U.S. Army Center for Health Promotion and Preventive Medicine

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GENERAL MEDICAL SERVICE STUDY
REPORT NO. 12-MA-01Q5-05
PREVENTION OF FOOTBALL INJURIES:
A REVIEW OF THE LITERATURE
2005

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14. ABSTRACT
INTRODUCTION. Football has been a leading cause of military and civilian injury hospitalizations and outpatient care. This report provides detailed descriptions of epidemiologic risk factor studies of football-related injuries, and presents evidence supporting and/or refuting the effectiveness of specific interventions to prevent football-related injuries. METHODS. Medical and public health literature (1970-2004) were searched to identify relevant articles. Search terms included "football" combined with "intervention," "prevention," "injury," and derivations of these (e.g., injuries). Quality of intervention papers was assessed using a standardized instrument. RESULTS. Two hundred twenty-four papers were reviewed; 39% were case reports/series and descriptive studies, 13% were laboratory studies, 31% were reviews, 15% were analytic epidemiologic studies, and 2% were intervention studies. Median quality scores of intervention papers ranged from 15-46 out of 100. CONCLUSIONS. Only one intervention, a ban on spearing, had scientifically-demonstrated effectiveness in preventing football-related injuries. Other measures such as holding games and practices on natural grass rather than artificial grass, pre-season conditioning, and use of knee and ankle braces deserve future consideration and evaluation. To be of greatest benefit, future intervention studies should clearly describe the study population and exposures, provide rates of injury, control for confounding, and consider contemporary equipment and policies.

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EXECUTIVE SUMMARY
GENERAL MEDICAL SERVICE STUDY
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PREVENTION OF FOOTBALL INJURIES: A REVIEW OF THE LITERATURE
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1. PURPOSE. This technical report presents the results from a systematic review of the medical and public health literature (1970-2004) describing injuries, injury risk factors, and injury prevention strategies related to American football and, more specifically —

a. Describes the analytic epidemiologic studies identifying risk factors for football injuries, and

b. Presents the evidence supporting or refuting the effectiveness of specific interventions to prevent injuries during this sport.

2. CONCLUSIONS.

a. The search identified 37 case series/case reports, 51 descriptive epidemiologic studies, 29 laboratory studies, 34 analytic epidemiologic studies, 69 review articles, and 4 intervention trials. The four intervention trials included two studies of knee braces, one study of swivel shoes, and one study of a pre-season conditioning program.

b. Few epidemiologic studies of football injuries are recent; of the 34 analytic epidemiologic studies published since 1970, only three were published since the year 2000. The most recent intervention trial was conducted in 1990.

c. The literature indicates that a few interventions, such as helmet use and a rule to ban spearing, have demonstrated effectiveness in preventing football-related injuries. Pre-season conditioning and holding games on grass (vs. artificial) surfaces are other promising prevention strategies. Studies of other strategies (e.g., cleat type, knee braces, ankle braces) suffer from too little evidence, discordant study results, and/or inconclusive results due to poor study design.

d. Risk factor studies suggest that player position, duration of time on the field during games, and length of practice sessions may influence injury risk during football. Intrinsic factors such as pre-existing injury, flexibility extremes (loose- or tight-jointedness), and higher body mass index (BMI) may also increase injury risk.

3. RECOMMENDATIONS.

a. While helmet use and enforcing the ban on spearing are important interventions to prevent injuries that occur during American football, the literature does not offer definitive evidence at this time of other interventions to implement. The most promising interventions (i.e., two or more studies showing similar results) deserving of consideration and further evaluation include pre-season conditioning and use of grass surfaces.

b. The next steps in football injury prevention would be best guided by updated descriptive and analytic epidemiologic studies describing current rates and trends of football injuries, including information on the severity, types, and causes of injury. Such studies would lend insight into leading causes of football injuries; information that could then be used to focus prevention research efforts on the most significant injury types or causes.

c. Given that methodological deficiencies precluded the usefulness of a number of studies, future descriptive epidemiologic, analytic epidemiologic, intervention trials, and program evaluations should strive to include—

(a) A clear description of the study population (e.g., number of players, ages, positions);

(b) A description of exposures in more detail (e.g., length of season, number and duration of practices, number of games in regular and post-seasons);

(c) Inclusion of confounders (e.g., prior injury, BMI) in analyses;

(d) A clear definition of outcomes (e.g., injury type, data sources for injuries); and

(e) Presentation of meaningful injury rates, with denominators such as athlete-exposures, rates per specified number of players per week, month, or season.

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I. REFERENCES. See Appendix A for a complete list of reference information. Appendix B contains detailed information on published football injury risk factor (analytic epidemiology) and intervention studies that were reviewed as part of this work.

II. PURPOSE. This technical report presents the results from a systematic review of the medical and public health literature (1970-2004) describing injuries, injury risk factors, and injury prevention strategies related to American football and, more specifically —

A. Describes the analytic epidemiologic studies identifying risk factors for football injuries, and

B. Presents the evidence supporting or refuting the effectiveness of specific interventions to prevent injuries during this sport.

III. AUTHORITY.

A. Under Army Regulation 40-5 (AR), *Preventive Medicine*, July 2005 (paragraph 2-19), the USACHPPM is responsible for providing support of Army preventive medicine activities, to include interpretation of surveillance data, identification of leading health problems, and assistance in prevention and control of leading health problems.

B. This project was initiated under a grant from the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Health Promotion and Prevention Initiatives (HPPI) Program.

IV. INTRODUCTION.

A. According to medical surveillance data and safety reports, sports have historically been a leading cause of military hospitalizations and outpatient care[231, 232]. Football was identified as the second leading cause of sports and physical training-related injury hospitalizations for the U.S. Army[108].

B. Among civilian populations, football is the most practiced contact sport at both the high school and college levels. It is estimated that 1,500,000 high school and college players participate in this sport, sustaining over 350,000 injuries annually[7,132]. Among group sports, it corresponds to the second leading cause of emergency department treatment in the United States population[233].

C. The rates of injuries sustained by college players during games have been high and stable since the mid-nineteen-eighties[8], except for catastrophic injuries (those involving disability at the time of injury) and fatal injuries[6]. During games, the injury rates were 37 per 1,000 athlete-exposures in 1985, and 33 in 2002. For catastrophic and fatal injuries, the rates were respectively 4.0 and 1.3 per 100,000 players in 1985, and 1.3 and 0.0 in 2002. Among high school players, a recent study showed that football presented the highest injury rate of ten selected popular sports: an overall average of 8.1 per 1,000 athlete-exposures, with rates of 5.3 injuries per 1,000 athlete-exposures during practice sessions, and 26.4 during games[158]. Knowledge of the associated risk factors and intervention strategies to prevent these injuries is important to provide guidelines that will make the sport safer.

V. METHODS.

A. Search Strategy.

1. Scientific studies published between January 1, 1970 to July 31, 2004 were identified by searching the following databases: Medline, Embase, Cumulative Index to Nursing and Allied Health Literature, SPORTDiscus, The Center for Disease Control and Prevention's (CDC) Morbidity and Mortality Weekly Report (MMWR), and Physiotherapy Evidence Database.

2. The key words were identified *a priori*, and databases were searched using the following terms: "intervention," "prevention," "injury," and derivations of these (e.g., injuries), in conjunction with "ankle injuries," "knee injuries," "anterior cruciate ligament (ACL)," "medial collateral ligament (MCL)," "athletic," and "sports".

3. All of the aforementioned terms were combined with "football." Further citations were identified from the reference lists of retrieved papers and from review papers from scientific journals and the Cochrane Collaboration.

B. Selection Criteria.

1. To best characterize the state of the literature regarding football-related injuries, all study designs fitting the search criteria were accepted. Papers were subsequently classified as case series or case reports, laboratory studies, descriptive epidemiologic studies, analytic epidemiologic studies, intervention studies, or review papers. Study classification was based on

definitions from *A Dictionary of Epidemiology*[107]. The search was restricted to the following additional criteria:

a. English language.

b. Military or civilian populations—high school age and over.
c. Focus on primary prevention.

d. Addressing head and neck, knee, and ankle injuries—

2. The search focused on knee and ankle football injuries because these injuries correspond to the highest rates observed among high school, college[132], and military populations[108]. The search included head and neck injuries, which are among the top ranked injuries in these same populations, and are addressed in this review due to the potential severity and disability imposed to the players.

3. Papers excluded were those focusing exclusively on touch football, flag football, rugby, Australian football, and soccer due to equipment use and rule differences.

4. Information on the location of the study, population studied, sample size, risk factors studied, injury rates or outcomes, and results of statistical significance testing were collected from each study. Meta-analysis of the results was not attempted because of the vast differences in the methodological approaches of the studies. Since the focus of this review is on identifying risk factors and preventive strategies, results, tables, and discussion are presented for analytic epidemiologic studies and intervention studies only.

5. Intervention studies are those involving intentional change in some aspect of the status of the subjects by the investigators, as defined in *A Dictionary of Epidemiology*[107]. In order to rate the quality of the intervention studies, a scoring system was adapted from Thacker et al.[194] and applied by three of the authors. This system comprises study characteristics with corresponding scores that total 100 points.

