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INJURY IN YOUTH FOOTBALL: PREVALENCE, INCIDENCE, AND BIOLOGICAL RISK FACTORS

presented by

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has been accepted towards fulfillment of the requirements for

Ph.D. degree in Kinesiology

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INJURY IN YOUTH FOOTBALL: PREVALENCE, INCIDENCE, AND BIOLOGICAL RISK FACTORS

By

Peter J. Morano

A DISSERTATION

Submitted to
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ABSTRACT

INJURY IN YOUTH FOOTBALL: PREVALENCE, INCIDENCE, AND BIOLOGICAL RISK FACTORS

By

Peter J. Morano

PURPOSE: To estimate injury rates and examine biological risk factors (height, weight, body mass index, and maturity status) as predictors of injury in a youth football population. Surveys of youth participants generally lack suitable exposure data for practices and competitions to permit estimates of injury rates. **METHODS**: Participants (n=354, 9-14 years) in two community youth football leagues in mid-Michigan were followed throughout a single season, mid-August through October. Grade in school was the unit of competition. A certified athletic trainer was on sight for practices and home games to record exposure statistics and injuries as they occurred; injuries occurring in road games were reported by coaches and verified the next day by the trainers. Height and weight were recorded at the beginning of the season with which body mass index was calculated. Informed consent from both parents and child were obtained from 296 participants. The informed consent allowed use of the biological parents' heights in order to predict the adult height of the athlete to estimate maturity status. A Risk of Injury in Sport Scale (RISSc) questionnaire was issued to and completed by the participants in order to examine psychological variables and the likelihood of injury. The

RISSc questionnaire was composed of 24 questions subdivided into 6 factors (uncontrollable, controllable, upper extremity, surface related, overuse, and reinjury). Also examine was a correlation analysis between the RISSc results and the biological variables. **RESULTS**: Estimated injury rates were significantly higher in 7-8th (1602/1000 athlete exposures) compared to 4-6th (7.5/1000 athlete exposures) grades (p<0.001). Injury rates per 1000 athlete exposure (AE) were higher among the 7th (18.2/1000AE) and 8th (17.6/1000AE) grade teams than the 4/5th (8.2/1000AE) and 6th (9.6/1000AE) grade teams. Late maturing individuals in the younger (4th-6th grade) population showed an increased likelihood of injury compared to on-time and late maturing players (p <.05). Having a high body mass index (BMI) was shown to be a predictor of injury in the younger group while the uncontrollable and reinjury RISSc factors were shown to be predictors of injury in the older group. **CONCLUSION**: Estimated injury rates increase with grade and probably age. Biological variables and a player's perception of risk of injury seem to partially influence the likelihood of being injured. There was no evidence of interactions of internal variables with the likelihood of injury in youth football.

To my parents and daughter:

Pete Sr., Barbara, and Sophia

“If you don't know your family's history, then you don't know anything”.

--Michael Chrichton

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CHAPTER 1

INTRODUCTION

Organized youth sports programs annually enroll approximately 25 million participants (Carnegie Corporation of New York, 1996). Participation has the shape of a pyramid with youth at the broad base and the elite at the top; high school and college athletes comprise the intermediate levels.

Risk of injury is inherent in sport and other activities of childhood and adolescence, but systematic study of the incidence of injuries in organized youth sports is still relatively limited. Even with the large numbers of youth involved in organized sports, most of the past and current research on athletic injuries has focused on the high school, collegiate, and elite levels of competition. Several reasons for this focus on higher levels of competition could be that researchers have easier access to the athletes, and/or that increased fan and financial interests which make research with these populations more appealing and fundable. It is also possible that injuries occur more frequently at more elite levels of competition. Organizations which manage higher levels of competition also have the financial resources to monitor injuries and perhaps fund research.

In addition to limited population-based research on youth sports, there is a lack of information regarding body size, biological maturity status and behavioral characteristics, alone or in combination, as potential risk factors for injury in sports. Many studies of injury in sport concentrate on environmental variables or external risk factors, such as field surface/conditions and equipment. This is somewhat surprising since growth and maturity characteristics are often indicated among player-related (internal) risk factors for injury in sports (Caine and Lindner, 1990). External variables are easier to observe, control and/or change if they are found to be unsafe.

The Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS) regularly maintain sport-related injuries, but data are limited to those who present to hospital emergency rooms for treatment (NEISS, 1981). NEISS published data on product related (external variables such as equipment) injuries for the 12-month period ending December 1981 and indicated that for every 100,000 participants 5-14 years of age, there were 359 injuries in baseball, 280 in basketball, 454 in football, 101 in gymnastics, 108.1 in soccer, 102.3 in wrestling, and 906.7 in bicycling. Player related variables such as body size and composition, biological maturity status, physique, and so on were not reported. Moreover, these player characteristics cannot be altered.

Athletes are sometimes grouped by internal or player-related variables, but this depends on league rules. There has long been an assumption in the medical community that grouping young athletes by size or maturity status may help to reduce the number of injuries (Roser and Clawson, 1970; Kreipe and Gewanter, 1985; Backous et al.; 1990, Malina and Beunen, 1996). Yet, these issues have not received systematic study. Some authors even suggest that contact sports for the physically immature are inherently unsafe, and do not recommend participation for children (Godshall, 1975; Roser and Clawson, 1970).

Nevertheless, all indications show an increase in sports participation at every age level. Since injuries occur in sports, the possibility of permanent damage as a result of athletic injury is a legitimate concern. Previous epidemiologic research has shown that good injury data can identify problem areas in which preventive measures can be implemented to reduce the incidence of injuries (Mueller and Blyth, 1982).

With regard to available studies of injury in sport, methodological concerns about data collection and athlete exposure are of critical importance (Backx et al., 1989; Watkins, 1996; Thompson et al., 1987). Some studies use retrospective accounts of injury. Athletes and/or parents and sometimes coaches are asked to recall an injury episode that occurred a day or sometimes months previously. With time, the recall of events may not be accurate so that details about severity, time loss, type of injury, and other factors (e.g., context) may be compromised. Other retrospective studies use hospital or insurance records, which may allow a detailed description of an injury, but such records include only injuries that were severe enough to be seen by a physician or reported to an insurance company. Injuries that are not seen by a physician, or that are seen by a family physician, may be missed or not reported in this type of data collection process. Moreover, personal experience indicates that many injuries require a participant to lose playing time, but are not deemed serious enough to report to a physician or hospital. Further, injuries associated with sports equipment, but not in the context of a sport event or practice, are often labeled as sport-related injuries in hospital and insurance records.

Studies that ask for weekly, monthly, or season ending reports from coaches have potential problems with accuracy and reliability. Coaches differ in detail of injury recording and may omit some injuries because of fear that their team will be viewed as unsafe. Coach accounts of an injury episode may also differ from what an athlete recalls. Given time constraints on coaches, many simply do not complete or superficially complete such forms.

Lacking in each of these situations is a health care professional to record injury data on-site on a day-to-day basis. Having a sports medicine professional on-site provides more opportunity for more accurate and detailed injury information.

Studies of injuries in a given sport vary with length of season and amount of athlete exposure. An exposure is an opportunity for an athlete to sustain an injury. Some studies define exposure by minutes, hours or sessions. The best way to capture the true risk of injury in any sport is to accurately cover the sport for at least an entire season, from preseason conditioning to competition. This includes all practice and game sessions. Some studies of youth sports only cover exposures, or opportunities for injury, during a tournament, especially youth soccer. Tournament settings are atypical of the regular season. Comparisons of injury data from a tournament with corresponding injury data throughout an entire season have limitations, but allow access to a large group of athletes in a very short period of time. Teams often play daily and sometimes more than once a day for several days or an entire week. And, within tournament settings, health care providers (commonly first aid technicians) are usually available to the athletes in case of injury. A problem with this type of service is quality control, internal consistency among health care staff, which may influence the accuracy of the data.

A major methodological concern in sports injury surveillance (injury reporting) is the definition of a reportable injury. There is no universally accepted definition of an athletic injury (Thompson et al., 1987). Without consistency in defining a reportable injury, comparisons of studies are difficult. The type of study may determine the definition of a reportable injury. At other times, researchers create their own definition to accommodate local needs. It is likely that one definition of a reportable injury is not appropriate for all types of sports injury studies mainly due to staff differences.

There are many potential risk factors for injury, whether or not a child or adolescent actually sustains an injury. Risk factors are generally categorized as: player/athlete-related and sport/environment-related risk factors. Player-related risk factors include physique, structural alignment, flexibility, strength, motor skill, proprioceptive / kinesthetic awareness, behavior, history of injury, the adolescent growth spurt, maturity status and perhaps others with few exceptions. Player-related risk factors are difficult to alter. However, athletes can be grouped with other athletes with similar characteristics. The specific role of individual player-related risk factors in injuries in youth sports is not well known (Malina, 2001).

Sport-related risk factors include training programs, playing conditions, equipment, age groups (size, maturity, and experience mismatches in broad age groups), coaching, parent behaviors, sport organizations, sport/league rules and inadequate rehabilitation from a previous injury. Sport or environment-related risk factors can be generally controlled. Even if an ideal sport environment were created, would injuries be eliminated? Smith et al. (1993) suggest that one-half of all injuries sustained in youth sports can be prevented. Unfortunately, systemic evidence to document this suggestion is not provided by the authors.

An athlete's perception of risk of the injury may also have an influence on the likelihood of injury in sport. Perception of risk may be related to or influenced by biological factors such as body size and skill level. Players who are larger may feel less likely to become injured, especially in collision sports, where size is usually considered an advantage. Therefore, this child may partake in behaviors involving more risk on the field. Also, an athlete who possesses high efficacy about his skill level may also take more risks during practices or games. Athletes with high self-efficacy may view injury as a negative episode and think that the chances of injury are unlikely (Kontos, 2000).

Research Questions

The present study concerned injury in a sample of sports participants 9-14 years of age in a single sport – American youth football – over the course of a single season. Several specific questions were the focus of the study:

1. What are the prevalence and incidence of injury in youth football?

2. Do injury rates differ by grade?

3. Are there biological variables (weight, height, biological maturity) that are associated with the risk of being injured, and are there interactions among these variables?

4. Is the perception of risk of injury in youth football related to the likelihood or frequency of injury?

The following hypotheses were tested:

1. Injury rates increase with grade.
2. Weight, height, the body mass index, and biological maturity by themselves do not increase the likelihood of injury in youth football.
3. Player's perception of risk influences the likelihood of injury.
4. Internal variables (player-related factors) interact with each other to influence the risk of injury in youth football.

Questions can be raised and variables can be examined in a child and adolescent population that cannot be considered with older subjects. Athletes 9-14 years of age show considerable variation in size and maturity status more so than during childhood and later adolescence. It is within this age range that boys enter adolescence, with associated changes in size, physique, body composition, performance, and behavior. Many boys will experience their maximum rate of growth, reaching peak height velocity (PHV), during this interval (Malina and Bouchard, 1991). Changes in size and physique, and individual differences in maturational timing are potential risk factors that are impossible to assess in older adolescent populations because most of the subjects will have already passed through the spurt and are close to physical maturity.

A unique feature of the present study is that it examines the risk of injury in youth football at the community level, a level that is not commonly considered in sport injury research. In addition to exposure data for practices and games for participants in two communities throughout a season, age, height, weight, the body mass index (BMI), estimated biological maturity status, and perceived likelihood of becoming injured in youth football are considered.

Limitations

A prospective, day-to-day analysis of athletic injuries in a youth football population is a new experience for athletes and coaches, as well as for certified athletic trainers (ATC), the primary data collectors. Certified athletic trainers are allied health professionals whose main job is to prevent, evaluate, treat, and rehabilitate athletic injuries. Most coaches and athletes at the youth level have never had the service of a certified athletic trainer and are unfamiliar with the role an athletic trainer plays with a sports team. This lack of knowledge about athletic trainers can contribute to inconsistency in data collection. Some athletes may not report an injury to the ATC for several days to weeks after initial onset. Coaches might not report injuries to the ATC. Parents may have uncertainty about the purpose of an ATC and may not cooperate with the trainer's evaluation of their child's injury.

Significance

The significance and implications of the study takes several directions. First, it provides season-long data for a single sport at the local level, including practices and games. Second, all data were recorded by two certified athletic trainers. And third, the study used a non-invasive method of estimating biological maturity status.

The results of the study can potentially be useful to parents, coaches, league organizers, and athletes involved in youth football, and perhaps to other sports. There may be a better understanding of the risks involved in youth football. The league, coaches, and parents could realize the benefit of having a certified athletic trainer on site to handle injuries on a day to day basis which could include a decreased loss of playing time, fast assessment of injuries, and less hassle in dealing with injuries themselves. If a non-invasive method of assessing physical maturity proves to be useful as well as being predictive of the likelihood of injury for youth football, it could be incorporated into youth leagues that have such concerns.

CHAPTER 2

REVIEW OF LITERATURE

Several types of literature need to be reviewed in order to understand the complexities of injury research with youth. Certainly, the literature on sports injuries, especially injuries in American football, is relevant. Because the population in this study is of child and adolescent age, specific sports injury studies of the same age and of the same sport may be limited in availability. An extensive literature search revealed that most sports injury surveillance studies deal with high school or college athletes; therefore, injury data on youth football is limited. With this in mind, any literature on child and adolescent sports injuries can be of value. Since biological maturity status is a potential risk factor for injury, the literature on growth and maturation are also of importance.

Injuries In Youth Sports

In general, injury data on youth sports are collected retrospectively using general survey design. The Child Health Supplement to the 1988 National Health Interview Survey (NHIS) conducted by the United States National Center for Health Statistics, for example, provided estimates of the incidence of injuries associated with sport and recreational activities in 1988 (Bijur et al., 1995). The survey considered injuries to children and adolescents 5-17 years of age who received medical attention during the year surveyed. An adult in the surveyed household reported the data. Injuries were defined as "...those that occurred in a place of recreation and sports" (Bijur et al., 1995, p. 1010). The overall incidence of injury from sports and recreation was 6.4/100 players. There was a sex difference in the estimated incidence, 8.3/100 players for males and 4.4/100 players for females. The injury rate was stable in boys from 5 to11 years, increased threefold from 11 to 15 years, and then declined after 15 years of age. Injury rates for girls were steady from 5 to 8 years of age, increased fourfold from 8 to 12 years of age, and then declined from 13 to 17 years. The most commonly reported injuries were sprains (1.9/100 injuries), fractures and dislocations (1.7/100 injuries), and contusions (0.6/100 injuries). When the data were grouped into age categories (5-9, 10-13, and 14-17 years), fractures were consistent at around 25% of the total sports injuries reported. The percentage of lacerations and sprains changed positions from the youngest age group to the oldest. In the 5-9 year age group, lacerations accounted for 43% of the total injuries and sprains accounted for 10%. Among youth 14 to 17 years, sprains accounted for 30% while lacerations accounted for 22% of all injuries (Bijur et al., 1995). The NHIS survey did not include information that would allow estimates for injuries in organized sports and specific sports, for exposures, and for sport specific contexts of injury.

The Canadian Hospital Injury Reporting and Prevention Program (CHIRPP) is an emergency room-based injury surveillance program constituting ten pediatric hospitals. The CHIRPP definition of an injury was "...any injury incurred while the victim (age 5-19) was engaged in a physical activity for which the main purpose was competition, practicing for competition or improved physical health; the competition or practice could have been formal or informal"

(Ellison and Mackenzie, 1993, p. 96). Sport injuries so defined accounted for 25% of total injuries in the CHIRRP database. Consistent with United States interview data, sports injuries presented to emergency rooms increased with age, reached a peak at 11-13 years in girls and 13-14 years in boys, and occurred more often in boys than girls by a ratio of more than 2:1. The three most common sports injuries were (1) sprains/strains (32%), (2) fractures (21%) and (3) hematoma (19%) (Ellison and Mackenzie, 1993).

Kvist et al. (1989) surveyed sports injuries in children and adolescents 6-15 years treated in the Turku (Finland) University Central Hospital over three years from 1980 to 1982. Sports injuries accounted for 21% of all injuries in this age group with nearly one-half occurring during the winter months. This is most likely due to a long Finish winter. Boys were injured more than girls by a ratio > 2:1. Sport injuries increased with age, and reached a peak at 12-13 years in girls and 14-15 years in boys. The three most common injuries were (1) fractures (26%), (2) sprains/strains (24%) and (3) contusions (22%) (Kvist et al., 1989).

