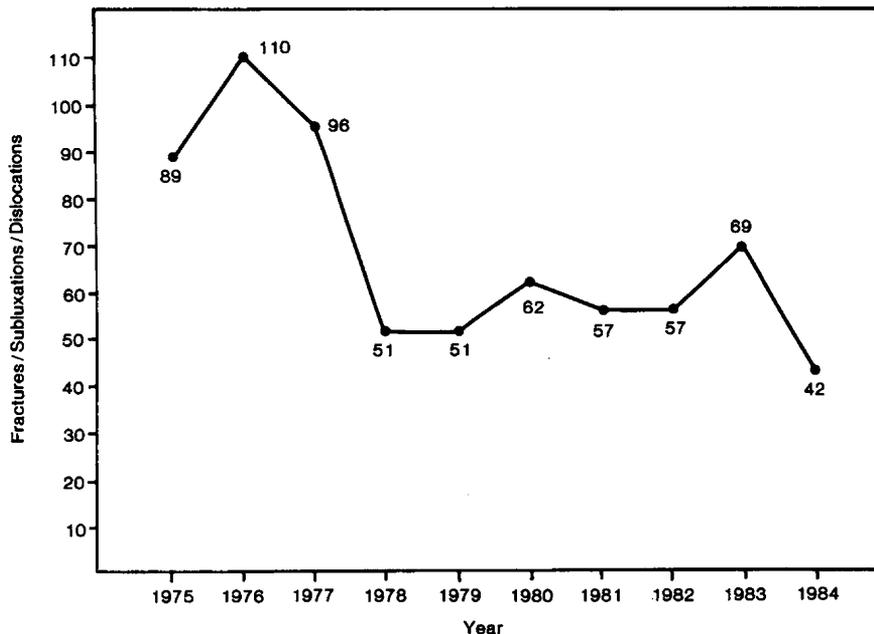


Fig 3.—Incidence of cervical spine fractures, subluxations, and dislocations for all levels of participation underwent dramatic decrease from 1976, first year of rules change, to 1978. This decrease has been maintained since 1978.

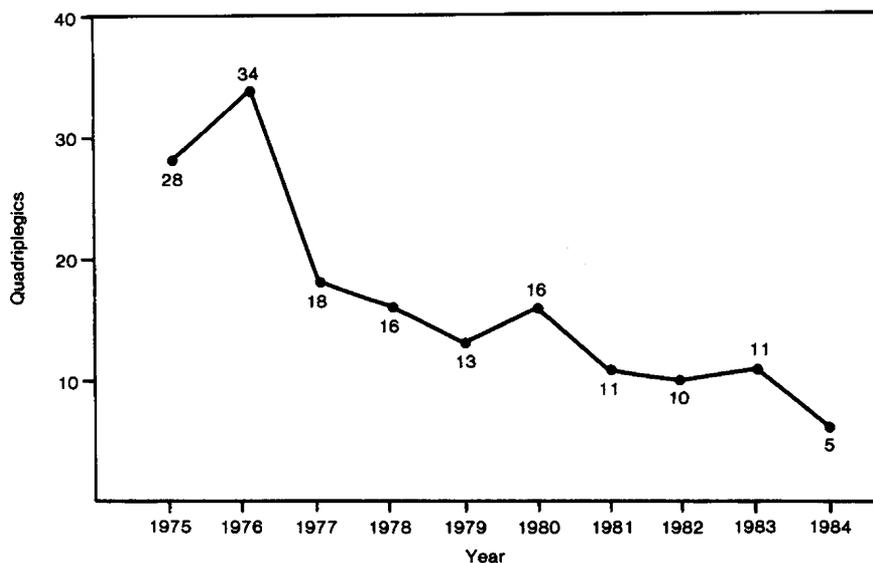


Fig 4.—Yearly incidence of permanent cervical quadriplegia for all levels of participation demonstrate significant decrease in 1977, first year after rules change. Total quadriplegia has continued to decline to low of five injuries in 1984.

the nine-year period from 1976 through 1984, 54% of the quadriplegias and 50% of the nonquadriplegic cervical spine injuries were caused by the same mechanism.

COMMENT

Identifying the cause and prevention of cervical quadriplegia resulting from football involves four areas: (1) the role of the helmet-face mask protective system; (2) the concept of

the axial loading mechanism of injury; (3) the effect of the 1976 rule changes banning spearing and the use of the top of the helmet as the initial point of contact in tackling; and (4) the necessity for continued research, education, and rules enforcement.