VI. RESULTS. The literature search identified 224 papers, of which 37 (16 percent) were case reports/case series, 51 (23 percent) were descriptive studies, 29 (13 percent) were laboratory studies, 69 (31 percent) were reviews, 34 (15 percent) were analytic epidemiologic studies, and only 4 (2 percent) were intervention studies (Table B-1). The review of analytic epidemiologic and intervention studies of football injuries showed that most of the research that has been done is related to risk factors (intrinsic and extrinsic). (See Tables B-2 to B-8.) Accordingly, the following synopsis of the literature on football injuries will be categorized based on risk factor topics, with intervention studies noted where appropriate.

A. Extrinsic Risk Factor Studies.

1. Environmental.

a. Surface Type.

(1) The debate about football injuries and surface type began with a study by Bramwell et al. that evaluated injuries to high school football players[34] (Table B-2). Based on information reported by coaches, the authors found a lower overall rate of 0.52 injuries per game on natural grass compared with a rate of 0.76 injuries per game on artificial surfaces. This difference was statistically significant ($p < 0.01$) and was even more pronounced when wetness of the playing surface was evaluated. The injury rates were higher on dry artificial surfaces than on wet surfaces (0.93 versus 0.61 injuries per game, respectively), and the authors found that 17 of the 19 most serious injuries occurred on dry artificial surfaces. Although the authors did not test their hypothesis in a controlled trial, they recommended wetting artificial surfaces prior to football play. Regarding mechanisms of injury, the authors postulated that the traction characteristics of the dry artificial surfaces were responsible for an increased injury risk.

(2) A study by Bowers evaluated injuries to West Virginia University football players. The author compared injury rates 2 years prior to the installation of an artificial surface (1969) with injury rates 2 years after the surface change[31] (Table B-2). A comparison of injury rates showed that non-surgical knee injuries increased 50 percent after the surface change. During the two consecutive years of spring practices and fall seasons prior to the change, there were 13 non-surgical knee injuries, a number that increased to 19 during the same time period after the surface change. Although corresponding statistics were not presented, the author stated that age, conditioning, size, previous experience, training methods, and length of practice periods did not change over the years and based on these results, concluded that football play on artificial surfaces increased injury.

(3) Although the classifications of wet and dry surfaces were made crudely, classified by touching the ground at the 50-yard line of the field, Adkinson et al. also found a higher overall rate of injuries on the artificial surface Astroturf® than on natural grass: 0.63 versus 0.51 injuries per game[11] (Table B-2). (Astroturf® is a registered trademark of AstroTurf, LLC., Dalton, Georgia.) Moreover, on Astroturf, injury rates were higher on dry surfaces (0.91 injuries per game) than on wet ones (0.55 injuries per game). The authors also argued that cleated shoes were generally used on natural turf, while soccer shoes were universally used on synthetic surfaces, which could indeed have underestimated the observed injury rate on Astroturf. The authors, however, did not consider shoe type in their analyses.

(4) Alles et al., using data from the National Athletic Injury/Illness Reporting System (NAIRS), found that the rate of knee sprains per 1,000 athlete exposures was significantly associated with play on artificial surfaces[17] (Table B-2). The standardized rate calculation by

athlete-exposures was proposed by NAIRS and corresponds to the product of the total number of athletes by the total number of practices or games in which the athlete participates. The authors also found a significant association between injuries and surface type, with both knee and ankle sprain rates higher on artificial surfaces than on natural grass. They concluded that the average college team could expect one to two additional knee injuries and two ankle injuries if all games were played on artificial surfaces.

(5) Powell echoed these findings and, using data from the National Football League (NFL®) clubs, reported that if an average team played all 20 games on Astroturf, there would be roughly two more cases of major injuries than if all games were played on natural grass[157] (Table B-2). (NFL® is a registered trademark of the National Football League, Unincorporated Association New York, New York.) For games played on Astroturf, the author found 0.47 knee injuries and 0.39 ankle/foot injuries per team-game, compared to 0.40 knee injuries and 0.28 ankle/foot injuries per team-game on natural grass.

(6) One paper did not report an association between injuries and playing surface. Nicholas et al. used data from a professional football franchise in New York and, over a 26-year period, did not find a statistically significant difference in the mean number of injuries per game on artificial and natural surfaces[145], although the differences were in the same direction as in other studies (Table B-2). The mean difference for significant injuries per game (player missed at least two consecutive games) was 0.11 ± 0.49. The mean difference for major injuries per game (player missed at least eight consecutive games) was 0.13 ± 0.38. In both cases, higher rates were seen on artificial surfaces. The authors cited limitations in how the types of surfaces were classified (i.e., by public relations departments or football staff).

(7) A later study of professional football teams in the NFL by Powell and Schootman also found that more knee sprains occurred during play on Astroturf[160] (Table B-2). Play on Astroturf was associated with a rate of 0.22 ACL or MCL injuries per team game, compared to 0.20 ACL and MCL injuries per team-game on natural grass. They also reported that for linemen–players starting each play on the line of scrimmage–nearly 43 percent of the MCL injuries were directly attributed to play on Astroturf.

b. Weather Condition.

(1) Orchard and Powell observed that the literature on playing surface and knee and ankle injuries did not adequately address weather condition[150]. Based on this premise, the authors evaluated 10 years of NFL data regarding surface type, knee, and ankle injuries and stratified the analysis by weather condition.

(2) In Orchard and Powell's study[150] (Table B-2), significant knee sprains (those corresponding to at least 7 days missed from game or practice participation) were significantly

reduced on grass surfaces on cold and wet days, compared to hot and dry days (relative risk (RR)=0.66, 95 percent confidence interval (95% CI) 0.47-0.93). In the same conditions, there was a reduction in significant ankle sprains, although not statistically significant (RR=0.83, 95% CI 0.57-1.2). On open turf, significant knee sprains were reduced on cold and dry days, compared to hot and dry days (RR=0.57, 95% CI 0.43-0.76), and so were significant ankle sprains (RR=0.67, 95% CI 0.48-0.95). As expected, games in domes did not present any difference in knee and ankle sprains related to weather condition. The authors concluded that for both grass and open turf surfaces, knee and ankle sprains were less likely when temperatures were cooler and, especially for grass, other surface characteristics like grass species, shoot density, and ground hardness might play a role in the observed outcomes.

c. Equipment.

(1) Helmets.

(a) Five studies evaluated the role of helmets in preventing concussions and cervical spine injuries. First, Robey evaluated the association of mounting type, fit, and condition of helmets with concussion rates in a sample of 7,800 high school football players[170] (Table B-3). A preliminary analysis had shown suspension helmets were more protective than both padded and combined padded-suspension helmets. In the present study, without mentioning other confounders, the author found that for suspension helmets, no difference was observed in concussion rates related to "fit" or "condition" of the helmet. For combined padded-suspension helmets, the concussion rate per player was 0.03 if the helmet fit was "too large;" 0.06 if the fit was "good;" and 0.07 if the fit was "too small." For padded helmets, the lowest concussion rates were again associated with a fit that was "too large." The rate per player was 0.04 if the helmet fit was "too large;" 0.08 if the fit was "good;" and 0.13 if the fit was "too small." The author also discussed the importance of a blow from a helmet as the mechanism responsible for more serious injuries in the opponent, or anyone coming in contact with the helmet other than the wearer. Thirty percent of fractures, 48 percent of lacerations, 34 percent of dislocations, 48 percent of ruptured blood vessels, and 93 percent of internal injuries were caused by this mechanism. The author suggested the importance of evaluating a soft outer covering on football headgear, which would reduce frequency and severity of injuries, with regard to both the wearer and his opponents.

(b) Based on a survey, Mueller and Blyth studied different risk factors associated with injuries in 8,776 North Carolina high school students, between 1969 and 1972[137] (Table B-3). The authors evaluated the following factors: helmet brand, surface type, cleat type, contact program, and prior injury. Concussion rates per player varied significantly according to the different helmet brands; from 0.02 for Rawlings® HC to 0.05 for Southern Athletic®. (Rawlings® is a trademark of the Rawlings Sporting Goods Co., Inc., Fenton, Missouri; Southern Athletic® is a registered trademark of Southern Atlantic, Inc., Corporation, Knoxville, Tennessee.) Knee and ankle injuries were significantly reduced if the playing surface was properly maintained and if the player wore soccer shoes. Schools with surfaced fields and where players used soccer shoes presented a combined knee and ankle rate per player of 0.12; whereas, schools with the same field condition, but where players used regular cleat shoes, presented an injury rate of 0.15. There was also a statistically significant 12 percent reduction in injury rates among players under a limited contact program, compared to those under the regular contact program. Finally, participants reporting prior injuries presented a significantly higher injury rate (0.62), than those without an injury history (0.44).

(c) Clarke and Powell, using data from the National Athletic Injury/Illness Reporting System, sought to evaluate the association between helmet type and neurotrauma[58] (Table B-3). The authors postulated that some helmets might be less likely to protect the head during contact, or "causing cervical spine injuries to its wearers by its posterior edge impinging on the cervical spine during forced hyperextension." Their analysis accounted for 13 different helmet types worn by high school and college players at practice sessions and games. The injury data showed that no particular helmet was disproportionately associated with concussions or cervical spinal fractures.