Consistent in all three surveys were the three most common injuries – contusions, sprains/strains, and fractures. Percentages differed slightly among studies, but the data suggested that geography and sport did not differ greatly in the type of injury. Another consistency between the CHIRPP and the Finnish studies was that contact of some kind during play or sport was involved in most of the injuries, whereas contact played lesser role in the NHIS. The NHIS study, however, included injuries due to bicycles, animals, other vehicles, playgrounds, struck/fall, overexertion, and other recreational activities (Bijur et al., 1995).

Intuitively, it can be assumed that contact was involved in bicycle, other vehicle, animal, and playground accidents, thus increasing the number of injuries that occurred as the result of some kind of contact. Quite often, injuries occur from bicycle and automobile collisions with other like vehicles, trees, poles, and so on; falling off playground equipment; and contact with aggressive animals.

An often-cited study of sport injuries in youth is that of Zaricznyj et al. (1980). Sport related-injuries in school age children in a midwestern community were followed for one year. The population consisted of 25,512 school children in grades K-12 (aged 5 years and older). Comparisons were made between elementary, junior high, and senior high school students, and among non-organized sports, physical educations classes, community team sports, and school team sports. Sources of data were the aggregate of (1) hospital records from two local hospitals, school accident insurance forms and local physicians reports, and (2) reports of principals, coaches and supervisors of community sports programs. An injury was defined as "...any traumatic act against the body sufficiently serious to have required first aid, filing of school insurance accident reports, or medical attention" (Zaricznyj et al., 1980, p. 318). A standard time loss definition of injury was not used because non-organized sports were included in this study.

Of the 25,512 school children comprising the study population, 1,495 (6%) sustained 1,576 injuries during the one-year period. Twenty-two percent (353) of the injuries occurred in elementary school children (5-11 years), 18% (282) occurred in junior high school students (12-13 years), and 59% (930) occurred in senior high school students (age 14+ years). Comparison by school population showed that sport-related injuries occurred in 3% of the total elementary population, 7% of junior high students, and 11% of senior high school students. The highest incidence of injury was at 15 years in boys (15%) and 14 years in girls (8%), but boys sustained twice as many injuries as girls when the data were combined across grades (Zaricznyj et al., 1980).

Non-organized sport activities produced the most injuries (40%), followed by physical education classes (38%). Organized school sports accounted for 15% of the injuries while community team sports accounted for the remaining 7%. Among organized sports, football accounted for four times more injuries than any other sport with 148 injuries (126 in school sanctioned football and 22 from community based football). Football also had the most injuries when levels of play were combined (295 injuries, 9.9% of all injuries).

Tursz and Crost (1986) examined sports-related injuries in children in a community in France. Data were collected on all accidents involving children aged 0-15 years (upper age limit in the French pediatric wards). An accident was defined as "...an unexpected, unintentional, and violent event affecting a child, with or without detectable lesion, and subsequently leading to medical attention..." (Tursz and Crost, 1986, p. 294). Data were mainly collected from two general public hospitals, their two mobile emergency and resuscitation units, and eleven private hospitals. Data were not recorded on level of competition or intensity of training. Very few cases of sport-related injuries occurred in children under 6 years of age; therefore, the results reflected only injuries sustained to children between of 6 and 15 years (Tursz and Crost, 1986).

There were a total of 7,182 accident cases recorded in the two public hospitals, the two mobile emergency and resuscitation units, and four of the 11 private hospitals that were most important in size and number of patients. Overall, 789 sports accidents were recorded, 597 (76%) in out-of-school sport activities and 192 (24%) in school physical education. Boys sustained more injuries than girls by a ratio > 1.5:1. Boys accounted for 487 sport accidents (62%) compared to 302 (38%) for girls. Out-of-school sporting activities resulted in more accidents in boys than girls, but there was no difference in school sport accidents. Fifty-three percent (421) of all sports injuries occurred to children 12-15 years of age. After the age of 6 years, sports accidents accounted for 17% of all reported accidents (Tursz and Crost, 1986).

Contusions and fractures in girls, and contusions and cuts/lacerations in boys were the accidents most frequently reported. In both sexes, contusions and sprains/strains increased with age, while cuts/lacerations decreased with age. A fall was the reported cause of injury in 58% of the sport - related accidents, followed by being struck by an object 16% and by being struck by another child, 9% (Tursz and Crost, 1986). These contexts can be categorized as contact, resulting in 78% of sports-related injuries in this survey.

Sport injuries in school-aged children were examined over a six - week period in the Netherlands in 1982 (Backx et al., 1989). Two classes from 175 schools were randomly selected. A total of 7,707 students, 8-17 years, comprised the study population. An injury was defined as "...physical damage caused by a sports-related incident and reported as such by the respondent..." (Backx et al., 1989, p. 235). A questionnaire was distributed to the students during physical education classes and completed with assistance of the teachers. A total of 7,468 students completed the questionnaire (96.9% of the study population). The first part of the questionnaire requested background information (age, sex, extent of sporting activities, and so on). The last question of the first section asked about newly sustained sport injuries. The second section contained detailed questions regarding these injuries, and was completed with the help of a teacher or a parent (Backx et al., 1989).

A total of 732 students accounted for 791 total injuries in the study population over a six - week period. A diagnosis was given in about 50% of the sport - related injuries. Of those with a diagnosis, 40% were sprains, 37% were strains, 7% were fractures, and 2% were concussions. Other types of injuries accounted for 8%. Most of the injuries were sustained during club sport activities: 29% in training sessions and 33% during matches. Physical educations classes accounted for 21% of sport-related injuries while non-organized sports accounted for 17%. The total incidence rate was 10.6/100 participants over the six - week period. Boys had a greater risk of injury than girls, 1.38:1. There also was a positive correlation with injury risk and age. Students 15 and 16 years had the highest risk ratio, 2.09, compared to students 8 to 10 years (Backx et al., 1989).

Basketball and field hockey had the highest risk ratio for both boys and girls in the Dutch study (1.99 and 1.83, respectively). Girls were twice as likely to become injured in field hockey than boys (Backx et al., 1989). Age categories were not determined for each individual sport. Unlike Zaricznyj et al. (1980), Backx et al (1989) found more injuries in organized sports than in non-organized sports and physical educations classes. Organized sports are more likely to have better recording methods. Note, however, the data were based on questionnaires completed by the students, which may have limitations. Like previous surveys on sport injuries to youth, only injuries serious enough to be reported were included.

Watkins and Peabody (1996) retrospectively examined sports injuries in children and adolescents who were treated at a sports injury clinic in London, England. Data were collected on all patients 5-17 years from January 1, through December 31, 1989. The clinic treated 394 sports injuries during the year. They represented 14% of all injuries seen at the clinic. Of the 394 sports injuries, 89% (351) occurred in training or competition in organized sports and 11% (43) occurred in free-play or recreational activities. Males sustained 55% (216) of the sport injuries compared to 45% (178) in females (Watkins and Peabody, 1996). The frequencies of injuries increased with age and peaked at 13-14 years in girls and 15-16 years in boys. Other studies (Bijur et al., 1995; Ellison and Mackenzie; 1993, Zaricznyj et al., 1980) also reported that boys sustain more injuries than girls at a rate of almost 2:1. The ages at highest frequency of injury in this study are consistent with previous surveys.

Soccer players were the most frequent male athletes treated at the London clinic, followed by rugby players. This, of course, reflects the popularity of these sports in England. Male soccer players sustained 48 injuries (22% of all sports injuries) and rugby players accounted for 36 injuries (17%). The most frequently treated female athletes at the clinic were those participating in athletics (36 injuries, 20%) and gymnastics (23 injuries, 13%). The authors attributed the sport - specific frequencies to two factors: a) the risk associated with the particular sports, and (b) the number of participants involved in the particular sports (Watkins and Peabody, 1996). It is no surprise that soccer and rugby accounted for most of the injuries in males, and athletics and gymnastics accounted for most injuries in females because they were the two most popular sports for each gender in the United Kingdom (Watkins and Peabody, 1996).

A survey of athletic injuries treated at an athletic medicine facility in upstate New York was reported by DeHaven and Lintner (1986). The study population was drawn from students at the University of Rochester (including athletes on NCAA Division III sport teams) and from the surrounding community over a period of 7 years from June 1976 through June 1983. The sample was categorized by age, sex, and sport of injury. The database consisted of 4,551 total cases with information on age, gender and sport for 3,431 of the cases (DeHaven and Lintner, 1986). Ages of the subjects ranged from < 13 years to 80 years. The authors did not specify the range for those under 13 years and treated these as a single age group. The number of injuries treated at the clinic increased from < 13 years to 16-19 years and then steadily decreased in every subsequent age category except for 31-40 years, which had more injuries than the 25-30 year age group. The 16-19 year age group had the most injuries, 1,408, more than double the number among 13-15 year olds, 514 injuries. Age categories were not further subdivided by sex. Of the 3,431 cases treated at the clinic, males accounted for 80% (2754) and females 20% (677) of the injuries (DeHaven and Lintner, 1986).

The sports in which the injury occurred were also documented. Football accounted for 2,193 injuries treated at the clinic, more than 12 times the number observed in the next most common sport, basketball (DeHaven and Lintner, 1996). This can be attributed to the larger number of athletes in football and the fact that the intercollegiate athletes at the University of Rochester were treated at the clinic.

Beachy et al. (1997) examined male and female high school students in grades 7 through 12 at a private school in Honolulu, Hawaii. A total of 14,318 athletes in 32 sports participated in the study over an 8-year span. Multi-sport athletes were counted once for each sport. An injury was defined as "...any athlete complaint that required the attention of the athletic trainer, regardless of the time lost from activity. Five injury classifications were used: 1) minor, no time lost; 2) mild, 1-7 days lost; 3) moderate, 8-21 days lost; 4) severe, 22 or more days lost; 5) catastrophic, permanent disability, dismemberment, or death..." (Beachy et al., 1997, p. 676). Sources of the injury data were evaluations by two full-time athletic trainers, one part-time athletic trainer, and two team physicians, all of whom were constant throughout the study.

Over the 8 years, there were a total of 11,184 injuries (7,026 in males and 4,158 in females). The athletes were divided into four levels of competition: intermediate (INT) - grades 7-9, junior varsity (JV) – grades 9-11, varsity/junior varsity (V/JV) – grades 9-12, and varsity (VAR) – grades 9-12. Table 1 shows injury exposure rates per 1000 exposures of each level of competition by sex. Estimated rates of injury were about equal for boys and girls. The sport with the greatest number of injuries and highest risk of injury was football (2,503 and 0.80, respectively). For girls, track had the highest number of total injuries at 1120, but soccer had the highest injury rate, 0.71/1000 exposures (Beachy et al., 1997).

The length of the study and number of subjects provided good data. The stability of the medical staff over the entire 8 years added to the reliability and validity of injury reporting. However, the definition of a reportable injury may not reflect the true rate of injuries sustained by this population. Any time an athlete had a health complaint and sought the attention of an athletic trainer, the episode was considered an injury regardless of the severity of the complaint. The definition of injury in this study was designed to emphasize the daily workload of a certified athletic trainer in the high school setting, which may have inflated the number of reportable injuries. A more precise label for the term injury, used in this study, would be athlete-trainer contact, which better represents the workload of athletic trainers in the high school setting.

Kontos (2000) was apparently the first to examine the combination of perception of risk, risk taking behaviors, and body size in the context of youth sport injuries. Two hundred and fifty two (142 male, 111 female) youth soccer players 11 to 15 years of age were surveyed regarding their perception of risk of injury in sport, risk taking behavior, and perceived skill level. Injury data were collected via phone conversations with coaches twice per week over an eight-week period.

Results suggested that the BMI, in part, influenced levels of perceived risk. Subjects with a higher BMI showed a higher level of perceived risk than those with a lower BMI. In soccer, being heavy is not an advantage. There is a general negative stigma in American society associated with a child being heavy and this may lead to heavy youth soccer players to view themselves as being less skilled, more awkward, and more likely to be injured playing soccer. The BMI was the best predictor of injury in this study. Soccer players with a high BMI (upper tertile of the study population) significantly sustained more injuries than players with a lower BMI in the lower tertile (Kontos, 2000).

In contrast to soccer, heaviness is often perceived to be an advantage in American football. Youth football players may exhibit a different perception of risk of injury than soccer players simply because of the nature of the sport.

Football Injuries

Football is classified as a high-risk sport, which implies that the sport, by its very nature, will produce a high number of injuries (Petersmarck, 1998; Culpepper and Neimann, 1983). Other sports that also fall under this umbrella are ice hockey and wrestling. These sports share high amounts of contact (body to body contact and body to playing surface contact). Football generally receives the most publicity with regard to injuries because of the popularity of the sport and the high numbers of participants from the youth through professional levels, and the rare catastrophic injury.

High School Football Injuries

A three - year injury surveillance study conducted by the National Athletic Trainers Association (NATA) examined 10 high school varsity sports, including football (Powell and Barber-Foss, 1999). Certified athletic trainers collected the data prospectively from 1995-1997. Data collection included reportable injuries, athlete exposures, time loss due to injury, injury location, and injury type. A reportable injury was defined as follows:

- “Any injury that causes cessation of participation in the current game or practice and prevents the player’s return to that session
- “Any injury that causes cessation of a player’s customary participation on the day following the day of onset.
- “Any fracture that occurs, even though the athlete does not miss any regularly scheduled session
- “Any dental injury, including fillings, luxations, and fractures.
- “Any mild brain injury that requires cessation of a player’s participation for observation before returning, whether in the current session or the next session” (Powell and Barber-Foss, 1999, p. 278).

An average of 133 high schools per year reported football injury data. Over the course of the study, 400 team-seasons, 21,122 player seasons, and 1,300,446 athlete exposures were reported. An athlete exposure occurred any time and athlete participated in a practice or game session, and had an opportunity to sustain an injury, regardless of the actual amount of time the athlete participated (Powell and Barber-Foss, 1999).

Football had the highest injury rate of the 10 sports surveyed (baseball, boys and girls basketball, boys and girls soccer, wrestling, field hockey, softball, and volleyball). Case rates (number of injuries divided by the study population), player rates (number of injured players divided by the study population) and exposure rates were calculated. Case rates included multiple injuries where player rates do not. Exposure rates were the total number of injuries divided by exposures (total exposures, practice exposures, and game exposures).

Injury rates for high school varsity football were as follows: case rates - 50.0/100 players and player rates - 34.6/100 players. Total exposure rates were 8.1/1000 athlete exposures. Even though practices accounted for over 56.4% of the injuries to high school football players, game rates, estimated at 26.4/1000 athlete exposures, were five times higher than estimated practice rates, estimated at 5.3/1000 athlete exposures. Most injuries (72.5%) occurring to high school football players were categorized as minor (loss of 1-7 days). Moderate injuries (loss of 8-21 days) accounted for 16.3% and major injuries (> 22 days lost) accounted for 11.2%. The three most common types of injuries were sprains (31.7%), general trauma (25.2%), and strains (21%) (Powell and Barber-Foss, 1999).

An early survey of football injuries, the North Carolina High School Football Injury Study (Blyth and Mueller, 1974), examined injuries in 43 high schools with 8,776 participants from 1969 through 1972. Trained investigators who visited the schools on the same day and time each week of the football season collected the data. Players who were injured the week before the investigators made a visit were interviewed to ascertain details of the injury. The definition of an injury was when medical treatment was sought or usual activity was restricted for at least one day beyond the injury (Blyth and Mueller, 1974).

The incidence over the combined four years of the study was 48.8%. Injury rates for each year did not differ greatly, with 1969 having the highest (53.2%) and 1970 having the lowest (47.5%) rates. Injuries were distributed about evenly between games and practices. Estimated incidence rates increased with age, height, and weight, but interrelationships among these three variables were not considered (Blyth and Mueller, 1974).

A study of high school football players in Texas (n = 4,399 from 75 schools) revealed that almost one-half of the athletes competing at the varsity level sustained an injury during the 1989 football season. The sources of injury data were reports form certified athletic trainers who worked for the high schools. The athletic trainers were present at each practice and game, and served a primary role in the valuation and treatment of the injuries. A reportable injury was defined as one that "...occurred in football and meeting one or more criteria: 1) any injury that causes a student athlete to miss all or part of a single practice or game; 2) any injury (including dental) that is treated by a physician; and 3) all head injuries reported to the athletic trainer..." (DeLee and Farney, 1992, p. 576).

