

Tennis-Related Injuries Treated in United States Emergency Departments, 1990-2011

Honors Research Thesis

Presented in partial fulfillment of the requirements for graduation *with honors research distinction* in the undergraduate colleges of The Ohio State University.

by

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ABSTRACT

Objective: To analyze the patterns and causes of tennis-related injuries using, for the first time, a nationally representative dataset.

Design: A retrospective cohort analysis was performed using the National Electronic Injury Surveillance System database.

Setting: All tennis-related injuries treated in U.S. emergency departments (EDs) from 1990 to 2011 were analyzed.

Patients: During the study period, an estimated 492,002 (95% CI=364668-619336) individuals, ages 5 to 94 years, presented to U.S. EDs for tennis-related injuries.

Assessment of Risk Factors: Independent variables include patient age and gender, mechanism of injury, and location of injury event.

Main Outcome Measures: Outcome variables include injury diagnosis, body region injured, disposition from ED, and involvement of the net.

Results: Most injuries were sustained by a nonspecific mechanism during play (37.9%) and occurred at a sport or recreation facility (83.4%). Children ages 5-18 years had a higher mean injury rate than adults older than 19 years. The most commonly injured body regions were the lower extremities (42.2%) and upper extremities (26.7%). Sprains or strains (44.1%) were the most common type of injury. The number of tennis-related injuries decreased by 41.4% from 1990 to 2011, and the rate of these injuries decreased by 45.2% - 53.4% during a 12-18 year period. Among the 3.4% of patients who were admitted to the hospital, two-thirds (65.6%) involved patients 56 years of age or older.

Conclusions: Despite the decrease in tennis-related injuries, the growing popularity of this sport warrants increased efforts to prevent injuries, especially among child and older adult participants.

INTRODUCTION

Tennis has been the fastest growing traditional sport in the United States during the past decade. With an estimated 46% increase in the number of participants, it has outpaced the growth of other popular sports, including baseball, ice hockey, gymnastics, and football.^{1, 2} The relatively low cost and ease of play of tennis, combined with its appeal to a wide demographic range, contributes to the sport's popularity.^{3, 4} There were nearly 27 million tennis players in 2008 and more than 30 million players in 2009.^{1, 4, 5} Recent efforts by the International Tennis Federation (ITF) and the United States Tennis Association (USTA) to adapt tennis rules and regulations for children younger than 10 years of age, including shrinking court size and manufacturing slower tennis balls, is likely to further expand the range of participating players.^{3, 6, 7}

Tennis players are subjected to repetitive, abrupt, or high energy stressors during play.⁸⁻¹⁰ General bodily strain during play, as well as unexpected events, have been linked to a variety of acute, subacute, and chronic injuries in nearly all major body regions.⁸⁻²⁹ Differences in skill level, court surface type, player age, and physical conditioning can further influence or complicate injury manifestation.^{9, 10, 15, 27, 30}

The literature on tennis injury epidemiology, though substantial in volume, is limited in scope. Most research has focused on elite or professional, rather than amateur, tennis players.^{13, 17-19, 23} Study limitations due to age group, location of play, or location of treatment prevent generalization of results to a large population.^{16-19, 22, 24} Furthermore, the mechanisms of tennis injury have not been adequately described. Among studies that describe injury mechanism during tennis play, many were based on small, non-representative samples.^{16, 17} Variations in

injury definitions and methodologies among previous studies complicate comparisons and prevent effective meta-analysis.³¹

Understanding patterns of injury among all tennis players is important in identifying injury trends and developing evidence-based injury prevention policies and measures. The objective of this research was to determine the epidemiology of tennis-related injuries treated in US hospital emergency departments (EDs) from 1990 through 2011. To our knowledge, this is the first study to comprehensively examine tennis-related injuries using a nationally representative dataset.