(d) One study evaluated a polyurethane football helmet cover on the *reoccurrence* of cerebral concussions. This device would be responsible for decreasing the forces and distributing the impact loading over a larger surface area of the skull. Through a survey conducted by the National Athletic Head and Neck Injury Registry, Torg et al. evaluated 119 football players with a previous history of concussion and who used the helmet cover during the seasons of 1992, 1993, or 1994[202] (Table B-3). The reoccurrence rates were 2.4 percent for players with one previous concussion, 4.9 percent for two previous concussions, 15.8 percent for three previous concussions, and 27.8 percent for four or more previous concussions. No confounders were taken into account in this analysis. Due to study limitations, the authors found the results inconclusive but still suggested the device for use in individuals with one or two prior concussion injuries.

(e) Marshall et al. aimed to further evaluate the role of helmets and concussions[123] (Table B-3). The authors compared the role of protective equipment regulations for football players versus rugby players. In football, the head is the sole body region that is fully protected; in rugby, protective headgear is not worn. The head injury rate for football players was one-tenth that of rugby players (RR=0.11, 95% CI 0.08-0.16), and injuries to the scalp, face, eyes, and ears were also substantially lower for football players than for rugby players (RR= 0.014, 95% CI 0.013-0.015). In addition, the rate of concussion per 1,000 player-games was 60 percent lower for football players: 2.1, versus 5.2 for rugby players. Based on their findings, the authors concluded that the reduced head injuries in football are due to differences in the regulation of protective equipment in both sports.

(2) Knee Braces.

(a) The following synthesis of the literature is limited to the studies of prophylactics that specifically addressed football play, as opposed to a general investigation of the role of preventive braces in sports.

(b) Hewson et al.[96], Rovere et al.[174], Teitz et al.[192], Grace et al.[89], and Deppen and Landfried[71], all reported that preventive knee braces were non-effective in decreasing knee injury rates when worn (Table B-4). Hewson et al. presented a medical record review of University of Arizona football players over an eight-year period[96]. The non-braced control period was from 1977 to 1981. Beginning in 1981, the Anderson Knee Stabler® was mandated for all games and practices for players at greatest risk—defensive linemen, linebackers, and tight ends. (Anderson Knee Stabler® is a registered trademark of Omni Scientific, Inc., Corporation, Lafayette, California.) The data showed no significant difference in knee injury rates in the pre- and post-brace mandated period (23.9 and 21.4 knee injuries per 100 players per season, respectively).

(c) Rovere et al. performed a 4-year study of all Wake Forest University football players who also wore the Anderson Knee Stabler[174] (Table B-4). The control period was the 2 years prior to mandated brace use. Although the authors did not present any results of significance tests, they found MCL injury rates of 4.0/100 players in the non-brace period and 4.8/100 players in the brace period. There was also a doubling of the number of knee operations performed during the brace period. Since the authors found that brace use did not significantly alter the frequency of MCL injuries by position or player, they concluded that the Anderson Knee Stabler was ineffective in preventing injury. Additionally, there were some reports of leg cramping with brace wear.

(d) Teitz et al. studied National Collegiate Athletic Association (NCAA®) Division I players and found that players who wore knee braces had a significantly higher injury rate than players who did not wear knee braces[192] (Table B-4). (NCAA® is a registered trademark of the National Collegiate Athletic Association, Unincorporated Association, Indianapolis, Indiana.) In 1984, players who wore knee braces had an 11.0 percent injury rate compared with 6.0 percent for those who did not wear knee braces; in 1985, players who wore knee braces had a 9.4 percent injury rate compared with 6.4 percent for those who did not wear knee braces. The authors found that player position, playing surface, mechanism of injury, or type of brace did not modify the injury rates. They also found that injury rates among braced players were higher at every skill level than rates for non-braced players. The authors advised against the use of knee braces as preventive measures.

(e) Brodersen and Symanowski studied the impact of the use of prophylactic double upright knee orthosis by Division I collegiate football players from the Iowa State University during the period of 1979 to 1987[36] (Table B-4). Knee bracing was instituted in 1982. The authors observed a decline in overall knee injuries among the braced players, as well as a shift of moderate and severe knee injury rates to mild ones among them, compared to non-braced players. The overall knee injury rates were 44 percent for non-braced players to 26 percent for braced ones. They concluded that this particular knee-bracing type was beneficial to football players.

(f) Deppen and Landfried looked at a population of high school football players and observed no significant difference over four seasons in the number of injuries sustained by players who wore knee braces compared with players who did not[71] (Table B-4). There were 23 knee injuries in 21,640 player-games and 26 knee injuries in 19,484 player-games among players with and without knee braces, respectively. The lack of a difference was not due to any difference in injury severity or mechanisms of injury. The authors concluded that the findings did not support the use of prophylactic knee braces for high school football players.

(g) Albright et al. evaluated NCAA Division I data over a 3-year period and found that knee injury rates by player position were lower for braced players compared to non-braced players[16] (Table B-4). The MCL sprain rates per 100 knee exposures were 0.098 (line), 0.053 (linebacker/tight end), and 0.036 (skilled) for braced players, versus 0.103, 0.069 and 0.049 among non-braced players, respectively; but there were no statistically significant differences between these groups. The authors discussed that these results were suggestive but not conclusive that preventive knee braces were effective in reducing MCL sprains.

(h) There were two intervention studies for knee braces. Grace et al. studied the effectiveness of two types of prophylactic knee braces among high school varsity and junior football players during the same season in New Mexico[89] (Table B-9). Players with either single-upright and single-hinged braces or single-upright and double-hinged braces were matched to non-braced players by height, weight, and playing position. Players with single-hinged braces were 3.7 times more likely to sustain a knee injury than non-braced players. There was no statistically significant difference between players that wore double-hinged braces and non-braced players. The authors also observed an increase in the severity of injuries among single-hinged braced players, compared to non-braced players. Additional injuries in the lower extremity, including foot and ankle fractures, were observed more frequently among braced players compared to non-braced players. The authors did not recommend either type of prophylactic knee brace for use by high school football players.

(i) In a randomized controlled trial testing, the effectiveness of prophylactic knee braces, Sitler et al. noted a decrease in the frequency and severity of knee injuries with prophylactic brace use[186] (Table B-9). This prospective study evaluated 1,396 intramural tackle football players at the United States Military Academy (West Point, New York). There were 700 non-braced controls and 691 braced players involved. The results showed a statistically significant decrease in the frequency and total number of MCL injuries in braced defensive men compared with the controls, but no difference was observed between braced and non-braced offensive players. They also did not find any difference between the players for foot and ankle injuries. The overall knee injury rates per 1,000 athlete-exposures were 1.50 for braced players and 3.40 for controls.

(3) Ankle Braces.

(a) One study specifically evaluated prophylactic ankle braces in football players. In a retrospective study, Rovere et al. evaluated medical records and found that ankle stabilizers were associated with a lower-ankle injury rate than taped ankles: 2.90 and 4.62 per 1,000 player-games, respectively[173] (Table B-4). Although the injury rates varied by position, the effect was consistent across all positions.

(b) The athletes in the study preferred ankle stabilizers as opposed to tape for prophylactic use. Low- and high-top football shoes were also evaluated; the ankle injury rates were 3.73 and 5.78 per 1,000 player-games for low- and high-top football shoes, respectively. The combination that presented the fewest injuries overall was low-top shoes and laced ankle stabilizers.

(4) Cleats/Shoes.

(a) Two analytic studies examined the role of shoe type or design and the risk of injury. Torg and Quedenfeld evaluated the effectiveness of a policy that mandated a change in the number of cleats on football shoes during the seasons of 1969 and 1970[204] (Table B-5). The authors compared knee injuries before the change, when athletes were wearing conventional shoes (seven 3/4-inch cleats), to knee injuries when modified shoes were worn (fourteen 3/8-inch cleats). They found a significant reduction in injury rates from 0.33 to 0.17 knee injuries per team-game in public high schools, and from 0.58 to 0.24 knee injuries per team-game in Catholic high schools. Tests of statistical significance were not presented. Based on this pre- and post-comparison, the authors emphasized the need for all football players to wear shoes with at least 14 cleats per shoe, with a minimum cleat-tip diameter of 1/2 inch and a maximum cleat length of 3/8 inch.

(b) Lambson et al. conducted laboratory testing of various shoe types and found a greater shoe-surface torsional resistance for the “edge”-cleat design—cleats at the peripheral margin of the shoe with a smaller number at the interior[105] (Table B-5). The authors evaluated only play-on-grass surfaces and compared edge and non-edge designs. The results showed a statistically significant higher rate of ACL injuries per player in the edge shoes (0.017) compared to non-edge (0.005). Although the authors did not discuss the number of cleats on the shoe, they strongly recommended the use of non-edge shoe design for football play.