This definition, according to DeLee and Farney (1992), was deemed as more comprehensive than a time-loss from participation or operational definition. DeLee and Farney (1992) gave two examples where the definition would include injuries that a time-loss definition would not. If a player sustained a concussion at the end of a Friday night game, the symptoms may have been resolved by practice on Monday. Second, if a player fractured a finger (offensive tackle), he may not miss any playing time due to the position played, whereas another athlete with the same injury (quarterback) would miss playing time (DeLee and Farney, 1992).

Over the course of the season, there were a total of 2,228 injuries (1242 in games, 986 in practices). This yielded an estimated incidence of 0.51 injuries per athlete per year. The estimated incidence of reportable injuries, as defined, was 0.003 injuries per hour of exposure (3/1000 hrs) per athlete.

DeLee and Farney (1992) did a better job describing injury type and anatomical location than many other studies. The source of the data was more consistent than other studies, where health professionals with the same credentials collected the injury data. One limitation was that the age of the subjects was not defined and incorporated into the analysis. Only the term varsity athlete was used, and this could include boys between 14 and 18 or 19 years of age.

A comparison of injury rates of high school football players playing on natural and synthetic surfaces was conducted by Adkison et al. (1974). The population included players participating on varsity football teams in 73 high schools in Seattle and Spokane, Washington, and Portland, Oregon, during the 1971 season. The total number of players was not given. A coach or student athletic trainer supervised by the coach, recorded injury and player data. An injury was defined as "…traumatic medical condition sustained during game play resulting in any one (or more) of the following: (1) necessitated discontinuation of participation for the remainder of the game (2) resulted in missing two or more practices (3) resulted in missing one or more subsequent games" (Adkison et al., 1974, p. 132). Injuries sustained during practice sessions were not counted.

A total of 349 injuries were sustained in 660 games during the 1971 season. Games played on natural grass surfaces (n = 424) accounted for 218 injuries with an estimated rate of 0.51 injuries per game on natural grass. There were 131 injuries to players competing on synthetic surfaces (183 games) with an estimated rate of 0.63 injuries per game. Total injury rate was 0.53 injuries per game (Adkison et al., 1974).

Adkison et al. (1974) did not include injuries sustained during practice sessions and, therefore, were not able to calculate injury rates for an entire season. Also, the actual numbers of participants was not included thereby making it impossible to calculate player rates or case rates. Data were lacking for number of participants and injuries occurring during practices, which would have been easy to amass allowing for a more detailed analysis of injury statistics.

Culpepper and Neimann (1983) conducted a study of high school football injuries in Birmingham, Alabama. The purpose of the study was to develop profiles of football injuries on high school athletes. Data were obtained from athletes treated at the Sports Medicine Clinic at the University of Alabama in Birmingham from 1976 through 1979. An injury was defined as "…any traumatic change in a student athlete's medical condition sustained during a regular practice session or game and for which professional treatment was received at the Sports Medicine Clinic…" (Culpepper and Neimann, 1983 p. 873).

A total of 1,877 injuries were treated at the clinic during four football seasons. The types of injuries sustained most often were sprains (32.2%), contusions (24.8%), and strains (12.4%). Running backs were the most commonly injured (19.6% of the injuries treated at the clinic), followed by offensive tackles (11.6% of the injuries). The body parts sustaining the most injuries were the knee (22.2%) and shoulder (13.3%). More than 17% of the injuries were to players <15 years of age. Injuries to other age groups were not counted (Culpepper and Neimann, 1983).

Violette (1976) was one of the few to examine the relationship between biological maturity and injury in football. The data were from the first year (1969) of the North Carolina study discussed previously (Blyth and Mueller, 1974). Subjects included junior high school (13-15 years) and high school (15-19 years) football players from 43 schools in North Carolina. The criterion for maturity was a composite score of three secondary sex characteristics: testicular volume, pubic hair, and axillary hair. Testicular volume and pubic hair were assessed on a 6-stage scale and axillary hair on a 4-stage scale. The maturity index combined the three assessments: 6+6+4 divided by 3. Along with the maturity index, height, weight, the subscapular skinfold, and grip strength were measured. The definition of injury was the same used for the North Carolina study.

Injury prevalence for junior high school football was estimated at 0.40 for 13 and 14 year old and 0.14 for 15 year old players. It was assumed that 15-year-old players had increased exposure to injury due to their experience; yet the injury prevalence was lower. It was concluded that 15-year-old junior high school football players were probably the cause of injuries to younger, less mature players. In contrast, 15-year-old players at the high school level had an estimated prevalence of 0.34 injuries. This group, however, was less biologically mature than the older players and was less exposed to the chance of injury because of their inexperience at the high school level (Violette, 1976).

Injured football players at the junior high school level were slightly less biologically mature than non-injured players within each age group. The maximum possible maturity index was 5.33. No one participating at the junior high school level had a maturity index above 5.00. The index ranged from 1.33-4.67 at 13 years, from 2.00-5.00 at 14 years, and from 2.00-5.00 at 15 years. The mean maturity index increased with age at every level (Violette, 1976).

Junior high football players at each age who measured low in subscapular skinfold, height, and weight sustained more injuries than athletes who had larger measurements. Increased grip strength was associated with increased injury in maturity the 14-year-old age group. On the other hand, 13 and 15 year old players who measured low on grip strength sustained more injuries than those who were stronger (Violette, 1976). These findings indicate that a smaller body size is associated with an increase chance of being injured. However, there were no clear trends regarding risk of injury and strength. Interrelationships among the variables and risk of injury were not analyzed.

YOUTH FOOTBALL INJURIES

According to Godshall (1975), there has been much criticism regarding safety and risk of injury in youth football. Godshall states that both lay people and physicians may be misleading in their reports because the conclusions are not based on objective data, but on general impressions and unfounded assumptions, and are perhaps influenced by the media on high school, college and professional athletes.

There are very little objective data on injuries sustained in youth football. After a review of mission, rules, and injury data made available from the Pop Warner Football League, Godshall (1975) concluded that the benefits of youth football far outweighed associated risks, not just the risk of injury, but also emotional stress, problems with parents, and interference with junior high school athletics. Roser and Clawson (1970) similarly stated that there is opposition to youth participating in contact sports from individuals (lay people and health care providers) who say that football poses too great a risk of injury. However, there are little reported data to validate these claims.

Godshall expressed these concerns in 1975. Yet, 27 years later there has been relatively little progress in gathering objective data on injury rates and risk of injury in youth football. The most recent report dealing exclusively with youth football injuries was that of Goldberg et al. (1988), who conducted a prospective study of six New England Pop Warner Football Leagues. The study included 5,128 boys 8-15 years of age from 257 teams. The boys were grouped by age, weight, and skill level into five divisions:

Junior Pee Wee -	8-11 years, 22.5 – 38.8 kg (n=692),
Pee Wee -	9-12 years, 29.3 – 45 kg (n=1,610),
Junior Midget -	10-13 years, 36 – 51.8 kg (n=1,489),
Midget -	11-14 years, 40.5 – 60.8 kg (n=1,160),
Junior Bantam -	12-15 years, 49.5 – 67.5 kg (n=177).

The coaches were the primary individuals responsible for reporting injuries, but coaches and players were contacted at the end of the season to provide the names of injured players. Only an injury that caused a player to miss at least one week of participation was recorded and labeled as a significant injury. Injuries were further categorized as moderate (8-21 days lost), major (>21 days lost), and severe (permanent disability).

Overall, 257 injuries were reported (Goldberg et al., 1988). The oldest and heaviest teams (Junior Bantam) had the highest injury prevalence (9.6%), while the smallest and lightest teams (Junior Pee Wee) had the lowest prevalence (1.9%). The authors examined several biological variables and their association with an increased chance of injury. There was no significant correlation between the age of players within a group and injury, but there was a significant correlation between weight of players and injury only in the Midget division.

The distributions of injuries in games and practices were 61.5% in games and 30.7% in practice; the remaining injuries occurred during scrimmages (7.8%). Scrimmages were not defined as inter-squad or intra-squad. Injuries during scrimmages were considered separate from injuries occurring during practice even though scrimmages usually take place during a practice session. Players with the most playing time were injured more often; > players who averaged playing at least 3 quarters incurred 90% of the injuries. Thus, as exposure time increased, risk of injury increased. Even though exposure time was estimated, exposure rates were not calculated.

Goldberg et al. (1988) only accounted for injuries that required cessation of participation for at least 7 days. With this criterion for a reportable injury, many injuries may go unnoticed, i.e., minor injuries requiring less than 7 days of cessation would not be included. If a different definition of a reportable injury were used, the injury rates in this study would probably be higher.

The method of injury reporting also has some limitations. Of the total number of 257 reported injuries, 211 were reported by the coaches. The coaches failed to report 46 injuries. Players reported 147 of the 257 total injuries (Goldberg et al., 1988). This suggests different perceptions of injury between players and coaches. For both coaches and players, end of the year reporting may not be the most reliable method of data collection. Even though instructions were given to the coaches on how to document injuries at the beginning of the season, close to 20% of the total injuries went unreported by the coaches.

In an earlier study by Goldberg and colleagues (1984), 436 athletes were studied in a prospective assessment of youth football injuries during the 1981 season in a Pop Warner youth football league in six New England towns. The league was divided into three divisions using weight and age:

Pee Wee: 9-12 year olds, 65-100 lbs (29.5 – 45.5 kg),

Junior Midget: 10-13 year olds, 80-115 lbs (36.4-52.3 kg),

Midget: 11-14 year olds, 100-130 lbs (45.5-59.1 kg).

Questionnaires were completed by league personnel, and included information on the diagnosis and site of injury, duration of disability, and age, weight and position of the injured athlete. If a physician diagnosis was not available, the researchers made the diagnosis based on a description of the injury. The definition of injury depended on the length of time the athlete was unable to participate. An injury that prevented participation from 1-7 days was categorized as minor, and one that prevented participation for more than 7 days was considered significant. There were three subcategories of significant injuries: moderate (restricting an athlete from 8-21 days), major (restriction more than 21 days), and severe (permanent disability). The injury criteria used in this study were established by NAIRS (National Athletic Injury/Illness Reporting System).

A total of 67 injuries were reported. The questionnaire completed by league personnel accounted for only 30 of the injuries, while telephone interviews with the families of 401 players reported 67 injuries. There was a significant difference in total injuries and significant injuries among age/weight divisions. The Peewee division had the fewest and the Midget division had the most injuries. There was also a significant difference within divisions between heavy and light athletes; heavier athletes showed an increased incidence of injury (Goldberg et al., 1984).

There are several limitations with this study. Similar to Goldberg et al. (1988), league officials failed to report all of the injuries. League officials reported less than one-half of the injuries which were reported by the families of the young athletes. Although 92% of the families were contacted, some information could be lacking. The authors also made injury diagnoses based on descriptions in telephone interviews. Sound practice suggests that a diagnosis should only be made during a clinical examination where the physician or certified athletic trainer has visual and palpatory contact with the athlete. Verbal descriptions by a child, adolescent and/or parent may not be sufficient for an accurate diagnosis.

Roser and Clawson (1970) conducted a prospective study of 2,079 boys participating in the Seattle Junior Football Program during the 1968 season. The program was organized onto five leagues (competitive divisions) with 70 teams participating. The leagues/divisions were divided according to the player weight and age:

Bee: 9-11 years old, up to 85 lbs (38.6 kg);

Midget: 9-11 years old, 86-98 lbs (39.1-44.5 kg), but teams could have five 12 year olds less than 75 lbs (34.1 kg);

Peewee: 10-12 year olds, 99-105 lbs (45-47.7 kg), but teams could have five 13 year olds less than 92 lbs (41.8 kg);

Gil Dobie: 13-14 year olds, 106-124 lbs (48.1-56.4 kg);

Bantam: up to 15 years old, 125-160 lbs (56.8-72.7 kg).

The season lasted 12 weeks. The first four weeks involved preseason practice, 2 hours per day, 6 days per week. After the first game, practices were reduced to three, 2-hour practices per week. Each team played 7-8 games throughout the season.

The data collection procedures involved a questionnaire which was completed by the coaches every time an athlete was injured severely enough to require missing a practice session or a game. The coaches were contacted several times throughout the season to ensure that the data were being collected. If an athlete was injured, the parents of that athlete as well as his physician were contacted to gain additional information and a proper diagnosis. At the end of the season, insurance companies were contacted to cross check all medical claims (Roser and Clawson, 1970).

The results indicated that only 2.3% of the athletes sustained a football injury severe enough to keep them out of at least one game or practice session. Each player spent approximately 96 hours practicing and 12 hours in games; yet the chance of injury in a game was 11 times higher than in practice. Lack of heavy contact in practices and increased aggressiveness during games probably contributed to this difference. Prevalence of injury varied by status: first-string players, 81%; second-string players, 17%; and third string players, 2% (Roser and Clawson, 1970). This finding probably reflected exposure time.

There was no association between age and the likelihood of injury in this study. The Peewee division sustained the highest percentage of injuries (4.3%), while the Gil Dobie division accounted for the lowest percentage (1.4%). The Bee, Midget, and Bantam divisions sustained, respectively, 0.2%, 2.3%, and 3.3% of the injuries (Roser and Clawson, 1970).

Silverstein (1979) suggested that injury rates in youth football are higher than those previously reported by Roser and Clawson (1970). Silverstein (1979) examined youth football injuries for three teams over two seasons (1977 and 1978). The three teams represented three different levels of competition, Peewee, Junior Varsity (JV), and Varsity (V):

Peewee:	age 8-11 years, up to 90 lbs (41kg),
Junior Varsity:	age 12-13 years, up to 110 lbs (50kg),
Varsity:	age 14 years, up to 130 lbs (59kg).

The overall injury prevalence was 18.1% during the 1977 season and 12.9% during the 1978 season. The Peewee team experienced an injury prevalence of 10.0% during the 1977 season and 14.4% during the 1978 season. Junior varsity players had an injury prevalence of 28.3% during the 1977 season and 13.0% during the 1978 season. The Varsity team sustained an injury prevalence of 20.6% in 1977 and 11.0% in 1978. The disparity in prevalence's between Junior Varsity and Varsity teams for the 1977 and 1978 seasons was attributed to a low number of participants during the 1977 season.

There are very few studies which deal with body size or biological maturity, and their possible relationships with injury in youth sport. It has been suggested that body fatness may increase the risk of musculoskelotal injuries, either directly or indirectly. Gomez et al. (1998) examined the relationship of fatness and injury rates in high school football linemen. The sample included 215 junior varsity and varsity linemen who participated in ten high schools in San Antonio, Texas. Athletic trainers employed at each high school collected the data. Preseason evaluations of each lineman at the participating schools included skinfold thickness at three sites (chest, abdomen, and front of the thigh), and height and weight. All skinfold measurements were taken by an individual experienced in the techniques. Body density was estimated using the equation of (Jackson and Pollock, 1985):

$$\text{Body density} = 1.10938 - 0.0008627\ (\text{sum of 3 skinfolds}) + 0.0000016\ (\text{sum of 3 skinfolds})2 - 0.0002574\ (\text{age}).$$

Density was subsequently converted to percentage body fat using the equation by Brozek et al (1963):

$$\%\ \text{body fat} = \{(4.57/\text{body density}\} - 4.412) \times 100$$

A total of 67 linemen suffered 86 injuries over the course of the season, an estimated injury rate of 5.66/1000 hours. Each school's athletic trainer, who recorded the data, estimated total exposure time per athlete. Total exposure time was equated with total playing time and was calculated by estimating the time each player spent physically participating in practices and games. The schools trainers estimated that players spent 60% (1.2 hours) of each practice actually engaged in physical activity. Players were credited with 6 minutes of playing time per quarter if an athlete played one-way (offense or defense) and 12 minutes if they played both. Practice and game time were added together to determine total exposure time for each athlete. There were no significant differences between groups above, and at or below different levels of body fat percentage. However, there was a significant difference in injuries to the lower extremity by level of fatness. Players with an estimated fatness > 20% had a significantly higher incidence of lower extremity injuries than those with body fat < 20%. However, a level of body fat (mean or median split, etc.) could not be determined where there was a consistently significant difference in estimated rates of injury between higher and lower fat groups (Gomez et al., 1998).