The protective capabilities provided by the modern football helmet have resulted in the advent of playing techniques that have placed the cervical spine at risk of injury with associ-

ated catastrophic neurological sequelae. Available cinematographic and epidemiologic data clearly indicate that cervical spine injuries associated with quadriplegia occurring as a result of football are not hyperflexion accidents.^{10,11,29} Instead, they are due to purposeful axial loading of the cervical spine as a result of spearing and head-first playing techniques.¹² As an etiologic factor, the present-day helmet-face mask system is secondary, contributing to these injuries only because of its protective capabilities that have permitted the head to be used as a battering ram, thus exposing the cervical spine to injury.

Classically, the role of hyperflexion has been emphasized in cervical spine trauma whether the injury was due to a diving accident, trampolining, rugby, or American football. Epidemiologic and cinematographic analyses have established that most cases of cervical spine quadriplegia that occur in football result from axial loading.^{10,11,29} Rather than an accidental, untoward event, techniques are deliberately used that place the cervical spine at risk of catastrophic injury. Recent laboratory observations^{30,32} also indicate that athletically induced cervical spine trauma results from axial loading.

In the course of a collision activity, such as tackle football, most energy inputs to the cervical spine are effectively dissipated by the energy-absorbing capabilities of the cervical musculature through controlled lateral bending, flexion, or extension motion. However, the bones, disks, and ligamentous structures can be injured when contact occurs on the top of the helmet with the head, neck, and trunk positioned in such a way that forces are transmitted along the longitudinal axis of the cervical spine.³²

With the neck in the anatomic position, the cervical spine is extended due to normal cervical lordosis. When the neck is flexed to 30°, the cervical spine straightens. In axial-loading injuries, the neck is slightly flexed and normal cervical lordosis is eliminated, thereby converting the spine into a straight segmented column. Assuming the head, neck, and trunk components to be in motion, rapid deceleration of the head occurs when it strikes another object,

such as another player, trampoline bed, or lake bottom. This results in the cervical spine being compressed between the abruptly decelerated head and the force of the oncoming trunk. When maximum vertical compression is reached, the straightened cervical spine fails in a flexion mode, and fracture, subluxation, or unilateral or bilateral facet dislocation can occur.³²

Refutation of the "freak accident" concept with the more logical principle of cause and effect has been most rewarding in dealing with problems of football-induced cervical quadriplegia. Definition of the axial-loading mechanism in which a football player, usually a defensive back, makes a tackle by striking his opponent with the top of his helmet has been the key in this process. Implementation of rules changes and coaching techniques eliminating the use of the head as a battering ram have resulted in a dramatic reduction in the incidence of quadriplegia since 1976. We believe that the majority of athletic injuries to the cervical spine associated with quadriplegia also occur as a result of axial loading.

Tator et al⁵ identified 38 acute spinal cord injuries due to diving accidents and observed that, "In most cases the cervical spine was fractured and the spinal cord crushed. The top of the head struck the bottom of the lake or pool." Scher,²³ reporting on vertex impact and cervical dislocation in rugby players, observed that, "When the neck is slightly flexed, the spine is straight. If significant force is applied to the vertex when the spine is straight, the force is transmitted down the long axis of the spine. When the force exceeds the energy-absorbing capacity of the structures involved, cervical spine flexion and dislocation will result." Tator and Edmonds²⁷ have reported on the results of a national questionnaire survey by the Canadian Committee on the Prevention of Spinal Injuries due to Hockey, which recorded 28 injuries involving the spinal cord, 17 of which resulted in complete paralysis. They noted that in this series, the most common mechanism involved was a check with the injured players striking the boards, "with the top of their heads, while their necks were slightly flexed."¹¹

These reports in the recent literature that deal with the mechanism of injury involved in cervical spine injuries resulting from water sports (diving), gymnastics, rugby, and ice hockey support our thesis.

CONCLUSIONS

The National Football Head and Neck Registry has documented severe and catastrophic head and neck injuries that have occurred in football. On the basis of this information, axial loading of the cervical spine has been established as the mechanism of injury responsible for quadriplegia. Identification of the axial-loading mechanism of injury and subsequent modifications of playing techniques have resulted in a significant decrease in football-induced cervical spine injuries. The necessity for continued research, education of coaches and players, and enforcement of rules is essential. It is also suggested that axial loading of the cervical spine is responsible for catastrophic injuries in water sports (diving), rugby, ice hockey, and gymnastics. Implementation of appropriate changes in playing techniques and/or equipment modification could possibly reduce the incidence of cervical spine injuries in these sports.

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