(c) Finally, an intervention study in 1969 evaluated the performance of swivel shoes in preventing knee or ankle injuries in high school players during the 1969 season[44] (Table B-9). The swivel shoe principle was introduced in 1962 in an effort to replace rigid cleating. Its evolution included movable forefoot cleats mounted upon a 360-degree turntable (a torsion joint) that were added to previously-designed cleatless shoes. This design further reduced fixation to the ground, allowing the player to be cleated but relatively protected from injury. The 466 players who wore swivel shoes presented a knee injury rate of 2.1 percent and an ankle injury rate of 3.0 percent; whereas, the 2,373 players who wore conventional shoes presented knee and ankle injury rates of 7.5 and 8.1 percent, respectively. However, no statistical significance tests were presented for these observations. Agility tests were also performed in the beginning and at the end of the season among 512 players who wore either swivel shoes or conventional shoes. The authors mentioned that no statistically significant differences were found between these groups in terms of function; given that swivel shoes were associated with lower knee and ankle rates during the season, the authors recommended their use by football players.

d. Behavioral.

(1) Spearing Rule Change.

(a) Torg et al. presented data that compared football injuries before and after the spearing ban, which was the only major change in college and high school football play in 1976, according to the authors[213] (Table B-6). With the development of a helmet-face mask system that provided protection as a battering ram in blocking, tackling, and butting, use of such methods increased; consequently, cervical spine injuries with fracture-dislocations and quadriplegia also increased. As a result, at the conclusion of the 1975 season, both the NCAA and the National Federation of State High School Athletic Associations adopted rule changes forbidding the aforementioned playing techniques. This study's data revealed that after the spearing ban, cervical spine injuries occurring during tackling were reduced among college football players by nearly 35 percent, from a rate of 30.1 injuries per 100,000 players in 1975 to 20.3 in 1977. Permanent quadriplegia, in the same population was reduced from a rate of 5.3 per 100,000 players in 1975 to 4.0 in 1977.

(b) Subsequent work by Torg et al. further supported the long-term benefits of the spearing ban[215] (Table B-6). The authors showed that 11 years after the ban, there was a 65 percent decrease in cervical spine injuries and a 100 percent decrease in permanent quadriplegia rates among college players. Cervical spine injuries were reduced from 30.7 per 100,000 players in 1976 to 10.7 in 1987. Quadriplegia was reduced from 10.7 per 100,000 players in 1976 to 0.0 in 1987.

(2) Training/Conditioning.

(a) One intervention study conducted by Cahill and Griffith during an 8-year period compared two groups of high school varsity football players with regard to total body preseason conditioning[42] (Table B-6). Preseason conditioning programs started 6 weeks before the official start date of football practice and consisted of a maximum of three weekly 80-minute sessions of exercises. The non-conditioned group (control) was evaluated from 1969 to 1972, and the conditioned group (study), from 1973 to 1976, right after the beginning of the preseason conditioning program among the study population. Overall, knee injury rates were significantly reduced from 6.8 percent to 4.1 percent with preseason conditioning and surgical knee injuries from 1.5 percent to 0.6 percent.

(b) Later, Cahill et al. retrospectively studied a 12-year period in which high school varsity football players underwent three different phases of preseason conditioning (PSC) programs: a no-PSC phase (1969 to 1972), a closely supervised PSC phase (1973 to 1976), and a less supervised PSC phase (1977 to 1980)[41] (Table B-6). Injury and injury severity rates were compared among the three phases. The authors observed a reduction in the injury rates as well as in the injury severity. Knee injury rates per 1,000 athletes were 68, 41, and 39 for the first, second, and third phases, respectively. Knee surgery rates per 1,000 athletes were 15, 5, and 2, respectively. The authors concluded that close supervision by a medical staff member is not necessary provided that instructors receive adequate orientation.

e. Other.

(1) Player Position and Play Type.

(a) In a demonstration of a multivariate analysis applied to the sports injury field, Buckley simultaneously addressed the association of concussion in college football players with player position, team (offense/defense), situation (rushing/passing), and activity (block/tackle)[40] (Table B-7). The highest risk of concussions was during rushing, and the lowest risk was found during passing plays regardless of team or activity. Offensive players involved in a block on a rushing play, for example, had an adjusted frequency of 274 concussions during games in 8 years of NAIRS observations compared to 18 concussions among defensive players involved in a tackle on a passing play.

(b) Turbeville et al. carried out a prospective study of high school football players in Oklahoma City to study the association between players' characteristics and injuries[219] (Table B-7). Controlling for age, body mass index (BMI) school, and coaching experience, the predictors for knee-ligament injuries were increasing player's experience in years (odds radio (OR) 1.48, 95 percent CI 1.07-2.06), and linemen position, versus all other positions (OR 3.26, 95 percent CI 1.15-9.26). The authors suggested further studies addressing injury prevention for linemen players, who presented the highest overall and knee-injury risk, as well as season-ending injuries, compared to players at other positions.

(2) Exposure Time.

(a) Dagiau et al. collected data on injuries as well as exposure time (in seconds) at all practice sessions and games at the University of Illinois during the 1976 and 1977 seasons[64]

(Table B-7). Game-injury data were analyzed according to 3 time intervals of plays: "low exposure" (0 to 125 seconds), "intermediate exposure" (126 to 275 seconds), and "high exposure" (276 to 375 seconds). In both years, the authors observed an inverse relationship between exposure time and injuries during games (i.e., a player participating in a game for up to 125 seconds (approximately up to 25 plays) was more likely to sustain an injury than a player participating for at least 276 seconds (approximately 50 plays or more) of a game.

(b) Further analysis by player position showed that offensive players were concentrated in the "low-exposure" interval. During practice sessions, a curvilinear relationship skewed to the right was observed for the same variables. Among five 25-minute practice intervals, injuries were more concentrated in the third (50 to 75 minutes) and fourth intervals (76 to 100 minutes) of practice. The authors suggested the need for more studies addressing exposure time to enable coaches to restructure safer practice sessions.

B. Intrinsic Risk Factor Studies.

1. Prior Head or Neck Injuries and Cervical Abnormalities.

a. Albright et al. prospectively evaluated 342 college freshman football players for 8 years at the University of Iowa[13] (Table B-8). They screened participants for history of previous head or neck injuries significant enough to have caused a loss of at least one day of participation from high school football. They also screened participants for abnormalities or pathologies of the cervical spine through physical examination and x-ray films.

b. Freshman players with an abnormal screening were twice as likely as those with normal screening to sustain a head or neck injury during their college careers (43 percent versus 23 percent, respectively). They also found that freshmen with higher degrees of neck abnormalities sustained more severe neck injuries in college ($r=0.36$, $p<0.05$), although the same relationship was not found for head abnormalities and injuries. The authors suggested that any evidence of abnormality on history or physical examination should be followed up with radiographic examination. Moreover, for players with a previous injury history, total injury recovery should be reached prior to the players' return to action.

2. Lower Extremity Joint Characteristics.

a. Nicholas physically evaluated the joint laxity of 139 professional players and assessed later their knee ligament rupture incidence[146] (Table B-8). Players with three or more indices of looseness were seven times more likely to undergo surgery for a ruptured ligament than those with less than three indices. The author recommended stretching exercises for tight-jointed individuals and strengthening exercises for loose-jointed ones.

b. Kalenak and Morehouse, through both subjective joint-laxity tests and biomechanical knee-ligament evaluations, found that tight-jointed and loose-jointed college football players sustained knee-ligament ruptures in almost equal numbers[100] (Table B-8). In contrast to Nicholas, the authors suggested that all players, regardless of their joint laxity, should participate in strengthening and stretching exercise programs.

c. Jackson et al. studied the relationship of physical and psychological traits of West Point cadets and California high school football players with the risk of injuries[98] (Table B-8). No significant associations were found between upper-and lower-extremity injuries and players' joint flexibility in either population group. Concerning personality traits, injury frequency was significantly higher in "tender-minded" high school players than in "tough-minded" ones. Data analyses of these associations were not provided. The authors proposed future studies to develop an injury-profile index including both physical and psychological traits that could help counselling athletes for the most adequate sports.

d. Woodford-Rogers et al. evaluated the uninjured knee of 14 ACL-injured football players and 8 ACL-injured female basketball players and gymnasts regarding their measures of navicular drop, calcaneal alignment, and anterior knee-joint laxity, and compared these measures with those of 22 athletes without history of ACL injuries, matched by sex, sport, position, and level of competition[228] (Table B-8). The former athletes presented greater subtalar pronation and anterior knee-joint laxity. The authors postulated that these factors could be screened and addressed by use of appropriate footwear or orthotics, and prescription of knee-muscle strengthening, respectively.

3. Body Mass Index.

a. One study by Gomez et al. evaluated the relationship between BMI and football injuries. Two hundred and fifteen high school football linemen were prospectively followed up during 12 weeks after BMI measurements[87] (Table B-8). No significant differences in overall injury rates were observed when comparing groups above and at or below various levels of BMI.

b. The association was observed, however, for lower-extremity injury rates, with higher BMI groups presenting significantly greater rates that increased from 26 kilograms per square meter (kg/m^2) to 42 kg/m^2, except at 34 kg/m^2. For example, the risk ratio of a player with a BMI above 28 kg/m^2, compared to a player with a BMI at or below 28 kg/m^2, was 3.0; whereas, the risk ratio with the cut point at 32 kg/m^2 was 1.9.