Limitations of this study are several. Error associated with the prediction of body fat from skinfolds was not considered. Moreover, measurement error tends to be greater in the case of larger skinfolds. Individual differences in body fat, weight and the BMI were not considered in the analysis. Instead, injury rates for specific BMI's, weight, and body fatness were calculated. The study sample was limited to high school football linemen, usually the largest athletes in the sport. It was hypothesized by the authors that increased body fat was a risk factor for injury in sports. As such, only the heaviest, and most likely fattest, athletes were included in the study. Athletes playing other positions besides offensive and defensive line were not included. Traditionally, skill positions players and linebackers are leaner than linemen. It would have been helpful to examine the weight, BMI, and percentage fat of all athletes.

Backous et al. (1988) estimated maturity status among male soccer players and examined its relationship to injuries sustained during a one-week soccer camp. Maturity status was estimated from grip strength and height. Three maturity levels were established: immature, mature, and mature but weak. Mature boys were > 165 cm in height and had a grip strength > 25 kg. Immature boys were < 165 cm in height and had a grip strength < 25 kg. Some boys were tall (above 165 cm) but did not demonstrate grip strength of ≥ 25 kg; these boys were labeled mature but weak. Tall but weak boys had a higher incidence of injuries than immature and mature boys. The authors assumed that tall, weak boys may have greater sexual maturity than muscular development, but sexual maturity status was not assessed. When comparing boys just on grip strength, there was no difference in injury rates among strong and weak boys (Backous et al., 1988).

Equating height and grip strength with pubertal maturity is a major concern in this study. The authors stated that boys less than 165 cm with a grip strength < 25kg would most likely be pubertally immature (Tanner stages 1-3). Specific stages of pubertal development were not indicated, i.e. pubic hair or genital development. Stages of sexual maturity described by Tanner (1962) are characteristic specific and should not to be averaged or combined. Further, boys in genital or pubic hair stage one are pre-pubertal, while boys in stages 2 or 3 are already pubertal (Malina and Bouchard, 1991).

Age Grouping in Youth Sport

Participants in youth sports are grouped in several ways. The most common method is by chronological age. Other methods are by grade in school, ability, and physical maturity. Sometimes a combination of methods is used, for example, if an athlete is in the appropriate by age, but exceeds the weight limit for the age group, he could be moved to the next higher level. Pop Warner Youth Football classifies children of similar age and size (Dick Butkus Football Network, 2001). They are the only league that uses an age/weight matrix, which is believed to reduce the number of injuries. Players who exceed a certain weight limit must participate at the next level of competition.

The Mid-Michigan Pony Football League (MMPFL) uses a different grouping method. Teams in the MMPFL are grouped primarily by grade in school, but there are several age restrictions secondary to grade. The primary safety rule used by the MMPFL is a weight restriction on primary ball carriers (quarterbacks, running backs, receivers). Fourth and fifth grade teams cannot use a player as a primary ball carrier who weighs more than 120 lbs (54.5kg) in full football attire. Players on the sixth grade teams cannot use primary ball carriers above 130 lbs (59 kg), and seventh grade teams above 140 lbs (63.5 kg). There is no weight restriction with the 8th grade team regarding primary ball carriers. Players exceeding the weight requirement must play from tackle to tackle (MMPFL, 2000). The rational for limiting the weight for ball carriers is that a much heavier athlete will not be able to run into lighter athletes who are playing defense. The rule that limits the weight on ball carriers does not apply for any defensive position. Therefore, the heavy athlete can play defense and presumably run full steam into a lighter ball carrier. Note, however, that boys 9-14 years of age differ considerably in size and maturity (Malina and Beunen, 1996).

Assessing Maturity Status

Size differences among children and adolescents reflect, to a large extent, individual differences in tempo of biological maturation, which are especially pronounced during the transition into puberty. The biological status of an individual can be assessed in several ways. These assessments include, but are not limited to, skeletal maturity using hand/wrist radiographs, sexual maturity using stages of secondary sex characteristics, dental maturity using dental X-rays, somatic maturity using age at peak height velocity (PHV), percentage of adult height, and perhaps muscular strength. Each method of maturity assessment has limitations with regard to accuracy, practicality and cost.

The development of the skeleton spans the entire period of growth and is perhaps the best bodily system for assessing maturity status (Malina and Bouchard, 1991). There are three methods of assessment, which are commonly used to estimate skeletal maturity: the Greulich-Pyle, Tanner-Whitehouse, and the Fels methods.

The **Greulich-Pyle** method involves matching, as closely as possible, the hand/wrist X-Ray of a child/adolescent with a series of standard hand/wrist X-rays plates in an atlas. The method should be applied by assessing the maturity status of each individual bone, but many studies simply compare the film of the child/adolescent as a whole to the plates in the atlas (Malina and Bouchard, 1991).

The **Tanner-Whitehouse** method is sometimes called the bone specific method. It entails matching the features of 20 individual bones of a hand/wrist X-ray to written criteria for each bone. Each stage is given a specific score and the scores for all bones are summed to give a maturity score. A skeletal age is then derived from the summed score for 20 bones. Separate skeletal ages can be assigned radius, ulna and short bones and to the carpals (Malina and Bouchard, 1991).

The **Fels** method also evaluates maturity indicators based on shape changes and ratios between linear measurements. Grading is done by matching the hand/wrist radiograph with the described criteria, and measurements of epiphyseal and metaphyseal widths. The assigned grades are entered into a personal computer, which calculates a skeletal age and the associated standard error (Malina and Bouchard, 1991).

Even though skeletal age may be the best method of assessing maturity during childhood and adolescence, there is little practicality for its use in studies of large samples. The cost of the X-rays and the time it would take to assess the films may be prohibitive. In addition, x-rays involve a low level of radiation exposure.

Sexual maturity is based on the assessment of secondary sex characteristics: breast and pubic hair development in girls, and genital and pubic hair development in boys. Five stages of development are described for each characteristic by Tanner (1962). Stage 1 is prepubertal; Stage 2 indicates the onset or initial development of each characteristic; Stages 3-4 represent further development; and Stage 5 indicates the adult or mature state. If a boy is assessed as having stage 2 genital (G) and stage 4 pubic hair (PH), it is expressed as G2 and PH4. Each characteristic should be treated separately, i.e., not combined into a single score. Also, it cannot be said that a child in a particular stage of development in one characteristic will automatically be in a certain stage of development in another characteristic, i.e., PH 3 does not equal G 3 (Malina and Bouchard, 1991).

Assessment of sexual maturity requires invasion of privacy. It should be done in a clinical setting by direct visual observation. This poses a problem because this type of assessment is invasive. It may be difficult to receive consent from parents and children to perform this type of assessment. Another limitation is that sexual maturity assessment is only of value only during the years of puberty. Some boys in the age range 9-14 years will be still prepubertal.

Dental maturity assessment requires the use of dental X-rays to evaluate the calcification of permanent teeth, but dental maturity proceeds independently of skeletal, sexual, and somatic maturity (Malina and Bouchard, 1991). Dental X-rays taken during a routine dental visit can be used to assess dental maturity.

Grip strength has been suggested as an indicator of maturity status and as a pre-participation screening criterion in some sports. Backous et al. (1990) suggested that grip strength combined with height is a good predictor of pubertal maturity. The criteria used by Backous et al. (1990) to classify a boy as "average" in maturity status were 25 kg of force using a hand-grip dynamometer (Jamar, Asimow Engineering Co., Los Angeles) and a height of 65 inches (165 cm). A boy was considered immature if grip strength and height fell below 25 kg and 65 inches (165 cm), and mature if they were above these levels. These criteria were compared to stages of pubic hair: stages PH 1 through PH 3 were considered immature, and stages PH 4 and PH 5 were considered mature. Using height and grip strength, 70% of the boys were correctly classified as mature or immature. Using grip strength combined with height might be an easy method of assessing maturity, but a significant number of boys were misclassified (30%). Further, defining PH 1 through PH 3 as immature is somewhat naïve, as is classifying PH 4 as mature. By definition, only Ph 5 is mature (Tanner, 1962). Grip strength is also influenced by body size independent of maturity status as well as the type of dynamometer used.

Assessing physical maturity in the preparticipation health evaluation may be important for two reasons. It may help to reduce serious injuries to immature athletes by limiting their participation in collision sports, and it may help to match participants with respect to their abilities (Kreipe and Gewanter, 1985). Nevertheless, data are lacking to suggest that the biologically immature athlete sustains serious injury with greater frequency than the biologically mature athlete in collision and other sports.

Somatic maturity is most often estimated as age at PHV, the maximum rate of growth during the adolescent spurt. Estimation of age at PHV requires longitudinal data, which limits its utility.

Expressing current height as a percentage of predicted adult height may provide an estimate of somatic maturity. If the subject's adult height can be predicted, then current height can be expressed as a percentage of predicted adult height and provide an indication of maturity status (Malina and Bouchard, 1991; Malina and Beunen, 1996). Data from longitudinal studies indicate that within an age group (e.g., 10 years), children advanced in maturity attain a greater percentage of adult height compared to average and late maturing children (Bayer and Bailey, 1959).

Prediction of adult stature usually requires a skeletal age assessment, in addition to age, weight, height and midparent height. Hand/wrist radiographs are not readily available in surveys and when they are available, relatively few individuals have the training to accurately assess them. A height prediction method has been developed that can be used in the absence of skeletal age to facilitate prediction of adult stature (Khamis and Roche, 1994). There are four predictor variables needed with the Khamis-Roche prediction method: current age, stature and weight of the child, and midparent stature. The regression equation has the following form within an age and sex group:

predicted adult height = $\beta 0$ + $\beta 1$ stature + $\beta 2$ weight + $\beta 3$ midparent stature,

where $\beta 1$, $\beta 2$, $\beta 3$ are the coefficients by which stature, weight and midparent stature should be multiplied. Coefficients change with each half-year of chronological age. The method decreases in accuracy somewhat when applied to boys around 14 years of age due to the omission of skeletal age (Khamis and Roche, 1994).

SUMMARY

Studies of sports injuries use different methods of data collection and definitions of injury. Both undoubtedly influence estimated injury rates. Tables 2 and 3 summarize the trends in the available studies of football. It is clear that some definitions of a reportable injury are more ambiguous or less strict than others, resulting in estimated injury rates ranging from 10.5% to 81.1% in high school football.

Data collection procedures can also have an impact on injury rates. Retrospective surveys and data obtained from insurance forms and/or hospital records show lower injury rates than direct, on-site interviews, or daily reports. According to Thompson et al. (1987), direct interview techniques offer the best source of incidence data, regardless of the scope of the study or definitions used for injury. Only two of the studies cited (Powell and Barber-Foss, 1999; DeLee and Farney, 1992) used certified athletic trainers to collect data on high school football injuries.

Much of the literature on youth sports includes data for an assortment of sports and activities, which makes it difficult to establish injury rates for specific sports. Large-scale surveys of sports injuries to children and adolescents adequately show how many people are injured, but risk factors are not taken into account.

Quality data on football injuries in community level youth programs are lacking. The accuracy of reported injuries has limitations. Retrospective telephone interviews require the parent or child to recall an injury event that may have occurred months ago. Other methods require a coach, league official, or team representative to collect and report injury data. These individuals may be lacking in medical training and also are busy with other responsibilities during games or practices. Regardless of instructions from researchers, uniform educational background on sports medicine injuries would be a benefit. The present study used a strict operational definition of a reportable injury and certified athletic trainers to collect injury data on a daily basis. Combining both of these methodological techniques should provide more accurate estimates of injuries in youth football.

There are several methods of estimating biological maturity status: skeletal age, secondary sex characteristics, dental maturity, somatic maturity using age at peak height velocity (PHV), and percentage of adult height. Skeletal age and sexual maturity have been used widely in growth and performance studies of young athletes (Malina, 1994, 1998), but have not been used on a regular basis in the study of injuries (Malina, 2001). Percentage of predicted adult height has apparently not been used to estimate maturity status of youth football players and has not been evaluated as a possible risk factor for injury in any youth sport. This method of estimating maturity and examining its possible relationship with injury is youth football is the most practical for this type of study. Estimating predicted adult height as a method of assessing maturity is non-invasive and requires only basic information from the subjects (height, weight, age, heights of biological parents).

CHAPTER 3

METHODS

The purpose of this study was to examine the prevalence and incidence of injury and the risk of injury in youth football participants. Internal variables, or player related risk factors, were considered, and their relationships with risk of injury in youth football were examined. The data for this study were from the first year of a two-year project funded by the National Athletic Trainers Association Foundation with Robert M. Malina as the primary investigator. The study was approved by University Committee on Research Involving Human Subjects (UCRIHS) at Michigan State University (Appendix I).

Population

The subjects were 355 youth football players 9-14 years of age in the 4th to 8th grades from two communities in south central Michigan (Holt [n = 210] and St. John's [n = 145]). The criterion for inclusion was registration with the youth football program in the community and membership on a team. In addition to permission from league officials, informed consent from both parents and child were obtained from 296 participants. The informed consent (Appendix II) allowed use of the biological parents' heights in order to predict the adult height of the athlete. There were 58 participants whose parents did not give consent for the study and, therefore, heights of the biological parents were not available. Although permission was not granted, these 58 boys were included in the exposure and injury statistics as per agreement with the league. Their heights and weights were also measured as per league requirement and request.

These boys, however, did not complete the questionnaire to assess perception of risk of injury.

Project Design

This is a prospective cohort study. Data were recorded as events unfolding during the season with few exceptions, such as injuries occurring at an away game (each team played four away games). The prospective nature of the study was not compromised even though each team played four away games that were not covered by an athletic trainer. Any injury sustained during an away game was investigated within a day after the game. Even if an injury surveillance study adheres to the strictest definition of being prospective, there are always some injuries that are not brought to the attention of the investigator immediately after they occur. Some athletes may sustain an injury and may not reveal the injury for days or weeks after the initial incident.

Cohort models are better suited for sport level analysis and for estimating injury rates. The case-control method was also used. Case-control models are better suited for player level analysis, deriving odds ratios (OR) and injury prediction.

The most important aspect of any study of injury in sport is the operational definition of an injury. Several definitions have been adopted during the history of injury surveillance. It is difficult, if not impossible, to compare injury studies when the definition of a reportable injury differs from study to study. The following definition of a reportable injury (Powell and Barber-Foss, 1999, pp. 278) has been used in high school injury surveillance studies and was used in the present study:

- "Any injury that causes cessation of participation in the current game or practice and prevents the player's return to that session
- "Any injury that causes cessation of a player's customary participation on the day following the day of onset.
- "Any fracture that occurs, even though the athlete does not miss any regularly scheduled session
- "Any dental injury, including fillings, luxations, and fractures.
- "Any mild brain injury that requires cessation of a player's participation for observation before returning, whether in the current session or the next session."

Since there were certified athletic trainers on site at each practice and home game in the present study, an operational definition of a reportable injury with this detail was applied. With retrospective data or data collected without on-site personnel, this definition of a reportable injury would not be appropriate.

Severity was also based on the model of Powell and Barber-Foss (1999). Injury severity categories were labeled as minor (1-7 days lost), moderate (8-21 days lost), and major (>21 days lost). If an athlete sat out one day for an injury, returned to competition/practice, then sat out another day for the same injury, he was counted as missing two days. If an athlete missed one day for an injury, returned to competition/practice, then missed one day for a new injury, the athlete was counted as missing one day for each injury.

Data Collection

The heights and weights of the players were measured at the beginning of the season (August). Boys wore shorts and a t-shirt, and shoes were removed. Height was taken with a field anthropometer (GPM, Martin type, Pfister Import-Export, Inc.) to the nearest millimeter, and weight was taken with a digital scale to the nearest 0.2 kg. The digital scale was checked at the beginning of every weighing session to make sure it started at zero. For height, the boy was standing erect without shoes and the field anthropometer was placed behind him and aligned with the spine. Replicate measurements were taken on 29 boys. The technical error of measurement (σe) was calculated as the square root of the sum of differences between replicate measurements squared divided by twice the number of replicates (Malina, 1995):

$$\sigma e = \sqrt{\Sigma d^2/2N}.$$

The intraobserver technical error for height was 0.22 cm.

The body mass index (BMI) was calculated as weight (kg) divided by height (meters) squared (kg/m^2). The BMI is an indicator of heaviness, not necessarily fatness in children and adolescents (Malina and Katzmarzyk, 1999).

The leagues established the grouping of participants. League enrollment was open to any child/adolescent in the two communities who was in the 4th through 8th grades. There were two methods of grouping, which were determined by the league (MMPFL, 2000). The teams were first grouped by grade. For example, anyone enrolled to participate in the football league and was in the 6th grade, played on the 6th grade team regardless of age. If a student was held back a year, or advanced a year in school, he participated with the grade in which he attended in school. The second method of grouping only applied if there were enough participants in a particular grade to form several teams. At the very beginning of the season all participants who were in the same grade practiced together. The coaches then had a "draft" and chose players for their respective teams.

The football season lasted from mid-August until the end of October. The first four weeks consisted of practice four times per week. It was mandatory for each player to undergo 8 hours (4 practice sessions) of conditioning before contact drills could be performed. If a player registered late, he still had to undergo the 8 hours of conditioning even if the rest of the team was practicing in full pads. Once games began, practice was reduced to three times per week, except for the eighth grade team, which was allowed to continue practicing four times a week. Each practice session lasted 2 hours. During this time, the athletes did a warm up consisting of a light jog, followed by stretching. After the warm-up, coaches had the players run through drills such as tackling, blocking, and agility. Each team had enough players to field a full offense and defense. The practices usually ended with the teams running plays.

Each team played six games over the seven-week season. A NATA certified athletic trainer (ATC) was on site to record the number of participants at all practices and games, i.e., coach-directed sessions which were opportunities for injury (exposures) and injuries as they occurred. The ATC was the primary on-site caregiver to injured athletes (as agreed by the league organizers) and the primary recorder of injury data. If an athlete was injured during a practice session or a game, the ATC recorded the athlete's grade, position or activity at the time of injury, the assessment of the injury (body part, type of injury), perceived severity, weather and field condition, and the action taken - return to participation, removal from participation, taken to hospital (Appendix III). With regard to away games, the ATC consulted with the head coach at the next practice session to inquire about injuries that may have occurred during the away game. If the coach indicated that an athlete did sustain an injury at an away game, the athlete was then interviewed by the ATC. The certified athletic trainer talked to the parents if the injury was perceived to be serious enough to warrant being seen by a family or emergency room physician. If a child did seek the attention of a physician, further contact was made with the parents of the injured child to attain a more detailed description of the diagnosis. The ATC inquired about the context of the injury, the body part involved, and any time loss. The ATC performed an evaluation of the injury and contacted the parents to discuss possible treatment options. Along with recording injury data, daily logs of attendance, type of session, activities carried out during the session, and weather conditions were recorded (Appendix IV). This information was used to estimate exposure and related conditions.

Participants were also asked to complete a 24-item questionnaire (Appendix V) dealing with the perception of risk of injury in sports (Kontos et al., no date). The questionnaire was administered to the athletes during a practice session. Athletes, who were absent from practice when the questionnaire was issued to their team, missed the opportunity to complete it. Efforts were made to track down athletes who were absent, but compliance was not high. Of the total sample, 240 (72%) boys returned completed questionnaires.

The Risk of Injury Sports Scale (RISSc) requires the participants to answer a series of questions on a six-point scale, 1=very unlikely, 2=unlikely, 3=somewhat unlikely, 4=somewhat likely, 5= likely, 6=very likely. All questions began with the following: What do you think are the chances that you will…? An example of 1 of the 24 possible completions to the beginning of the question is: … injure yourself in a collision with an opponent?

Predicting Adult Height

Percentage of predicted adult height was used to estimate biological maturity status. The procedure is based on the assumption that the closer an individual is to his adult height, the greater his level of maturity (Malina and Bouchard, 1991; Malina and Beunen, 1996). The prediction equation used in the study required the current age, height, and weight of the boy, and midparent height of his biological parents.

Reported heights of both biological parents were obtained for 296 athletes. Since individuals ordinarily over estimate self-reported heights, a correction for reported heights was used (Epstein et al., 1995). The correction formula for males was:

$$2.316 + (0.955 * \text{reported height in inches}),$$

and for females was:

$$2.803 + (0.953 * \text{reported height in inches})$$

Midparent height, the average of parental heights, was calculated as follows:

$$\frac{\text{corrected height, father} + \text{corrected height, mother}}{2}$$

The chronological age of each athlete was converted to a decimal age at the time of examination. This is done by subtracting date of birth from date of examination.

The Khamis-Roche Method for predicting adult height was used. The method requires the child's, current age, height and weight, and midparent height. The formula used for predicting adult heights is as follows:

$$\beta 0 + (\text{stature} * \text{stature constant}) + (\text{weight} * \text{weight constant}) +$$
$$(\text{midparent height} * \text{MPH constant}),$$

where height is in centimeters, weights in kilograms, and MPH in centimeters. The intercept and the constants change for each half-year of decimal age (Khamis and Roche, 1994).

A median absolute deviation (MAD) was used by Khamis and Roche (1994) at each chronological age to measure the accuracy of the prediction method. The MAD is the "...median of the absolute values of the differences between the actual 18 year statures and the predicted 18 year statures" (p. 505). The MAD for the Khamis-Roche (KR) method was compared to the modified RWT (Roche, Wainer and Thissen) method of height prediction, which incorporated skeletal age in the formula. The 90% error bounds for the KR method slightly exceeded those for the modified KWT method by about 0.3 inches or 0.76 cm in males (Khamis and Roche, 1994).

Predicted adult heights were estimated for 36 of the 58 subjects for whom parental data were not available. Mean midparent height of the population was used in the equation. Adult height was not predicted for the remaining 22 boys because one or more of the necessary variables for the calculation were not recorded (age, height or weight).

Predicted adult height and percentage of predicted adult height was estimated for 36 participants for whom parental heights were not available. The mean midparent height of the population (Table 4) was used in the prediction equation. The mean percentage of predicted adult height was 84.2% in boys for whom parental heights were reported with a range of 74.2% to 95.9%. In the sample for which mean midparent height was substituted, the mean percentage of predicted adult height was 83.6% with a range of 74.0% to 94.8%. There does not appear to be a difference between the samples.

After the predicted adult stature was derived for each athlete, maturity status was estimated by expressing current height as a percentage of the predicted adult height. This was done by dividing current height by predicted adult height and expressing it as a percentage. The derived variable is continuous.

The boys were also divided into maturity categories. An athlete whose percentage of predicted adult height was > 1 SD above the mean-for-age reported by Roche et al. (1983) for the Fels longitudinal sample was considered advanced (early) in maturity, and an athlete whose percentage of predicted adult height was >1 SD below the mean-for-age was considered delayed (late) in maturity status. An athlete who fell within +/- 1 SD of the mean for age were considered average or "on time" in maturity.

Roche et al. (1983) report means and standard deviations for single age groups from 5 to 15 years; half-year estimates were not reported. Children in the Fels study were seen within one month of their birthdays. For classifying youth football players in this study as early, average or late in maturity, the Fels means and standard deviations closest to the age of each football player were used. For example, boys between 10.50 and 11.49 years were considered 11 years old, and the mean and standard deviations for 11-year-old boys in the Fels sample was used.

There are very few published articles examining any type of biological maturity indicator and the risk of injury in youth sports. The method of predicting adult stature to assess maturity status has apparently not been used in a sports injury study. Because the Khamis-Roche method is non-invasive, it may be a practical method of estimating the maturity status of children and adolescents.

Injury Rate Analysis

Along with injury information, the ATC recorded exposure data for each grade. For the purposes of the study, an exposure occurred any time an athlete participated in a game or practice session and had a chance of injury. League rules required that a player participating on a 4th-7th-grade team play at least 6 plays in each half of a game. There were no set minimum of plays for 8th grade players. Exposure data were recorded for each practice and each game (home and away). Exposure data allowed for the calculation of injury rates per Athlete

Exposures (AE). Exposure rates were calculated for the entire population, each community, and each grade, and were also differentiated between practice and game rates. The formula for calculating exposure rates was as follow:

(total injuries / athlete exposures) x 1000,

where exposure rate is expressed as injuries per 1000 AE (Powell and Barber-Foss, 1999).

Player rates and case rates were calculated for the population as a whole, each community, and for each grade. These were expressed as player rate/100 players and case rate/100 players. These rates are different from each other because case rates include multiple injuries (Powell and Barber-Foss, 1999). Case rates will always be equal to or higher than player rates. The formulae for calculating player rates and case rates were as follows:

Player rates = # of athletes injured at least once / total # of players

Case Rates = # of total injuries / total # of players

Statistical Analysis

Descriptive statistics were calculated for age, height, weight, the BMI, and percentage of predicted adult height by whole year age group, i.e., 10.0 to 10.99, 11.0-11.99, etc., and by grade. Descriptive statistics were established for each community, each grade/division within each community and each grade/division combined. Age-specific means and standard deviations for height, weight, and the BMI were compared to reference values for American boys (Centers for Disease Control and Prevention, 2000). Age-specific means and standard deviations for the percentage of predicted adult height were compared to the corresponding means and standard deviations for boys in the Fels sample (Roche et al., 1983). After describing the characteristics of the sample, descriptive statistics on injury type, location, position, and rates were calculated.

Chi square ($\chi 2$) analysis was used to compare actual and expected injury distributions. Height, weight, BMI, and maturity status were divided into tertiles as well as a mean split within grade for these analyses. These variables were also cross-tabulated with injured and non-injured players. Tertile categories were established based on the study population. Tertile categories based on the study population rather than national reference data was more appropriate for 2 reasons. First, the study population is not-representative of the national population. Participants in a football league are not a random cross-section of the population. Secondly, there will be too few subjects representing the highs and lows for each variable. For example, if the BMI were categorized into light, average, and heavy according to national reference values, there would be very few subjects in the light range, and an excess number of boys in the heavy range. Grouping into tertiles according to the population allowed a more equal distribution of subjects. Even though a subject might be considered light or short by national reference values, the subject may fit into a different category within the population of youth football players.

The case control method focused on an injured player (case) and three randomly selected teammates (controls) who were participants in the game/practice at which the injury occurred. The cases (injured players) and controls (non-injured players) were compared. Body size and maturity status were split into high and low groups using appropriate methods (i.e., median split, mean split, quartile split) in order to calculate the odds ratio (OR). Odds ratios were calculated for body size (height, weight, BMI) and maturity status. The 95% confidence interval was estimated for each OR. Odds ratios were compared using a Mantel-Haenszel $\chi 2$ test to determine the association between each risk factor and injury. This OR was calculated by dividing the sum, over all strata of XeYo/N by the sum, over all strata of YeXo/N. The Mantel-Haenszel OR is different than a normal OR in that it is a precision-weighted average of the stratum-specific estimates of the uniform OR (MacMahon and Trichopoulos, 1996). The OR takes values between zero ('0') and infinity. One ('1') is the neutral value and means that there is no difference between the groups compared; close to zero or infinity means a large difference. An OR larger than one means that group one has a larger proportion than group two, if the opposite is true the OR will be smaller than one. If you swap the two proportions, the OR will take on its inverse (1/OR) (SISA, 2001).

Because the body size and maturity variables are continuous, logistic regression was used to assess their relative and combined contribution to the prediction of injury in youth football. Linear regression deals with finding a function that relates a continuous outcome variable (dependent variable) to one or more predictors. Logistic regression is a variation of ordinary linear regression, useful when the observed outcome is restricted to two values, which usually represent the occurrence or non-occurrence of some outcome event, in this case injured or non-injured. It was hypothesized that the predictor variables will interact with each other to influence injury. Therefore, within the logistic regression model, two-way and higher order interactions between the predictor variables and injury were evaluated.

Answers from the RISSc questionnaire were grouped into 6 factors: uncontrollable, controllable, overuse, upper-body, surface related, and re-injury (Kontos et al., 2000). A mean score for each factor was calculated. After mean scores for each factor were calculated, logistic regression was used to predict injury, since injury is a binary outcome variable. Descriptive analysis and logistic regression results were compared to results from Kontos (2000) to examine similarities and/or differences in RISSc data among youth football players and youth soccer players. Table 17 shows the reliability analysis of the RISSc questionnaire.

CHAPTER 4

RESULTS

The present study is set in the context of four questions related to injury in youth football:

1. What are the prevalence and incidence of injury in youth football?

2. Do injury rates differ by grade?

3. Are there biological variables (weight, height, biological maturity) that are associated with the risk of being injured, and are there interactions among these variables?

4. Is the perception of risk of injury in youth football related to the likelihood of injury?

Each of the questions is subsequently addressed after the descriptive characteristics of the sample are considered.

Descriptive Statistics

Descriptive statistics for the participants from the two communities and total population are given in Table 5. Data are separated by grade because teams in the Mid-Michigan Pony Football League (2000) were formed according to current grade in school. There are, on average, no significant differences in age, height, weight, the BMI, and the percentage of predicted adult height between players in the two communities. Because participants were grouped by grade in school, there is about a 2-year difference between the youngest and oldest player on each team (Table 4).

Descriptive statistics for height, weight, and the BMI for the combined sample of the two communities grouped by age are shown in Figures 1-3 relative to the reference values for United States boys (Center for Disease Control and Prevention, 2000). The youth football participants in the two mid-Michigan communities are taller (at the 75th percentile) and heavier (above the 75th percentile) than the general population of American boys of the same age. They in turn have a higher BMI, which exceeds the 75th percentile of the reference data

The mean percentage of predicted adult height of the football players is compared to mean values for boys from the Fels Longitudinal Study in Figure 4. On average, the percentage of predicted adult height in the youth football sample attained at each age is consistent with the Fels sample. There is more variation among the football players because they are grouped within whole year age categories whereas the boys in the Fels sample were seen within one month of their birthdays (Roche et al., 1983).

The athletic background of the sample is varied. The subjects had played anywhere from none to 6 other sports besides youth football, with 3 being the median number of sports (Table 6). The most frequent first sports played were tee ball (35.5%) and then soccer (31.0%). Only 6.6% of the sample population reported football as the first organized sport experience (could have been either tackle or flag football).

Almost 30% of those responding to the of sport background questionnaire reported sustaining a previous injury. The detail in the injury description varied greatly among the reports as no operational definition of an injury was indicated in the questionnaire.

Question 1: What are the prevalence and incidence of injury in youth football?

During the course of the season, 100 boys (28%) sustained a reportable injury. Chi square analysis of injuries between the two communities showed no significant difference ($p = .254$, $\chi 2 = 1.353$) in the prevalence of injuries (30% and 26%). The prevalence of reportable injuries increased with grade level and to some extent with age (Table 7). The older population (7th and 8th grade) sustained significantly more injuries ($p = .000$, $\chi 2 = 21.962$) than the younger population (4th-6th grade) of youth football players.

Frequencies of injuries (including multiple injuries to an athlete) by type are summarized in Table 8. Of the 100 boys who were injured, 31 boys sustained a second injury and 6 boys sustained a third injury resulting in a total number of reportable injuries to 137. The most common injury was general trauma (41%), followed by strains (14%) and sprains (13%). There were 12 cases of neurotrauma (concussions, 9%). Over two-thirds (69%) of the injuries were graded as minor (missing less than 7 days), 10% were graded as moderate (missing 8-21 days), and 13% were graded as major (missing more than 21 days and including 10 fractures regardless of time loss). Grading of the remaining 8% of injuries was incomplete. In some cases the athlete never returned to play after sustaining an injury and time loss was unable to be established, or athletes were cleared to play, but did not by their own choice or their parents. Seventh grade subjects sustained 4 of 9 fractures and 4 of 9 neurotraumas (concussions). Sixth and eighth grade subjects sustained most of the general trauma injuries (11 and 13 of 42 injuries, respectively).

Reportable injuries by position or activity at the time of injury are summarized in Table 9. Offensive linemen (tackle to tackle and tight end, excluding split ends, flankers, wide receivers), defensive linemen (ends, tackles, nose guards), and running backs accounted for more than one-half (53%) of the reportable injuries.

Question 2. Do injury rates differ by age and grade?

Injury rates based on athlete exposures are summarized by community and grade for practices, games, and both combined in Tables 10 -14. Exposures were coach-directed sessions, i.e., practices and games (Table 10). Injuries were more common in games (Table 12) than in practice (Table 11), although the ratio of exposure was about 4 to 1 for practices versus games. The differences in estimated injury rates for practices and games between communities across grades were small, 12.1 and 9.7 per 1000 AE for communities A and B, respectively. However, there was variation by grade between communities. Sixth grade players from community A had higher estimated practice, game, and overall rates than 6th grade players in community B, whereas 7th grade players in community B had higher estimated practice, game and overall rates than 7th grade players in community A. Estimated injury rates (per 1000 AE) for grades and communities combined were 9.6 for practices and 18.0 for games (Table 14). The overall injury rate for practices and games together was 11.1 per 1000 AE.