VII. DISCUSSION.

A. Extrinsic Risk Factors.

1. Surface Type, Weather Condition, and Shoes.

a. Seven out of eight studies on surface type showed that artificial surfaces are associated with higher injury rates, compared with natural grass. Weather condition and surface wetness also seem to influence the association of surface type with lower-extremity injuries. On both natural and artificial surfaces, lower-extremity injuries were less likely when the temperature was cooler or the surface wet; proper wetting of the surface may reduce injury risk.

b. Laboratory tests by Torg et al. suggested that injuries on various surfaces did not result simply from the type of playing surface[206]. Rather, the release coefficient - a measure for a given shoe-surface interface combination - was related to cleat design and condition (wet or dry) of the surface, in addition to the surface type. A study by Torg and Stilwell further revealed that ambient temperature also affected the shoe-surface interface friction[212]. Although these two biomechanical studies were completed in laboratory settings, they offered additional insight into the relationship between injury and surface type.

c. In football, certain types of cleats may be more beneficial than others. However, since only three studies have addressed this issue and two of these studies were conducted in the seventies, an evaluation of the differences among modern shoe designs in reducing injury risk is needed.

2. Helmets.

a. Traditionally, the effectiveness of helmets for the prevention of head injuries has been evaluated in laboratory settings, where leading helmet manufacturers compete for the development of improved designs.

b. For this report, five analytic epidemiology papers were reviewed. Three studies evaluated helmet type on the occurrence of concussions and cervical spine injuries; one focused on the effect of a polyurethane football helmet cover on the reoccurrence of cerebral concussions, and the most recent paper evaluated the effectiveness of helmet use on the prevention of head and neck injuries, mainly concussions. This last study, written by Marshall et al., was a methodologically-sound paper comparing concussion rate differences between two groups[123]. It showed that there were more head injuries during contact sport for players who were not wearing helmets.

c. Since the mandatory use of helmets in 1939 by the NCAA and in 1940 by the NFL, helmet design has tremendously evolved. The overall increase in football injuries led to the development of prospectively collected data; the continued increase in head and spinal cord injuries led to the implementation of stricter rules in the mid seventies—namely, the spearing ban. The National Operating Committee on Standards for Athletic Equipment was founded in 1969 and implemented the first safety standards in 1973. Since then, improved helmet design has been tested to meet stricter requirements, such as a high-posterior cut to avoid potential cervical injuries and inner suspension systems to distribute forces generated by impact uniformly over the head. Standardized laboratory tests have been performed, which undoubtedly contributed to the evolution of football helmets and, ultimately, to the decrease in head injuries. It must be pointed out, however, that in real-life settings, impacts occur at various speeds and angles and under more complex ways than those tested in laboratory settings. Therefore, more advanced analytical and modeling techniques will have to be developed to adequately assess safety in helmet design[112].

3. Knee and Ankle Braces.

a. Laboratory studies suggest that braces should prevent lower-extremity injuries. Baker et al. tested commercially available preventive knee braces and showed that prophylactic braces were able to reduce the abduction angle of the knee that occurs during impact and supported their potential role in the prevention of knee injuries[22].

b. Despite these laboratory studies, compelling epidemiologic evidence is lacking regarding the effectiveness of prophylactic braces to prevent knee injuries. Six of eight studies that evaluated knee braces found either no statistically significant difference or higher knee-injury rates among braced players, compared to non-braced players. One of the two studies that supported knee brace use also showed no difference between these groups when evaluating offensive players.

c. Many of the epidemiologic studies have design limitations and biases that make it difficult to draw conclusions on prophylactic brace use. However, the studies seem to indicate that the effectiveness of prophylactic knee braces is related to the level of play (e.g., high school, college, recreational), the player position, and the type of brace. It is difficult to make firm recommendations on brace use since almost all studies have been completed on college-level athletes, and a number of the studies did not disclose the specific type of brace worn.

d. Further complicating the debate regarding prophylactic brace use is that findings vary regarding their effect on performance. During speed and agility drills, Greene et al. found that performance among college football players varied by type of brace[90]. Among six different knee braces tested, two yielded significantly slower performance during drills, and only one of these braces also showed significantly greater medial-lateral migration, when compared with all other braces. Macpherson et al. showed that semi-rigid and soft-shell prophylactic ankle stabilizers did not affect performance in male high school football players in tests of vertical jump, speed, and agility[119]. Wilkerson, based on biomechanical tests of ankle motions before and after taping, showed that a modified ankle-taping method restricted the ankle more than the standard-taping method[226]. The author stated that the modified method could reduce ankle injuries, outweighing any performance decrement caused by it.

e. The only study on ankle braces found a lower-ankle-injury rate among braced players, compared to non-braced ones and also evaluated low- and high-top shoes, with the former associated with the lowest injury rates. Because of the limited testing of ankle stabilizers, their use cannot be recommended until further controlled or prospective studies and biomechanical testing are completed.

f. Finally, studies evaluating the effectiveness of braces should be randomized and prospective, rather than done in a laboratory setting. Although useful, the laboratory tests are difficult to extrapolate to real settings because they cannot simulate the dynamics of real-life impacts.

4. Training/Conditioning.

a. The two studies identified by this systematic review supported total body pre-season conditioning for football players.

b. Despite the scarcity of studies presented in this section, there seems to be agreement in the literature as to the adequacy of full-year programs directed to strengthening and conditioning of sports participants in general.[132] The lack of these programs may also be viewed as a potential risk factor for football injuries, as is suggested by the higher injury rates observed in spring practices compared to regular practices among college football players[8].

5. Other.

a. Two studies analyzed player position and play type, and one study examined the influence of exposure time on the risk of injuries. In the study by Turbeville employing multivariate analysis, linemen were particularly susceptible to injury. Mueller et al. suggested that offensive and defensive linemen are at greatest risk of injury because they are involved in contact in every play[132]; this player position deserves further attention for injury prevention[219].

b. In Dagiau et al., the study of exposure time showed an interesting relationship between exposure and injury; players participating for shorter periods of time during games (approximately up to 25 plays—predominantly offensive players) were at higher risk of injury compared to players participating for longer periods of game time (50 plays or more). Additionally, injuries during practice were concentrated between 50-100 minutes into practice sessions.

B. Intrinsic Risk Factors.

1. There are few and variable studies that provide some knowledge on personal characteristics, and suggest their association with injury risks. The only study on cervical abnormalities, for example, showed an association with cervical injuries.

2. The four studies on the association between joint flexibility and injury risk are conflicting; only two studies found an association between lower-extremity flexibility and injuries. It is also of particular note the limited number of analytic studies assessing body mass as a potential risk factor for injuries; only the results of one study supported an association between higher BMI with lower-extremity injury rates among linemen.

C. Conclusions and Implications for Prevention.

1. The literature search identified 37 case series/case reports, 51 descriptive epidemiologic studies, 29 laboratory studies, 34 analytic epidemiologic studies, 69 review articles, and 4 intervention trials. The four intervention trials included two studies of knee braces, one study of swivel shoes, and one study of a pre-season conditioning program.

2. Few epidemiologic studies of football injuries are recent; of the 34 analytic epidemiologic studies published since 1970, only three were published since the year 2000. The most recent intervention trial was conducted in 1990.

3. This review found that only a few interventions, such as a rule to ban spearing, have scientifically-demonstrated effectiveness in preventing football-related injuries. However, this review identified many studies that suggested potentially effective prevention strategies. Measures such as holding games and practices on natural grass surfaces rather than artificial grass surfaces (or at least wetting field surfaces regardless of their type), implementing pre-season conditioning, and using knee and ankle braces deserve future consideration and evaluation. Other prevention strategies (e.g., cleat type, knee braces, ankle braces) suffer from too little evidence, discordant study results, and/or inconclusive results due to poor study design. Risk factor studies suggest that player position, duration of time on the field during games, and length of practice sessions may influence injury risk during football. Intrinsic factors such as pre-existing injury, flexibility extremes (loose- or tight-jointedness), and higher body mass index may also increase injury risk.

4. Perhaps the most effective intervention strategy to date, the 1976 spearing ban, focused on the reduction of catastrophic and fatal injuries in football. However, non-fatal injury rates sustained by college and high school players remain consistently high (33/1,000[8] and 8/1,000[161] athlete-exposures, respectively) suggesting that adequate evaluation and implementation of evidence-based interventions focused on the reduction of *non-fatal* injuries is greatly needed.

5. To address these gaps in football-injury-prevention knowledge, a systematic approach is needed. Such an approach would include new studies on the basic descriptive epidemiology of football-related injuries; the severity, types, and causes of injuries incurred in current football play. Analytic epidemiologic (risk factor) studies that measure multiple factors are needed to identify the most important risk factors. Future intervention studies should then focus on methods to reduce the most important injury types or causes.

6. As methodological issues often precluded the usefulness of prior research, future studies should also strive to ensure sound epidemiologic methods. Studies must offer a clear description of the study population (e.g., number of players, ages, positions); a description of exposures in more detail (e.g., length of season, number and duration of practices, number of games in regular and post seasons); inclusion of confounders (e.g., player conditioning, prior injury) in analyses; a clear definition of outcomes (e.g., injury type, data sources for injuries); and presentation of meaningful injury rates, with denominators such as athlete-exposures, or rates per specified number of players per week, month, or season.