Injury rates during practice sessions were two times higher among 7th and 8th grade participants compared to 4-6th grade participants. Injury rates during games increased with grade level from 4/5th to 7th grades; the lower game rate among 8th grade participants probably reflects sampling variation (only one of the two communities had an 8th grade team). The incident density ratio (game rate/practice rate) was highest for the 6th grade (2.11), identical for the 4/5th and 7th grades (1.65) and lowest for the 8th grade (1.28). The injury rate per 1000 AE was more than two times higher for games than practices among 6th grade players.

For practice sessions and games combined, estimated injury rates differed only slightly between 4/5th -6th grade participants and between 7th - 8th grade participants. Overall injury rates for practices and games combined in 7th and 8th grade players were about twice as high as in 4/5th and 6th grade players.

Table 15 shows cases rates and player rates for each community and the total sample. Table 16 shows player rates and case rates for each grade. Both player and case rates increase with grade. As expected, case rates were higher than player rates because case rates count the total number of injuries and player rates only count the number of injured athletes. Players who sustained more than one injury were counted only once in player rate analysis, yet each injury was used to calculate case rates.

Question 3. Are there biological variables (weight, height, biological maturity) that are associated with the risk of being injured, and are there interactions among these variables?

In order to calculate the odds ratio (OR) to compare injuries at the player level, height, weight and the BMI were split into two equal groups at the mean (high and low). Each of the three variables was plotted on a 2 by 2 table and the OR was calculated. Results are summarized in Table 17.

Odds ratios were calculated by using a mean split for height, weight and BMI for each grade. Lower values (short, light in weight, and low BMI) had a higher relative risk of injury or OR than the upper values in all cases and grades except the 7th grade. Seventh graders, who were taller, had higher BMIs and higher weights were nearly 1.5 times more likely to sustain an injury than seventh grade players who had lower values in height, weight and the BMI. The only significantly high OR was between 4/5th grade boys with a low and high BMI where lower BMI athletes were 3.18 times more likely to sustain an injury than players with a higher BMI ($p = .021$, $\chi 2 = 5.340$). The next group with the highest relative risk was light 4/5th grade players. They are 2.5 times more likely to sustain an injury than heavier 4/5th grade players.

In order to evaluate differences between physical characteristics and injuries, participants within each grade were divided into tertiles for weight, height and BMI. Percentage of predicted adult height was used to divide the sample into three contrasting maturity groups - early, on time, late.

Chi-square analysis of weight, height, the BMI, and estimated maturity status for injured versus non-injured players were run separately for each variable. The chi-square for height, weight and BMI were split into tertiles based on the study population, as well as mean splits within grade. Maturity was divided into tertiles based on the Fels reference data. Results showed that there were no statistically significant differences in injury distribution among players in the tertiles when the population was split by to grade. However, when 4-6th grade subjects were grouped together, subjects with low BMI sustained significantly more injuries than subjects with medium and high BMIs ($p = .038$, $\chi 2 = 6.546$) and less mature subjects sustained significantly more injuries than on-time and early maturers ($p = .009$, $\chi 2 = 9.420$). Older subjects (7-8th grade) combined together did not show any significant differences in injury distribution between low, medium and high categories of height, weight, BMI and estimated maturity.

Chi-square analysis was run with the sample split into younger (4-6th grade) and older (7-8th grade) grades with the biological variables (height, weight, BMI) divided by a mean split into high and low values. A significant difference in injury distribution between high and low values of BMI was seen in the younger group. Lighter subjects were injured more than heavier subjects ($p = .015$, $\chi 2 = 5.920$).

When the population was split according to grade, and height, weight and BMI split into high and low values, chi-square analysis showed that 4/5th graders with a low BMI value sustained more injuries than those with higher BMI's ($p = .021$, $\chi 2 = 5.340$). There were no other significant differences in injury distribution with any other grade level and variable.

A backward stepwise logistic regression was run to analyze possible predictors to injury. Backward stepwise logistic regression begins analysis with all of the desired variables and then removes them one by one if they do not contribute enough to the regression equation. For this analysis, the dependent variable of injured versus not injured was run with height, BMI, and percentage of predicted adult height as the independent biological variables along with the six RISSc factors (uncontrollable, controllable, upper extremity, surface related, reinjury and overuse) as independent psychological variables. Each independent variable was arranged into tertiles. Because of grade related differences in injury rates, separate analyses were done for subjects in the 4th-6th grades and 7th-8th grades.

In the younger population (4th -6th grade), the BMI was the only significant predictor of being injured. The final model showed that an increase in the BMI was protective in nature (Table 19). The BMI was associated with an OR [EXP (B)] of .426 ($p = .044$). In the older population (7th-8th grade), the final model (Table 20) showed that higher concern for uncontrollable injuries was protective in nature ($p = .040$), and higher concern for being reinjured increased the risk of injury ($p = .002$). The OR [EXP (B)] for the RISSc factor labeled uncontrollable was .438 and the odds ratio for the reinjury RISSc factor was 3.88.

Question 4. Is the perception of risk of injury in youth football related to the likelihood of injury?

Partial correlations were run for each biological variable (height, weight, BMI, maturity) with the six RISSc factors (uncontrollable, controllable, overuse, upper extremity, surface related and reinjury). There were significant negative correlations with each biological variable and the uncontrollable RISSc factor in the older population (Table 21). Perception of risk of an uncontrollable injury increased with an increase in height, weight and the BMI. There were no significant correlations in the younger population.

The results of the study can be summarized in the context of the four hypotheses generated:

1. Injury rates increase with grade. This hypothesis was accepted. Injuries in youth football increased with grade level of the competitors.
2. Weight, height, the BMI, and biological maturity by themselves do not increase the likelihood of injury in youth football. This hypothesis was also accepted. Weight, height, the BMI, and estimated maturity status were not significant risk factors for injury in youth football.
3. Player's perception of risk influences the likelihood of injury. This hypothesis was partially supported, but only in older players (7th and 8th grades). Two expressed concerned related to perception of risk were significant predictors of injury: uncontrollable factors and re-injury.
4. Internal variables (player-related factors) interact to influence the risk of injury in youth football. This hypothesis was not supported in the analysis. There were no significant interactions terms.

CHAPTER 5

DISCUSSION

Youth football is a popular sport. Because football is a contact sport, it often results in injuries to participants. It is also a sport that is subject to scrutiny regarding safety and the appropriate age, size and maturity of youth participants. The present study is set in the context of four questions related to injury in youth football:

1. What are the prevalence and incidence of injury in youth football?

2. Do injury rates differ by age and grade?

3. Are there biological variables (weight, height, biological maturity) that are associated with the risk of being injured, and are there interactions among these variables?

4. Is the perception of risk of injury in youth football related to the likelihood of injury?

The results of this study have relevance to several areas. First, there is limited data on injuries in youth football. This study provides in-depth analysis of injury rates in present day youth football in two communities. It thus addresses issues at the local level of youth sports, a level that has received much less consideration than the interscholastic level. The most recent study on injuries in youth football is that of Goldberg et al (1988). None of the previous studies on injuries in youth football employed certified athletic trainers to record injuries on a day-to-day basis. The prospective nature of this study is unique and important especially with regard to accuracy in time loss from participation and the follow up of injuries. The results of this study have the potential to build a base for subsequent studies. The approach used in the present study provided sound data. In addition, having a certified athletic trainer on hand for practices and games permitted on field care of injuries as they occurred.

From a second perspective, player-related risk factors for injury in youth football have not been systematically evaluated. The dissertation by Violette (1976) was one of the only studies to evaluate biological maturity status in the context of interscholastic football injuries. However, risk analysis using this variable was not done. Violette assessed maturity with a composite score of three secondary sex characteristics – testicular volume, pubic hair and axillary hair. Estimating biological maturity in this manner is not practical for several reasons. A trained individual is needed to assess secondary sex characteristics. It would be best for one individual to assess the secondary sex characteristics, but it would take too much time. Having several people perform the assessment (such as physicians performing pre-participation physical examinations) would decrease the reliability. Also, in today's social climate, it would be very difficult to gain parental consent to perform such an invasive assessment on a child or adolescent. Therefore, a non-invasive method of estimating biological maturity could be of value. The method of estimating biological maturity in this study has apparently not been used previously in this context. If youth football leagues were concerned about matching participants by maturity status, coaches or league officials could easily utilize the non-invasive method adopted in this study.

The study design could be modified to examine body size and maturity as risk factors for injury in other sports, as well as for the estimation of injury rates. Height and weight are relatively easy measurements, and the BMI is a rather simple calculation. In fact, youth football leagues usually require height and weight, and coaches and league officials will most likely be happy to have a researcher take the heights and weights.

A comparison of this study to previous research is difficult. There are no previous studies that use similar study design, definition of a reportable injury, or population in examining injuries in youth football. A three-year study conducted by the National Athletic Trainers Association (Powell and Barber-Foss, 1999) examined 10 high school varsity sports, including football. The exposure criteria and definition of a reportable injury were similar to this study with the main difference being the age of the players. For both studies, injury rates were higher in game sessions than during practices. Game rates were four times higher than practices in the NATA 3-year study and were about twice as high in this study. In both studies, most injuries were classified as minor (loss of 1-7 days). High school players in the NATA 3-year study suffered more sprains than any other type of injury (31.7%), while youth football players in this study suffered more general trauma injuries than any other (40%), with sprains ranking third with 13.1% of the injuries. Injury rate comparisons between the youth football players in this study and the high school players in the NATA study revealed that high school football players have higher case and player rates yet the youth football players had a higher exposure rate.

There are several published studies on injuries in youth football and even though injury rates in those studies do not resemble the injury rates of this study, there are some similar trends. The study by Goldberg et al. (1988) examined six New England Pop Warner Football Leagues and established that the older, heavier players had the highest injury rates and the smaller, lighter teams had the lowest injury rates. Similar results were found in an earlier study by Goldberg (1984); however, a study by Roser and Clawson (1970) did not show this trend.

Another similarity between this study and the study by Goldberg et al. (1988) is the risk of injury between practice and game sessions. Although Goldberg and colleagues did not estimate exposure rates, they established that twice as many injuries occurred during games than in practices, much like this study.

The injury rates established in previous studies (Goldberg et al., 1988; Goldberg, 1984, Roser and Clawson, 1970; Silverstein, 1979) were in most cases much lower than this study. There are two main reasons for this; the definition of a reportable injury and the method of reporting injuries were different. Even if a study was listed as prospective, there was always some period of time (usually at least a week) before the injuries were reported. Roser and Clawson were the only investigators that established a system of daily reporting of injuries by the coaches. Only injuries that caused a player to miss at least one week of participation were counted which made the injury rate very low.

In the present study, injury rates were higher among the older athletes (7th - 8th grades) than younger athletes (4th – 6th grades) and injuries occurred twice as often in games than in practices across the sample population. The athletic trainer to player ratio was much smaller during games than practices, which could be a factor in higher injury rates during games. Body size is considered and advantage in American youth football, however, body size in general had little impact on the risk of injury in the present study. Only the BMI in the younger players was a predictor of injury. From the perspective of perception of risk of injury, concerns related to uncontrollable factors and re-injury appeared as predictors of injury in the older players. Although estimated biological maturity status as used in this study was not a significant predictor of injury in youth football, this study showed the practicality of using predicted adult height as a maturity indicator rather than traditional methods such as skeletal age.

In summary, results of this study showed that body size, maturity status, and perception of risk of injury may, in some instances, be predictive of injury in youth football. However, there are no clear trends throughout the study population. The greatest differences in injury distribution occurred with younger players (4-6th grades) who are less mature and have a lower BMI. This is potentially important information for youth football leagues, coaches, and parents who are concerned about the size and maturity of the participants. If a small child or adolescent wants to play football, the risk of injury seems to be greater for a light and less mature child whereas a lighter and/or less mature adolescent is at relatively the same risk as a heavier, more mature player. This seems to contradict the view of many parents who worry about the safety of their child and urge the child to play another sport, which they feel is safer, or poses less risk of injury. It is difficult to assess whether or not football is any more dangerous than other sports such as soccer, but knowing that participants, in general, have a similar risk of injury in youth football is important.

There seems to be a biological influence on the psychology of being injured in older youth players. This could be the result of the socialization into football related to body size. Larger, heavier players are more likely to have positive reinforcement in football than lighter players and, therefore, to have a lower perception of risk of injury. These results differ from those of Kontos (2000) in a study of youth soccer players. Heavier players had a higher perception of risk of injury than lighter players, most likely due to a negative association between being larger in size in a sport where speed and agility is preferred. The biological influence seems to be limited to heaviness (BMI) and not to height or weight. Also, the population of youth football players is taller and heavier than national reference data, suggesting that direct or indirect selection of youth football participants. A taller, heavier, and likely more mature child / adolescent is more likely encouraged to participate in youth football, or the child himself may want to participate because of his body size.

Results from this study or from similar studies in the future have implications for youth football and perhaps other youth sports. Injury rates, injury types and injury severity will be better understood. Hopefully the true risk of injury in youth football will be made clearer and myths associated with this sport will be diminished. The significance of body size and biological maturity with regard to risk of injury and team selection will be better understood and utilized.

Injury surveillance and medical coverage at the community level could be regarded as an important and valuable service. The use of certified athletic trainers is expanding and there could be a market at the community level.

Future research should focus on comparison of different sports and also on different leagues of youth football that institute different sets of safety rules. The Mid-Michigan Pony Football League's rules are different than Pop Warner football rules regarding the matching of players. The same type of study on other sports such as soccer, basketball, ice hockey should be done for comparison of injury rates as well as examination of biological risk factors. It is possible that studies will reveal that the incidence and prevalence of injury in other sports are higher or lower than youth football or that player-related risk factors better predictors of the risk of injury in those sports. Regardless, there are limited studies on injuries in youth sports at the local level and a larger focus should be placed on scientific research at this level because of the sheer numbers of participants involved.

Longitudinal studies should be conducted to better examine injury patterns, rates, type and severity. One season of data can give a general indication of injury rates and patterns. Data collected over a five-year time period will likely follow the many of the same athletes throughout a career in youth football (4th-8th grade). Specific to this study, future measurements of the actual adult height attained by the participants of this study will show the accuracy of the predicted adult height method used to estimate maturity status.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The present study concerned injury in a sample of sports participants 9-14 years of age in a single sport – American youth football – over the course of a single season. Several specific questions were the focus of the study:

1. What are the prevalence and incidence of injury in youth football?

2. Do injury rates differ grade?

3. Are there biological variables (weight, height, biological maturity) that are associated with the risk of being injured, and are there interactions among these variables?

4. Is the perception of risk of injury in youth football related to the likelihood of injury?

The subjects were 355 youth football players 9-14 years of age in the 4th to 8th grades from two communities in south central Michigan (Holt [n = 210] and St. John's [n = 145]). The heights and weights of the players were measured at the beginning of the season (August). Boys wore shorts and a t-shirt, and shoes were removed. The body mass index (BMI) was calculated as weight (kg) divided by height (meters) squared (kg/m2).

Participants were also asked to complete a 24-item questionnaire dealing with the perception of risk of injury in sports (Kontos et al., no date). The questionnaire was administered to the athletes during a practice session. Of the total sample, 240 (72%) boys returned completed questionnaires.

Percentage of predicted adult height was used as an estimate biological maturity status. The procedure is based on the assumption that the closer an individual is to his adult height, the greater his level of maturity. The prediction equation used in the study required the current age, height, and weight of the boy, and midparent height of his biological parents. Reported heights of both biological parents were obtained for 296 athletes. Since individuals ordinarily over estimate self-reported heights, a correction for reported heights was used. The Khamis-Roche Method for predicting adult height was used. The method requires the child's, current decimal age, height and weight, and midparent height.

Predicted adult heights were estimated for 36 of the 58 subjects for whom parental data were not available. Mean midparent height of the population was used in the equation. Adult height was not predicted for the remaining 22 boys because one or more of the necessary variables for the calculation were not recorded (age, height or weight). Predicted adult height and percentage of predicted adult height was estimated for 36 participants for whom parental heights were not available. The mean midparent height of the population was used in the prediction equation. Maturity status was estimated by expressing current height as a percentage of the predicted adult height.

The boys were also divided into maturity categories. An athlete whose percentage of predicted adult height was > 1 SD above the mean-for-age for the reference samples (Fels longitudinal study) was considered advanced (early) in maturity, and an athlete whose percentage of predicted adult height was >1 SD belo

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below the mean-for-age was considered delayed (late) in maturity status. An athlete who fell within +/- 1 SD of the mean for age were considered average or “on time” in maturity.