7. In summary, effective interventions to control football-related injuries exist and should be implemented, particularly during contact football (e.g., helmets, spearing ban). Other injury prevention strategies (e.g., pre-season conditioning) have less evidence of effectiveness, but deserve consideration and evaluation. Certain interventions (e.g., knee and ankle braces, modern cleat designs) require further study. Identification and testing of additional strategies to prevent non-fatal injuries is needed.

VIII. POINT OF CONTACT. Refer questions regarding this report to Dr. Michelle Canham Chervak at (410) 436-1377/3534 or by e-mail, Michelle.Chervak@us.army.mil.

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APPENDIX A

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APPENDIX B

SUMMARY TABLES

Appendix B consists of tables containing detailed information on published risk factor and intervention studies dealing with football-related injuries. All studies summarized in these tables are also discussed in the text.

Table B-1. Published Studies on Football-Related Injury by Type of Study and Year of Publication

Year Of Publication	Case Series/ Reports	Descriptive Epidemiologic Studies	Laboratory Studies	Analytic Epidemiologic Studies	Intervention Studies	Reviews	Total
1970-1979	6	8	8	12	2	7	43
1980-1989	12	10	5	10	1	21	59
1990-1999	10	20	6	9	1	25	71
2000-2004	9	13	10	3	0	16	51
Total	37	51	29	34	4	69	224
Reference numbers (see reference list)	14,19,25,26,29,48,54,63, 72,75,76,103,115-117,120,126,141,155,163, 177,180,181,183-185,189,191,201,207,208, 210,211,214,218,221,224	3,5,9,15,18,20,21,23,24,30, 32,33,45,50-53,66,68,69,73,74,81,83, 91,92,97,101,102,106,108, 109,124,135,138-140,148,152,158,159,161, 162,171,188,203,205,216, 217,227,230	22,28,43,55,59,65,77,85,88, 90,99,113,114,119,128,131 142-144,153,154,165, 166,182,206,212,220,226,229	11,13,16,17,31,34,36,40,41, 58,64,71,87,96,98,100,105, 123,137,145,146,150,157, 160,170,173,174,192,202, 204,213,215,219,228	42,44,89,186	1,2,4,10,12,27,35,37-39,46,47,49,56,57,60-62,67,70,78-80,82,84,86,93-95,104,110,111,118,121,122, 125,127,129,130,133,134, 136,147,149,151,156,164, 167-169,172,175,176, 178,179,187,190,193-200,209,222,223,225	

Table B-2. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Surface Type and Weather Condition

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Bramwell et al., 1972[34]	Prospective study; 1 year; Greater Seattle area	228 games played by 26 varsity high school teams	Surface type	Natural grass (n=148) Dry field (n=88) Wet field (n=60) Artificial surface (n=80) Dry field (n=41) Wet field (n=39)	Injuries per game: 0.52 (overall) 0.50 (wet) 0.53 (dry) 0.76 (overall) 0.61 (wet) 0.93 (dry)	1.0 1.0 1.0 1.49 1.23 1.74	 1.21-1.83 0.86-1.77 1.35-2.22	 <0.01 0.26 <0.001
Bowers, 1973[31]	Retrospective cohort study with historical control; 6 years; West Virginia	52 games, West Virginia University football players	Surface type	Natural grass period (1967-68, spring and fall seasons)[†] Artificial surface period (1970-71, spring and fall seasons)[†]	Number of injuries: Knee nonsurgical: 13 surgical: 5 Ankle: 34 Knee nonsurgical: 19 surgical: 4 Ankle: 35	NP	NP	NP

[†] Exact number of players, practices, or games were not provided.
NP: not presented in article
CI: confidence interval

Table B-2. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Surface Type and Weather Condition (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Adkison et al., 1974[11]	Prospective, study; 2 years; Seattle and Spokane, Washington, & Portland, Oregon	660 high school varsity tackle football games	Surface type and field condition (wet or dry)		Injuries per game:			
				Natural grass (n=424)	0.51 (overall) 0.46 (wet) 0.57 (dry)	1.0 1.0 1.0		
				Artificial surface: Astroturf (n=183)	0.63 (overall) 0.55 (wet) 0.91 (dry)	1.23 1.18 1.63	1.06-1.43 0.95-1.46 1.31-2.03	<0.01 0.02 <0.001
				Tartanturf (n=53)	0.28 (overall) 0.42 (wet) 0.17 (dry)	0.55 0.90 0.31	0.38-0.80 0.56-1.45 0.17-0.59	<0.01 0.66 <0.001

CI: confidence interval

Table B-2. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Surface Type and Weather Condition (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Alles et al., 1979[17]	Retrospective cohort study; 3 years; NAIRSd	NAIRS college athletes	Surface type		Meniscus/ knee sprains and ankle sprains per 1,000 athlete-exposures:			
				Natural grass (n=674,000 exp.)	Knee sprain rate higher on artificial surface than grass	NP	NP	p<0.05
				Artificial surface (Astroturf and Tartanturf) ‡ (n=450,000 exp.)	Ankle sprain rate higher on artificial surface than grass	NP	NP	p<0.01
Powell, 1987[157]	Retrospective cohort study; 6 years; NFL	NFL clubs; 3,296 team-games	Surface type		Knee and ankle/foot injuries per team-game:			
				Natural grass (n=1,520 team-games)	0.40 (knee) 0.28 (ankle/foot)	1.00 1.00		
				Astroturf (n=1,450 team-games)	0.47 (knee) 0.39 (ankle/foot)	1.18 (knee) 1.39 (ankle/foot)	1.08-1.28 1.26-1.54	<0.001 <0.001

‡ Injuries were not provided for artificial surfaces.
NAIRS: National Athletic Injury/Illness Reporting System; NFL: National Football League
NP: not presented in article; CI: confidence interval

Table B-2. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Surface Type and Weather Condition (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Nicholas et al., 1988[145]	Retrospective cohort study with historical control; 26 years; New York	Professional football franchise (New York Jets); 373 games	Surface type‡‡		"Significant" injuries (player missed ≥ 2 consecutive games) and "major" injuries (player missed ≥ 8 consecutive games) per game:	Mean differences:		
						Significant injuries/game 0.11±0.49	--	NS
						Major injuries/game 0.13±0.38	--	NS
				Artificial surface (n=84 games)	Significant 0.70±038 Major 0.36±0.29			
				Natural grass (n=177 games)	Significant 0.59±0.26 Major 0.23±0.16			
Powell and Schootman, 1992[160]	Retrospective cohort study; 10 years; NFL	NFL clubs	Surface type		Knee sprains (ACL and MCL) per team-game:			
				Natural grass (n=2,572 team-games)	0.20	1.00		
				AstroTurf (n=2,604 team-games)	0.22	1.13	1.0-1.27	0.04

‡‡ Authors did not explain on which surface type the other 112 games were played.
NFL: National Football League; CI: confidence interval; NS: non-significant (as reported by authors)

Table B-2. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Surface Type and Weather Condition (continued)

Authors	Study Design, Duration And Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. Of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Orchard and Powell, 2003[150]	Retrospective cohort study; 10 years; NFL teams	5910 NFL teams	Weather condition	Natural grass=2910 team games Artificial surface – open turf (n=1624 team games) Artificial surface – dome (n=1376 team games)	Significant knee sprains per team-season (=per 20 team-game): grass=3.4 cold&wet=2.4 hot&dry=3.6 open turf=4.1 cold&dry=3.1 hot&dry=5.4 dome=4.4 Significant ankle sprains per team-season: grass=2.3 cold&wet=2.0 hot&dry=2.3 open turf=2.7 cold&dry=2.2 hot&dry=3.2 dome=3.3	Significant knee sprains: grass:dome =0.77 grass:open turf=0.83 Significant ankle sprains: grass:dome =0.71 grass:open turf=0.73	0.66-0.91 0.71-0.97 0.58-0.87 0.60-0.89	$p \leq 0.05$ $p \leq 0.05$

NFL: National Football League
CI: confidence interval

Table B-3. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Helmets

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Robey, 1972[170]	Retrospective cohort study; 3 years; North Carolina	7,800 high school players[†]	Helmet type, fit and condition	Type: (1) suspension (2) combined padded-susp. (3) padded	Concussion rates per player: (1) Good condition: fit too large: 0.01 fit good: 0.02 fit too small: 0.02 (2) Good condition: fit too large: 0.03 fit good: 0.06 fit too small: 0.07 (3) Good condition: fit too large: 0.04 fit good: 0.08 fit too small: 0.13	NP	NP	$p<0.05$

[†] Sample size categories were not provided.
CI: confidence interval
NP: not presented in article

Table B-3. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Helmets (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Mueller and Blyth, 1974[137]	Prospective study; 4 years; North Carolina	8776 students from 43 high schools	Helmet use	13 different helmet brands	- Concussion rates per player:	NP	NP	
					All helmet brands combined=0.03			
					Rawlings JRC=0.01	1.00		
					Southern Athletic=0.05	2.95	1.26-6.88	p<0.05
			Contact program	Regular contact program (n=3633) Limited contact program (n=569)	- Overall injuries per player:			
					Regular contact program=0.48	1.00		
					Limited contact program=0.42	0.87	0.79-0.96	p<0.01
			Prior injury	Prior injury No (n=5621) Yes (n=2200)	- Overall injuries per player:			
					Prior injury (no) = 0.44	1.00		
					Prior injury (yes) = 0.62	1.43	1.36-1.50	p<0.001

CI: confidence interval
NP: not presented in article

Table B-3. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Helmets (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. Of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Clarke and Powell, 1979[58]	Cross-sectional study; 3 years; NAIRS	5,361 high school and college football players	Helmet type and brand	Helmet type (13 different helmet types) Helmet brand (7 different helmet brands)	Concussions per 1,000 athlete-exposures: 4.7 (overall) rates varied from 2.1 to 6.8 Major cervical spine fractures per 100,000 athlete-exposures: 0.5 (overall) rates varied from 0 to 4	NP NP	NP NP	NS NS
Torg et al., 1999[202]	Survey; 3 years; national level	119 football players	Concussions while wearing a polyurethane football helmet cover	Number of prior concussions per player: 1 – 2 – 3 – 4+ (n=41 – 41 – 19 – 18)	Concussion reoccurrence rate (%): 2.4 – 4.9 – 15.8 – 27.8 (1/41–2/41–3/19–5/18)	NP	NP	NP

NAIRS: National Athletic Injury/Illness Reporting System
CI: confidence interval; NP: not presented in article; NS: non-significant (as reported by authors)

Table B-3. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Helmets (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Marshall et al., 2002[123]	Ecologic study; 2 years; (NCAA) Injury Surveillance system (U.S.) and Rugby Injury and Performance Project (New Zealand)	9,120 U.S. Collegiate football players and New Zealand club Rugby Union players	Protective equipment regulations		Injuries per 1,000 player-games:			
				Rugby Union	114.07 (overall) 21.21 (head) 5.16 (conc.)	1.00 1.00 1.00		
				North American Football	39.89 (overall) 2.44 (head) 2.11 (conc.)	0.35 (overall) 0.11 (head) 0.41 (conc.)	0.31-0.40 0.08-0.16 0.22-0.75	p<0.05 p<0.05 p<0.05

CI: confidence interval

Table B-4. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Knee and Ankle Braces

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Hewson et al., 1986[96]	Retrospective cohort study with historical control; 8 years; Arizona	450 University of Arizona football players	Knee brace		Knee injuries per 100 players-season:			
				Nonbrace period (n=29,293 exp.)	1977-1981: 23.89	1.00		
				Brace period (n=28,191 exp.)	1981-1985: 21.43	0.92	0.63-1.36	0.69
Rovere et al., 1987[174]	Retrospective cohort study with historical control; 4 years; Wake Forest University	742 college football players	Knee brace		Knee injuries per 100 players:			
				Nonbrace period (n=368)	1981-82: 6.1 (overall) 4.0 (MCL)	1.00 1.00		
				Brace period (n=374)	1983-85: 7.5 (overall) 4.8 (MCL)	1.23 (overall) 1.20 (MCL)	0.88-1.69 0.80-1.81	0.24 0.38

CI: confidence interval; MCL: medial collateral ligament injury

Table B-4. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Knee and Ankle Braces (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Teitz et al., 1987[192]	Retrospective cohort study; 2 years; NCAA	11,752 players NCAA Division I	Knee brace		Knee injuries per player:			
				Non brace	6.0 % (1984) 6.4 % (1985)	1.00 1.00		
				Brace	11.0% (1984) 9.4 % (1985)	1.71 (1984) 1.48 (1985)	1.45-2.01 1.23-1.78	p<0.001 p<0.001
Brodersen and Symanowski, 1993[36]	Retrospective cohort study; 1979-1987; Iowa State University	776 Division I-A collegiate football players	Prophylactic double upright knee orthosis	Brace=503 Non brace=273	- Overall knee injury: nonbraced: 44% braced: 26%	 1.00 0.59	 0.48-0.72	 <0.001
					- Knee injury severity (time-loss): Type I (1-14 days) nonbraced: 25% braced: 23%	 1.00 0.92	 0.70-1.18	 0.49
					Type II (15-28 days) nonbraced: 15% braced: 3%;	 1.00 0.20	 0.12-0.33	 <0.001
					Type III (29 days-1 year) nonbraced: 4% braced: 0.2%	 1.00 0.05	 0.01-0.21	 <0.001

NCAA: National Collegiate Athletic Association; CI: confidence interval

Table B-4. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Knee and Ankle Braces (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Deppen and Landfried, 1994[71]	Prospective cohort study; 4 years	524 high school football players	Knee brace	 Nonbrace Brace	Knee injuries per player-game: 26/ 19,484 23/ 21,640	 1.00 0.80	 0.46-1.39	 0.43
Albright et al., 1994[16]	Prospective cohort study; 3 years; NCAA	987 NCAA Division I college football players	Knee brace	 Nonbrace (n=76,811 knee-exposures) Brace (n=78,911 knee-exposures)	MCL sprain per 100 knee-exposures: 0.060 (overall) 0.103 (line) 0.069 (linebacker/tight end) 0.049 (skilled) 0.068 (overall) 0.098 (line) 0.053 (linebacker/tight end) 0.036 (skilled)	 1.00 1.00 1.00 1.00 1.14 (overall) 0.95 (line) 0.76 (linebacker) 0.74 (skilled)	 0.77-1.70 0.48-1.87 0.32-1.84 0.32-1.71	 NS NS NS NS

NCAA: National Collegiate Athletic Association; MCL: medial collateral ligament injury
CI: confidence interval
NS: non-significant (reported by authors)

Table B-4. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Knee and Ankle Braces (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Rovere et al., 1988[173]	Retrospective cohort study; 6 years; North Carolina	297 Wake Forest University football players	Ankle stabilizers and shoe type		Ankle injuries per 1,000 player-games:			
				Ankle stabilizer	2.90			
				Ankle taping	4.62	0.62	0.42-0.80	p=0.003
				Low-top shoe	3.73			
				High-top shoe	5.78	0.65	0.52-0.84	p=0.004

CI: confidence interval

Table B-5. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Cleat/Shoes

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Torg and Quedenfeld, 1971[204]	Prospective cohort study with historical control; 3 years; Philadelphia	Philadelphia Public High School Football League (18 teams, 594 players/season) and Philadelphia Catholic League (16 teams, 704 players/season)	Shoe cleat design	Conventional shoe period (3/4" cleats) Molded sole shoe period (3/8" cleats)	Knee injuries per team-game: Public school 1968: 0.33 (conv.) 1969: 0.14 (mold.) 1970: 0.17 (mold.) Catholic school 1969: 0.58 (conv.) 1970: 0.24 (mol)	1.00 0.47 0.55 1.00 0.41	0.31-0.71 0.37-0.81 0.31-0.54	<0.001 <0.001 <0.001
Lambson et al., 1996[105]	Prospective cohort study; 3 years (1989-1991); Texas	3,119 high school football players	Shoe cleat design	Edge (n=2,231) Non-edge (n=888) Flat (n=832) Screw-in (n=46) Pivot disk (n=10)	ACL injuries per player: 0.017 0.005 0.004 0.015 0.000	3.8 (edge/non-edge)	1.46-9.79	p<0.01

CI: confidence interval; ACL: anterior cruciate ligament injury

Table B-6. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Spearing Rule Change and Training/Conditioning

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Torg et al., 1979[213]	Retrospective cohort study with historical control; 7 years; National Football Head and Neck Injury Registry	High school and college football players	Rule change - periods (spearing ban)	Spearing period (1975) Non spearing period (1977)	Rates per 100,000 players per season: Cervical spine fractures and dislocations: High school:			
					5.70 (1975)	1.00		
					5.50 (1977)	0.96	0.67-1.40	0.85
					College:			
					30.10 (1975)	1.00		
					20.30 (1977)	0.66	0.57-0.81	p<0.001
					Permanent quadriplegia: High school:			
					1.90 (1975)	1.00		
					1.20 (1977)	0.63	0.31-1.29	0.21
					College:			
					5.30 (1975)	1.00		
					4.00 (1977)	0.75	0.50-1.14	0.18

CI: confidence interval

Table B-6. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Spearing Rule Change and Training/Conditioning (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Torg et al., 1990[215]	Retrospective cohort study with historical control; 12 years; National Football Head and Neck Injury Registry	266,665 high school and college football players	Rule change - periods (spearing ban)		Rates per 100,000 players per season:			
					Cervical spine fractures and dislocations:			
				Spearing period (1976)	High school:			
					7.70 (1976)	1.00		
					2.30 (1987)	0.30	0.19-0.46	p<0.001
				Non spearing period (1987)	College:			
					30.66 (1976)	1.00		
					10.66 (1987)	0.36	0.18-0.69	p<0.01
					Permanent quadriplegia:			
					High school:			
					2.24 (1976)	1.00		
					0.73 (1987)	0.32	0.14-0.71	p<0.01
					College:			
					10.66 (1976)	1.00	--	
					0 (1987)	0		