The leagues established the grouping of participants by grade. The football season lasted from mid-August until the end of October. The first four weeks consisted of practice four times per week. It was mandatory for each player to undergo 8 hours (4 practice sessions) of conditioning before contact drills could be performed. Each team played six games over the seven-week season.

A NATA certified athletic trainer (ATC) was on site to record the number of participants at all practices and games, i.e., coach-directed sessions, which were opportunities for injury (exposures) and injuries as they occurred. The ATC was the primary on-site caregiver to injured athletes (as agreed by the league organizers) and the primary recorder of injury data. If an athlete was injured during a practice session or a game, the ATC recorded the athlete’s grade, position or activity at the time of injury, the assessment of the injury (body part, type of injury), perceived severity, weather and field condition, and the action taken - return to participation, removal from participation, taken to hospital. With regard to away games, the ATC consulted with the head coach at the next practice session to inquire about injuries that may have occurred during the away game. If the coach indicated that an athlete did sustain an injury at an away game, the athlete was then interviewed by the ATC. The certified athletic trainer talked to the parents if the injury was perceived to be serious enough to warrant being seen by a family or emergency room physician. If a child did seek the attention of a physician, further contact was made with the parents of the injured child to attain a more detailed description of the diagnosis. The ATC inquired about the context of the injury, the body part involved, and any time loss. The ATC performed an evaluation of the injury and contacted the parents to discuss possible treatment options. Along with recording injury data, daily logs of attendance, type of session, activities carried out during the session, and weather conditions were recorded. This information was used to estimate exposure and related conditions.

Along with injury information, the ATC recorded exposure data for each grade. For the purposes of the study, an exposure occurred any time an athlete participated in a game or practice session and had a chance of injury. League rules required that a player play at least 6 plays in each half of a game. Exposure data were recorded for each practice and each game (home and away). Exposure data allowed for the calculation of injury rates per Athlete Exposures (AE). Exposure rates were calculated for the entire population, each community, and each grade, and were also differentiated between practice and game rates.

Descriptive statistics were calculated for age, height, weight, the BMI, and percentage of predicted adult height by whole year age group, i.e., 10.0 to 10.99, 11.0-11.99, etc., and by grade. Age-specific means and standard deviations for height, weight, and the BMI were compared to reference values for American boys (Centers for Disease Control and Prevention, 2000), and corresponding values for the percentage of predicted adult height were compared to the corresponding means and standard deviations for boys in the Fels sample.

Chi square ($\chi2$) analysis was used to compare actual and expected injury distributions. Height, weight, BMI, and maturity status were divided into tertiles as well as a mean split within grade for these analyses. These variables were also cross-tabulated with injured and non-injured players.

The case control method focused on an injured player (case) and three randomly selected teammates (controls) who were participants in the game/practice at which the injury occurred. The cases (injured players) and controls (non-injured players) were compared.

Body size and maturity status were split into high and low groups using appropriate methods (i.e., median split, mean split, quartile split) in order to calculate the odds ratio (OR). Odds ratios were calculated for body size (height, weight, BMI) and maturity status. The 95% confidence interval was estimated for each OR. Odds ratios were compared using a Mantel-Haenszel $\chi2$ test to determine the association between each risk factor and injury. Logistic regression was used to assess their relative and combined contribution to the prediction of injury in youth football.

Injury rates show an increase with grade, which is logical because players in higher grades are larger and more force is created with impact and torque. It is difficult to compare the injury rates of this sample with previous studies because research is lacking and there are different definitions of an injury in available research. Although biological variables (height, weight, BMI, maturity status) do not seem to interact to influence the chance of injury, there is some evidence that individual variables are associated with an increased likelihood of injury. An increase in BMI is associated with an increased likelihood of injury in the younger population (4th-6th grade). Of the six factors in the RISSc questionnaire, only 2 (reinjury and uncontrollable injury) seem to be predictors of injury, but only in the older population (7th-8th grade).

Youth sports is an area where there are large numbers of participants and a serious lack of research examining injuries. Most of the few studies that do exist do not examine player-related risk factors such as height, weight, body mass index and especially maturity status. These are areas that need systematic examination due to the variability in body size and maturity of the participants. After the examination of injuries and body size in a midwestern youth football league, it is clear that further research needs to be conducted. Factors that have been reached in this study are:

- Injury rates increase with grade.
- Most injuries are minor – not requiring long periods of time before return to play.
- Most injuries occur to interior linemen.
- Contusions/General trauma are the most prevalent injury type.
- Maturity status expressed as a percentage of predicted adult height does not seem to influence the chance of injury.

Table 1. Injury rates per 1,000 exposures by sex and level of competition of numerous high school sports over an 8-year period1.

Level	BOYS	GIRLS
Intermediate	0.66	0.69
Junior Varsity	0.91	0.66
Junior Varsity and Varsity	0.63	0.57
Varsity	1.38	0.65
Total	0.89	0.64

1 Adapted from Beachy et al. (1997)

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Table 2. Injury rates among high school football players by source of data and definition of injury.

Investigator	Method of data collection	Definition of injury	Injury rate (%)
Adkison et al., (1974)	Daily reports by a team representative	Traumatic medical condition during game play resulting in any one of the following: necessitated discontinuation of participation for the remainder of the game; resulted in missing two or more practices; resulted in missing one or more subsequent games.	53.0a
Blyth and Mueller (1974)	Weekly, direct interview	Medical treatment or usual activity restricted 1 day beyond the injury.	48.8
Garrick and Requa b (1978)	Weekly, direct interview	One or more practices altered or missed.	81.1
Olson c (1979)	School generated reports	Two or more practices missed.	10.5
Prichett d (1980)	Insurance claims	Claim filed	24.9
DeLee and Farney (1992)	Daily reports by certified athletic trainers	Causing to miss all or part of a practice or game; treated by a physician; all head injuries reported to an athletic trainer.	50.6
Powell and Barber-Foss (1999)	Prospective, daily reports by certified athletic trainers; direct interview	Any injury that causes cessation of participation in the current game or practice and prevents the player's return to that session; Any injury that causes cessation of a player's customary participation on the day following the day of onset; Any fracture that occurs, even though the athlete does not miss any regularly scheduled session; Any dental injury, including fillings, luxations, and fractures; Any mild brain injury that requires cessation of a player's participation for observation before returning, whether in the current session or the next session.	37.6

a Games only

b,c,d Adapted from Thompson et al., (1987)

Table 3. Injury rates among youth football players by source of data and definition of injury.

Investigator	Method of data collection	Definition of injury	Injury rate (%)
Roser and Clawson (1979)	Questionnaires filled out by coaches when a player was injured	Missing a practice or a game	2.3
Silverstein (1979)	Direct observation	None	1977 – 18.1 1978 – 12.9
Goldberg et al., (1984)	Questionnaires completed by league personnel and telephone interview with parent of injured child	Missing at least one practice or game session	15.4
Goldberg et al. (1988)	Retrospective telephone survey at end of season	Greater than seven days restriction	5.0

Table 4. Characteristics of players by grade and community.

	Community A			Community B			Total		
	N	M	SD	N	M	SD	N	M	SD
Age (years)									
4/5th	80	10.1	0.67	53	10.3	.65	133	10.2	0.66
6th	41	11.5	0.41	43	11.7	.46	84	11.6	0.46
7th	63	12.5	0.34	42	12.8	.47	95	12.6	0.42
8th	35	13.5	0.36				35	13.5	0.36
Height (cm)									
4/5th	76	141.6	8.2	48	143.0	7.1	124	142.1	7.8
6th	40	149.2	6.6	44	151.9	7.0	84	150.6	6.9
7th	52	157.0	6.5	41	160.3	8.2	93	158.5	7.4
8th	34	167.1	7.6				34	167.1	7.6
Weight (kg)									
4/5th	76	42.0	12.5	52	41.4	11.5	128	41.8	12.1
6th	40	46.7	14.3	43	50.1	12.0	83	48.5	13.2
7th	52	54.7	13.3	45	57.2	13.9	97	55.9	13.6
8th	34	66.6	15.8				34	66.6	15.8
BMI (kg/m2)									
4/5th	76	20.6	4.3	47	19.9	4.1	123	20.3	4.2
6th	40	20.7	4.7	42	21.5	3.9	82	21.1	4.3
7th	52	22.1	4.4	41	22.2	4.3	93	22.1	4.4
8th	34	23.7	4.6				34	23.7	4.6
Percentage of predicted adult ht.									
4/5th	73	79.4	2.8	46	79.9	2.7	119	79.6	2.7
6th	39	83.3	2.4	38	84.2	2.3	77	83.7	2.4
7th	51	87.2	2.5	37	88.7	2.6	88	87.8	2.6
8th	33	91.7	3.0				33	91.7	3.0

Table 5. Mean corrected parental heights and midparent heights (cm).

	Mean	SD	Minimum	Maximum
Father	178.4	6.6	153.6	202.4
Mother	164.9	6.3	151.2	183.8
Midparent	171.7	4.8	153.1	191.9

Table 6. First organized sports reported by the study population.

Sport	N	%
Tee ball	103	35.5
Soccer	90	31.0
Baseball	19	6.6
Football	19	6.6
Floor Hockey	16	5.5
Basketball	13	4.5
Other *	9	3.1
Ice Hockey	7	2.4
Wrestling	6	2.1
Softball	5	1.7
Swimming	3	1.0

* Other – martial arts, bowling, track & field

Table 7. Prevalence of injured players during the season by grade and age group.

Grade	N	N Injured	%
4-5th	134	24	17.9
6th	87	19	23.0
7th	99	39	39.4
8th	35	18	51.4
Total	355	100	28.5

Age	N	N Injured	%
9	30	5	16.7
10	54	8	14.8
11	87	19	21.8
12	81	22	27.2
13/14	82	35	42.7
Total	347	98	28.2

Table 8. Types of reportable injuries sustained during the football season, communities combined.

Injury	Frequency	%
General Trauma	55	40.0
Strains	20	14.6
Sprains	18	13.1
Others 1	13	9.5
Neurotrauma	12	8.8
Fractures	10	7.3
Overuse	4	2.9
Non-specified	5	2.2

1 Others include upset stomach, general feeling of malaise, headache, and other illnesses that could have been heat related. However, there was only one case of heat exhaustion.

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Table 9. Frequency of reportable injuries by position or activity during the season, communities combined.1

Position/Activity	Frequency	%
Offensive Line	25	18.2
Defensive Line	25	18.2
Running Back	22	16.1
Drills	15	10.9
Defensive Back	14	10.2
Wide Receiver	8	5.8
Quarterback	8	5.8
Linebacker	6	4.4
Special Teams	5	3.6
Non-specified	7	6.6

1 Position refers to the specific position that an athlete was playing when the injury occurred. Many boys played more than one position.

Table 10. Athlete exposures by practices, games, and both combined by community.

Practices	Community A	Community B	Combined Communities
4/5th grade	2143	1486	3629
6th grade	1150	1265	2415
7th grade	1567	1320	2887
8th grade	1156	0	1156
Games			
4/5th grade	453	306	759
6th grade	240	260	500
7th grade	383	288	671
8th grade	291	0	291
Practice & Games Combined			
4/5th grade	2593	1792	4388
6th grade	1390	1525	2915
7th grade	1950	1608	3558
8th grade	1447	0	1447
Total	7383	4925	12308

Table 11. Estimated practice rates per 1000 athlete exposures (AE) by grade and community.

	Community A	Community B
4/5th	5.6	6.7
6th	11.3	2.3
7th	12.8	15.9
8th	14.7	
Total	10.6	8.1

Table 12. Estimated game rates per 1000 athlete exposures (AE) by grade and community.

	Community A	Community B
4/5th	11.0	13.1
6th	25.0	7.7
7th	21.1	31.3
8th	20.6	
Total	18.3	17.6

Table 13. Estimated game and practice rates combined per 1000 athlete exposures (AE) by grade and community.

	Community A	Community B
4/5th	6.5	7.8
6th	13.7	3.3
7th	14.2	18.7
8th	15.9	
Total	12.1	9.7

Table 14. Estimated game and practice injury rates, and rates for games and practices combined per 1000 athlete exposure (AE) by grade in the total sample.

	Practices	Games	Total
4/5th	6.1	11.9	7.1
6th	6.6	16.0	8.2
7th	14.2	25.8	16.3
8th	14.7	20.6	15.9
Total	9.6	18.0	11.1

Table 15. Estimated injury case rates and player rates per 100 players by community, and communities combined.

	Communities A	Communities B	Communities Combined
Injury Rate			
Case Rate	42.4	33.1	38.6
Player Rate	30.5	24.8	28.4

Table 16. Estimated player rates and case rates per 100 players by grade.

Grade	Player Rates	Case Rates
4/5th	18	24
6th	22	26
7th	39	60
8th	51	66

Table 17. Odds ratios of being injured for upper (above the mean) and lower (below the mean) values of height, weight and body mass index.

Variable	Low	High
4/5 grades		
Height	1.7	0.6
Weight	2.5	0.4
BMI	3.2	0.3
6th grade		
Height	1.0	1.0
Weight	1.5	0.7
BMI	1.8	0.6
7th grade		
Height	0.7	1.5
Weight	0.7	1.5
BMI	0.7	1.5
8th grade		
Height	1.6	0.6
Weight	1.6	0.6
Body mass index	1.0	1.0

Table 18. Reliability of the RISSc questionnaire.

Factor	YOUNGER - Alpha	OLDER - Alpha
Uncontrollable	.75	.77
Controllable	.80	.78
Overuse	.75	.74
Upper Body	.75	.74
Surface Related	.64	.63
Re-Injury	.60	.62

Table 19. Logistic Regression final model in 4th-6th grade.

Variables	EXP (B)	95% Confidence Interval for EXP (B) Lower	Upper
BMI	.426	.210	.867

Table 20. Logistic Regression final model in 7th-8th grade.

Variables	EXP (B)	95% Confidence Interval for EXP (B) Lower	Upper
Uncontrollable	.438	.099	.965
Reinjury	3.883	1.629	9.256

Table 21. Partial correlations for biological variables (height, weight, BMI, maturity) and the Uncontrollable RISSc factor in the older population.

	Correlation	Significance
Height	-.2662	.009
BMI	-.1873	.071
Weight	-.2516	.014
Maturity	-.2029	.052

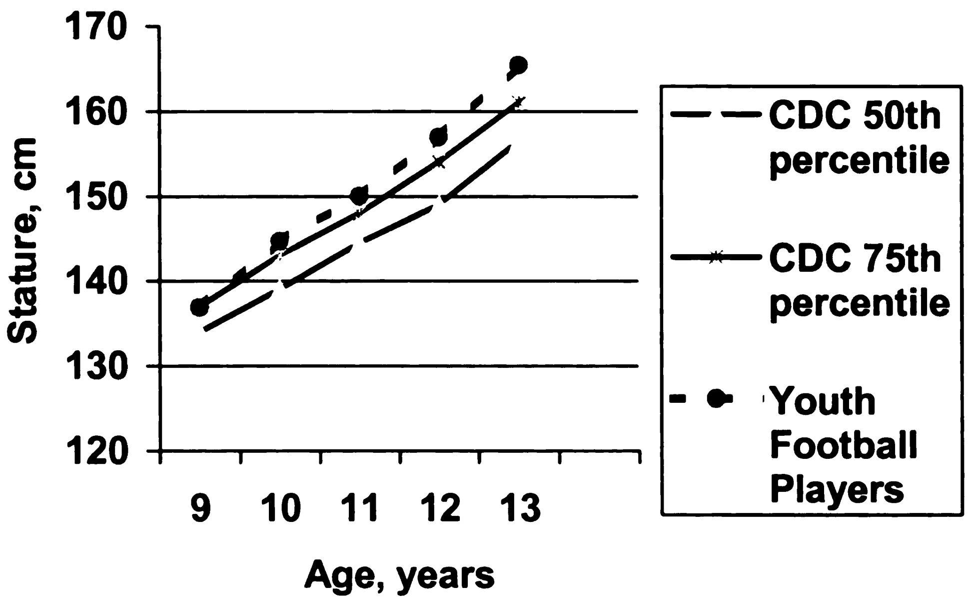

Figure 1. Mean heights of youth football players relative to reference values for United States boys.