CI: confidence interval

Table B-6. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Spearing Rule Change and Training/Conditioning (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Cahill et al., 1984[41]	Retrospective cohort study with historical control; 12 years; Peoria, Illinois	8 varsity high school teams	Preseason conditioning program (PSC)	NC: No PSC group (1969-1972) C1: Closely supervised PSC group (1973-1976) C2: Less supervised PSC group (1977-1980)	Operations per 1,000 athletes: NC=15 C1=5 C2=2 Knee injuries per 1,000 athletes: NC=68 C1=41 C2=39	NC 1.00 C1 0.33 C2 0.13 NC 1.00 C1 0.60 C2 0.57	 0.13-0.87 0.04-0.46 0.42-0.88 0.39-0.84	 0.02 <0.01 <0.01 <0.01

CI: confidence interval
NC: no conditioning; C1: conditioning group one; C2: conditioning group two

Table B-7. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Other Extrinsic Risk Factors

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Buckley, 1988[40]	Cross-sectional study; 8 years; (NAIRS)	49 college teams; 395 team-seasons (35,879 athlete-seasons)	Team, situation, activity	Offense/ defense Rushing/ passing Tackle/ block	Number of concussions by team, situation, and activity: offense, rushing play, block: 274 defense, passing play, tackle: 18	NP	NP	p<0.05
Turbeville et al., 2003[219]	Prospective study; 2 years; Oklahoma city, Oklahoma	717 high school football players	Experience and player position	Experience (median, years) Linemen versus other positions	Knee ligament injuries: NP	OR 1.48 OR 3.26	1.07-2.06 1.15-9.26	p≤0.05 p≤0.05
Dagiau et al., 1980[64]	Prospective cohort study; 2 years (1976-1977); Illinois	University of Illinois: Practice data: entire varsity football team Game data: 54 members of the traveling squad	Exposure time	Time in seconds or minutes	Practice: curvilinear relationship skewed to the right between exposure time and injuries Games: inverse relationship between exposure time and injuries	NP	NP	NP p≤0.05

NAIRS: National Athletic Injury/Illness Reporting System
CI: confidence interval; NP: not presented in article; OR: odds ratio

Table B-8. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Intrinsic Risk Factors

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Albright et al., 1985[13]	Prospective cohort; 8 years; University of Iowa	342 college freshman football players [†]	Past history of head or neck injuries + abnormalities of the cervical spine on physical or x-ray examination	Abnormality degree: 1. Normal (no abnormalities) 2. Abnormal: Ranged from 1 (any examination finding) to 4 (positive history + positive examination + positive x-ray film)	Head or neck injuries: Normal players=23% Abnormal players=43%	 1.00 1.90	 1.24-2.81	 p<0.01
Nicholas, 1970[146]	Prospective cohort; 6 years; New York	139 professional football players	Knee stability	Looseness 0 trait=50 1-2 traits=50 ≥3 traits=39	Surgical knee ligament ruptures: 0 trait: 2/50 2 traits: 7/50 ≥3 traits: 28/39	 1.00 3.50 17.95	 0.85-14.37 7.69-41.90	 0.08 <0.001

CI: confidence interval
[†] Sample size categories were not provided.

Table B-8. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Intrinsic Risk Factors (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Kalenak and Morehouse, 1975[100 †]	Prospective cohort study; 3 years; Pennsylvania	410 college football players	Knee stability		No. of knee injuries:			
				Loose-jointed	19			
				Tight-jointed	24	NP	NP	NS
Jackson et al., 1978[98]	Cross-sectional study; 2 years; West Point and southern California	2300 West Point cadets; 110 players from 6 southern California high schools	Joint flexibility and laxity (goniometric measures)	5 indices of joint flexibility:	Ankle and knee injuries: no significant association with joint flexibility among the cadets (data NP)	NP	NP	NS
			Personality (Cattell's 16 PF – Personality Factor)	16 PF	Injury (in general) frequency significantly higher in tender-minded, compared to tough-minded high school participants (data NP)			$p<0.05$
					Injury (in general) severity significantly higher in reserved, compared to outgoing high school participants (data NP)			$p<0.05$

CI: confidence interval; NP: not presented in article; NS: non-significant (reported by authors)
† Sample size categories were not provided.

Table B-8. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Intrinsic Risk Factors (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Woodford-Rogers et al., 1994[228]	Cross-sectional study; 2 years; location-NP	14 ACL- injured male high school and college football players and 8 female high school and college gymnasts and basketball players; 22 ACL-non-injured controls matched by sex, sport, position, skill level	Knee and ankle characteristics	- Males: Anterior displacement of tibia on femur (millimeter (mm)) Navicular drop (mm) Calcaneal eversion in stance (degrees) - Females: Anterior displacement of tibia on femur (mm) Navicular drop (mm) Calcaneal eversion in stance (degrees)	5.0±2.6 (injured) 4.4±2.1 (non-injured) 8.4±4.2 (injured) 5.9±2.4 (non-injured) 3.9±2.8 (injured) 4.5±2.4 (non-injured) 5.3±2.6 (injured) 3.8±2.2 (non-injured) 5.0±2.5 (injured) 3.0±1.1 (non-injured) 3.9±1.3 (injured) 5.9±1.6 (non-injured)	--	--	--

CI: confidence interval; ACL: anterior cruciate ligament injury

Table B-8. Results of Analytic Epidemiologic (Risk Factor) Studies on Football-Related Injury: Intrinsic Risk Factors (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value
Gómez et al., 1998[87]	Prospective cohort study; 12 weeks; San Antonio, Texas	215 high school football linemen from 10 public high schools	Body mass index	Different categories, from 20 to 42 kilograms per square meter (kg/m^2)	Overall injuries per 1000 hours of playing time per category: NP Lower-extremity injuries per 1000 hours of playing time:	NP	NP	$p<0.05$
					BMI>28: 4.5 BMI≤28:1.5	BMI>28/ BMI≤28 = 3.0	NP	$p\leq0.05$
					BMI>32: 5.0 BMI≤32:2.8	BMI>32/ BMI≤32 = 1.9	NP	$p\leq0.05$

CI: confidence interval
NP: not presented in article

Table B-9. Results of Intervention Studies on Football Injury Prevention Strategies

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value	Quality Score (100 Points Maximum)
Grace et al, 1988[89]	Prospective cohort; 13 weeks; Albuquerque and Santa Fe, New Mexico	580 high school varsity and junior varsity football players	Knee brace		Knee injuries:				Median=46 Range=41-49
				B0 (nonbraced)=250	B0=10/250 (4%)	1.00			
				B1 (braced, single-upright, single-hinged)=247	B1=35/247 (14%)	B1/B0=3.5	1.89-6.64	<0.001	
				B2 (braced, single-upright, double-hinged)=83	B2=5/83 (6%)	B2/B0=1.5	0.53-4.28	0.44	
Sitler et al., 1990[186]	Randomized controlled trial; 2 years; West Point, New York	1,396 US Military Academy cadets	Knee brace		Knee injuries per 1,000 athlete-exposures:				Median=38 Range=37-39
				Nonbrace (n=10860 athlete-exposures)	3.40 (overall) 2.30 (MCL)	1.00 1.00			
				Brace (n=10710 athlete-exposures)	1.50 (overall) 1.12 (MCL)	0.44 (overall) 0.49 (MCL)	0.25-0.77 0.25-0.95	p<0.05 0.04	

CI: confidence interval; MCL: medial collateral ligament injury

Table B-9. Results of Intervention Studies on Football Injury Prevention Strategies (continued)

Authors	Study Design, Duration and Location	Population and Sample Size	Risk Factor Studied	Risk Factor Level or Category (No. of Subjects)	Injury Rate or Outcome	Injury Risk Ratio	95% CI	p-value	Quality Score (100 Points Maximum)
Cameron and Davis, 1973[44]	Non-randomized controlled trial; 1969 season; Duke-Durham area	2839 high school football players	Swivel shoes	- Swivel shoe (n=466) - Conventional shoe (n=2373) Cleated shoe (n=2055) Heel plate (n=52) Soccer shoe (n=266)	Knee/ ankle injury (%) swivel: 2.14/ 3.00 cleated: 7.88/ 8.46 heel plate: 5.77/ 7.69 soccer: 5.27/ 5.64	Knee 1.00 (swivel) 3.52 (others) Ankle 1.00 (swivel) 2.71 (others)	1.97-6.26 1.64-4.47	<0.001 <0.001	Median=15 Range=11-18
Cahill and Griffith, 1978[42]	Intervention trial with historical control; 8 years; Peoria, Illinois	8 teams of high school football players	Pre-season conditioning	Non conditioning period (1969-1972) Preseason conditioning period (1973-1976)	Knee injuries (%): 6.8 (overall) 1.5 (surgical injuries) 4.1 (overall) 0.6 (surgical injuries)	1.00 1.00 0.60 0.38	 0.43-0.84 0.16-0.86	 <0.05 0.02	Median=16 Range=15-17

CI: confidence interval