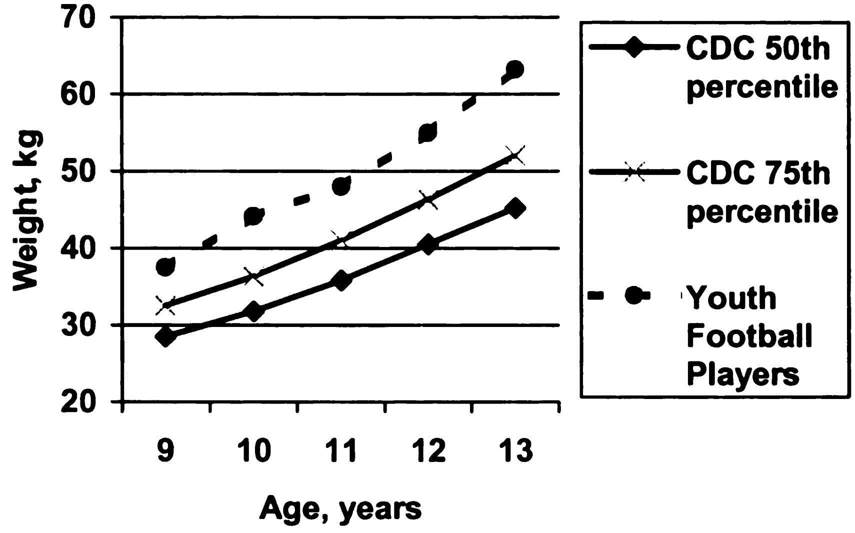

Figure 2. Mean weights of youth football players relative to reference values for United States boys.

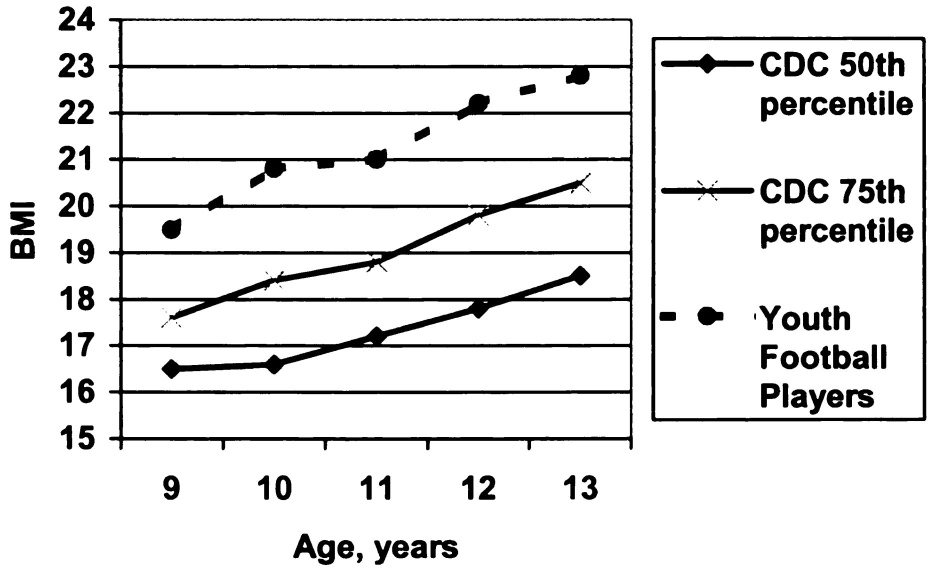

Figure 3. Mean BMI's of youth football players relative to reference values for United States boys.

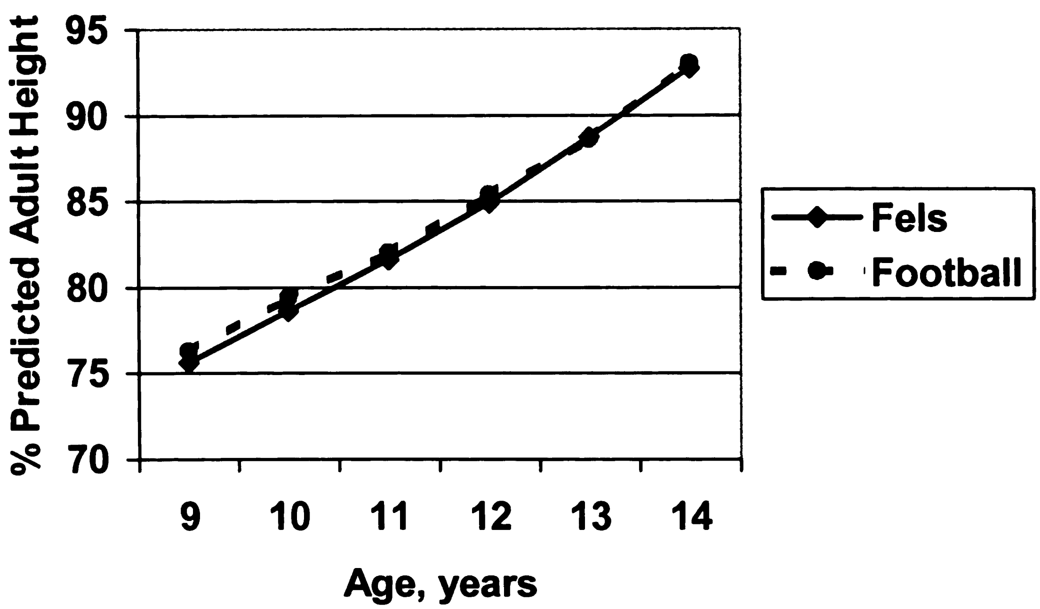

Figure 4. Mean percentage of predicted adult height in youth football players compared to corresponding data for males from the Fels Research Institute longitudinal growth study upon whom the height prediction equations were based

Appendix I

MICHIGAN STATE
UNIVERSITY

June 5, 2001

TO: Robert MALINA
128 IM Sports Circle

RE: IRB # 00-282 CATEGORY: FULL REVIEW
RENEWAL APPROVAL DATE: June 4, 2001

TITLE: INCIDENCE AND PLAYER RISK FACTORS FOR INJURY IN YOUTH FOOTBALL

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the UCRIHS APPROVED THIS PROJECT'S RENEWAL.

This letter also notes approval for addition of Co-PIs (Morano and Barron), revised consent form.

RENEWALS: UCRIHS approval is valid for one calendar year, beginning with the approval date shown above. Projects continuing beyond one year must be renewed with the green renewal form. A maximum of four such expedited renewal are possible. Investigators wishing to continue a project beyond that time need to submit it again for complete review.

REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please use the green renewal form. To revise an approved protocol at any other time during the year, send your written request to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.

PROBLEMS/CHANGES: Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of further assistance, please contact us at 517 355-2180 or via email: UCRIHS@pilot.msu.edu.

Sincerely,

Ashir Kumar, M.D.
Interim Chair, UCRIHS

AK: br

cc: Peter Morano
128 IM Sports Circle

OFFICE OF
RESEARCH
AND
GRADUATE
STUDIES

University Committee on
Research Involving
Human Subjects

Michigan State University
246 Administration Building
East Lansing, Michigan
48824-1046

517/355-2180
FAX: 517/353-2976
Web: www.msu.edu/user/ucrihs
E-Mail: ucrihs@msu.edu

Appendix II

Participant Consent Form

Michigan State University
Institute for the Study of Youth Sports
213 IM Sports Circle
East Lansing, MI 48824-1049
517 355-7620

Thank you for participating in this study designed to assess the thoughts you have concerning being injured when playing sports. This study will provide information concerning the events that might lead to injury in youth sport participants.

For this study, you will be asked to complete a questionnaire regarding your thoughts on being injured in sports. We will also measure your weight and height. This will be done at the beginning of the season at equipment handout and will take approximately 10 minutes of your time. In addition, any injury or injuries that you have during your football season will also be recorded by a certified athletic trainer. If you are injured, we will call you to discuss your injury in more detail. You will also be asked to provide written information about your age, previous injuries, and experience in sport.

All data that you provide, and the results of this study will be confidential and anonymously reported. You will be assigned a coded identification number to be used on all information. All questionnaires and individual data will be stored in a locked area accessible only to the investigators of the study. Only group data will be used in any reporting or future use of the information from this study. Group results will be made available to you on request.

Participation in this study is voluntary. You may choose not to participate at all, refuse to answer certain questions, or withdraw from the study at anytime, without penalty.

Any questions concerning participation in this study should be directed to Robert M. Malina, Professor of Kinesiology, 517 355-7620. If you have additional questions or concerns about your rights in this research study, please feel free to contact David Wright, Michigan State University's Chair of the Committee on Research Involving Human Subjects at 517 355-2180.

Thank you for your time and cooperation.

I have read the above description of this study. I understand my rights as a participant and agree to participate in this study.

Please Print: ____

First Name Initial Last Name

______________________ ______________________

Signature Date

Appendix III

Parental Informed Consent Form

Michigan State University
Institute for the Study of Youth Sports
213 IM Sports Circle
East Lansing, MI 48824-1049
517 355-7620

Dear Parents/Guardians:

Hello! Robert M. Malina, Ph.D., Professor of Kinesiology and Mary Barron (ATC, certified athletic trainer), a master' student and another master's student (an ATC, to be named) at Michigan State University are currently working on a study entitled "Incidence and Player Risk Factors for Injury in Youth Football." Dr. Jeffrey Kovan, Head Physician for the MSU Sportsmedicine Team, is a consultant for the project. This study will assess the relationship between the perception of risk of injury and body size on injury occurrence among youth football participants.

The study will involve your son's participation at the beginning and end the football season in completing a questionnaire designed to learn more about his thoughts regarding injuries in sport. Your son's height and weight will also be measured at the beginning of the season. You will be asked to provide information on your son's previous experiences in youth sports and about injuries in sport if he has had any. In addition, we will ask you to report your own height, that is, that of the boy's father and mother. This information will be used to estimate how tall your son will be as a young adult, so that we can express his current height as a percentage of his predicted adult height. This will provide us with an estimate of his maturity status, boys closer to their predicted adult height are more mature than boys who are further removed from their adult height.

During the course of the football season, the certified athletic trainer participating in the study, will record information concerning injuries that occur during a practice session or a game during the course of the season. If your son is injured, we will contact you by phone to obtain more detailed information about the injury (type, severity, treatment). With your permission, we also will discuss the injury with your son to get his view of what happened and how it might influence his return to the sport.

All identities and recorded information from the study will remain confidential and be analyzed using individual identification numbers. Participants will remain anonymous in any reporting of the data from the study.

In order for us to complete the study, we will need your written consent in the space below to allow your son to participate in the study. Participation in the study is voluntary and your son can decide to discontinue participation at any time. If your child decides to discontinue participation, his will not be used.

Any questions concerning participation of your child in this study should be directed to Robert M. Malina, Professor of Kinesiology, 517 355-7620. If you have additional questions or concerns about your son's rights in this research study, please feel free to contact David Wright, Michigan State University's Chair of the Committee on Research Involving Human Subjects at 517 355-2180.

I, _________________________ agree to allow my child ___________________
Your name-printed Your child's name-printed

to participate in this study.

___________________________ ____________________
Your signature Date

Thank you for your consent for your child's participation in this study. **Please have your child return the completed form to us at the equipment handout session.**

Thank you,

Robert M. Malina, Ph.D., FACSM
Department of Kinesiology
128 IM Sports Circle
Michigan State University
East Lansing, MI 48824
517 355 7620
RMALINA@pilot.msu.edu

Appendix IV

Background in Sport Information

Child's Name________________________________

Date of Birth:________________________________

Today's Date:________________________________

How old was your child when he first began to play on an organized sport team (such as soccer, t-ball, football) that practiced and played a regular schedule of games, or when he first began to regularly practice and compete in an organized sport program (such as football, swimming)? Organized means that you had an assigned coach for your team or sport.___________________

What was the first organized sport that your son played?____________________

What other organized sports has your son played and how many years has he played each sport?

SPORT YEARS

____

____

____

____

____

Has you son ever been injured during a sport practice or during a game/competition?

Yes No

Please continue on the next page

If yes, please circle the appropriate answer:

1. What specific body part was injured?

   head/neck face shoulder/arm forearm-wrist-hand

   trunk hip-thigh-leg knee ankle-foot other

2. What type of injury was it?

   sprain/strain fracture laceration general trauma

3. Did your son receive treatment? Yes No If yes, was he treated at:

   an emergency room or hospital Yes No

   a doctor's office Yes No

   at home Yes No

4. Did your son miss any games/competitions/practices due to the injury? Yes

   No

In evaluating the height and weight of your son, it is important to know the size of the biological parents. Please report the height of both parents to the nearest 1/4 inch (without shoes):

Father's height___________________________

Mother's height___________________________

Appendix V

Game/Practice Information Form

DATE________________________________

LOCATION______________________________

TYPE OF SESSION: __________PRACTICE __________GAME

NUMBER OF ATHLETES__________________

LENGTH OF SESSION_________________________min.

IF PRACTICE: SPECIFIC ACTIVITIES

____

____

____

____

____

____

____

____

Appendix VI

Injury Report Form

NAME______________________ DATE______________

Athletic Session

Game: Warm-up 1st Quarter 2nd Quarter 3rd Quarter 4th Quarter

Practice:

Position of injured played: Offense________________Defense_______________

Type of surface _________Natural _________Artificial

Surface condition ________Dry ____Wet ____Muddy ______Frozen

Weather conditions:.Hot___Warm___Cool_________Cold___Rain_____Snow

Point in Season____

Action Taken:_____Removed from participation and returned immediately
______Returned from participation and returned after resting
______Removed from remainder of participation
______Taken to hospital by parent
______Taken to hospital by ambulance

Clinical Impression:
Injured Part of Body:

Head Neck Shoulder Upper Arm Elbow/Forearm Hand/Wrist/Fingers/Thumb
Hip Thigh Knee Shin Calf Ankle Foot/Toe(s)
Back Abdomen Chest Other

Type of Injury:

Sprain Strain Fracture General Trauma Neurotrauma
Laceration Overuse Other

Perceived severity of injury: Mild Moderate Severe

Summary of Evaluation:____

____

____

____

Appendix VII

Risk of Injury in Sports Scale (RISSc)

Please indicate how likely you think it is that the following events will happen to you while playing your sport.

WHAT DO YOU THINK ARE THE CHANCES THAT YOU WILL (Circle your answers):

		Very Unlikely	Unlikely	Somewhat unlikely	Somewhat likely	Likely	Very Likely
1.	Injure yourself in a collision with an opponent?	1	2	3	4	5	6
2.	Have the same injury that someone else on your team recently had?	1	2	3	4	5	6
3.	Re-injure an area that you have recently injured?	1	2	3	4	5	6
4.	Be injured in a practice?	1	2	3	4	5	6
5.	Fall down and injure yourself?	1	2	3	4	5	6
6.	Be injured from a foul or 'cheap shot' by an opponent?	1	2	3	4	5	6
7.	Be injured by more aggressive opponents?	1	2	3	4	5	6

8.	Be injured running into an object on the field or court (e.g., goal posts, vault, boards, etc.)?	1	2	3	4	5	6
9.	Be injured by bigger or stronger opponents?	1	2	3	4	5	6
10.	Be injured from not 'taking a break' from your sport?	1	2	3	4	5	6
11.	Be injured trying to perform a skill that you have just learned?	1	2	3	4	5	6
12.	Injure yourself on a poor playing surface (e.g., wet or bumpy field, dusty floor, etc.)?	1	2	3	4	5	6
13.	Be injured from playing too many sports at the same time?	1	2	3	4	5	6
14.	Be injured performing a skill that is hard for you to do?	1	2	3	4	5	6
15.	Injure your ankle?	1	2	3	4	5	6
16.	Be injured practicing too hard?	1	2	3	4	5	6
17.	Be injured by not paying attention to what you are doing?	1	2	3	4	5	6

18.	Injure your neck or spine	1	2	3	4	5	6
19.	Be injured from competing too hard?	1	2	3	4	5	6
20.	Be injured by losing your focus while playing your sport?	1	2	3	4	5	6
21.	Trip and injure yourself?	1	2	3	4	5	6
22.	Injure yourself on a dangerous piece of equipment?	1	2	3	4	5	6
23.	Injure your arm or wrist?	1	2	3	4	5	6
24.	Injure your shoulder?	1	2	3	4	5	6

Factors and Corresponding Items:
'Uncontrollable'- 1, 6, 7, 9; 'Controllable'- 8, 11, 14, 17, 20, 22; 'Overuse'- 10, 13, 16,19;'Upper-body'- 18, 23, 24; 'Surface-related'- 5, 12, 15, 21; 'Re-injury'- 2, 3, 4.

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