METHODS

Data

Data for this study were obtained from the National Electronic Injury Surveillance System (NEISS), which is operated by the US Consumer Product Safety Commission (CPSC). The NEISS provides information on consumer product-related and sports and recreational activity-related injuries treated in US EDs.³² Approximately 100 hospitals contribute to the NEISS, which represents a stratified probability sample of approximately 6100 hospitals with a 24-hour ED with at least 6 beds in the US and its territories. Professional NEISS coders review ED medical records at each participating hospital and record data regarding patient's age, gender, injury diagnosis, affected body area, product(s) involved, disposition from the ED, location where injury occurred, a brief narrative regarding the circumstances of the incident, and other variables. Data from NEISS are weighted to calculate nationally representative estimates of injuries treated in US EDs.^{32, 33}

Case Selection

For this study, all cases of tennis-related injuries were identified using the NEISS product code 3284 for tennis, which includes activity, apparel or equipment. Data for 13,006 actual cases of tennis-related injury reported from January 1, 1990 through December 31, 2011 were identified. Each case was examined to verify inclusion in the study, and cases were excluded on the basis of the narrative description if the injury involved tennis equipment or apparel not used for the purposes of playing tennis, a spectator or bystander, or a fatality. Patients under the age of 5 were excluded based on the nature of the activity. Fatalities, all of which were cardiac arrests, were excluded on the basis of small sample size (12 actual cases) and because the NEISS does not capture fatalities well. Analysis for this study was conducted from June 2012 to October 2012.

Variables

NEISS case narratives were individually reviewed to generate two new variables for primary mechanism of injury and net involvement. The mechanism of injury variable included 6 categories: (1) twist, (2) trip/fall, (3) hit with racket, (4) hit with ball, (5) play/playing tennis, which encompasses injuries incurred during the activity of playing tennis where the exact mechanism could not be determined or is unknown, and (6) other, which includes movements (sudden stop, lunging, bending over, hyperextending), cutting a finger on a tennis ball can, or jammed body parts. In instances of potential overlap among these categories, the cause that occurred first in the sequence of events was considered the primary cause. Narratives that explicitly implicate tennis nets in the mechanism of injury were classified separately from those that did not using the new variable for net involvement.

The NEISS variables for age, injury diagnosis, body region, disposition from the ED, and location were regrouped. Age was regrouped into 5 categories: 5-10, 11-18, 19-40, 41-55, 56+ years based on current league age divisions established by the USTA.^{34, 35} Injury diagnosis was regrouped into (1) laceration (including NEISS categories of amputation, laceration, and non-dental avulsion), (2) soft tissue injury (including contusion/abrasion and hematoma), (3) concussion/closed head injury (including internal organ injuries to the head), (4) dislocation, (5) fracture, (6) strain/sprain, and (7) other (including ingestion, crushing, foreign body, dental injury, nerve damage, hemorrhage, radiation [sun] burns, internal organ injury not to the head, poisoning, dermatitis/conjunctivitis, and other).

Body region injured was regrouped into (1) upper extremity (including NEISS categories of shoulder, elbow, upper arm, lower arm, wrist, hand, and finger), (2) lower extremity (including knee, upper leg, lower leg, ankle, foot, and toe), (3) trunk (including upper trunk, lower trunk, and pubic region) (4) head/neck (including head, face, eye, mouth, neck, and ear), and (5) other (including internal organs, and injury to greater than 25% of the body). Disposition from the ED was regrouped into 3 categories: (1) released, (2) hospitalized (including NEISS variables of treated and transferred, treated and admitted, and held for <24 hours for observation), and (3) left against medical advice. Location of injury was regrouped into school/public property, sports/recreation place, and other (including NEISS categories of home, farm, apartment/condo, and street/highway).

Data Analysis

Data were analyzed using SPSS version 19.0 (SPSS Inc., Chicago, IL) and SAS 9.3 (SAS Institute, Cary, NC), and national injury estimates were calculated based on statistical weights provided by the CPSC.³³ All data reported in this article are national estimates unless otherwise noted. U.S. Census Bureau July 1 intercensal population estimates from 1990 to 2011³⁶ and Tennis Industry Association estimates of tennis participation from 1990 to 2007^{5, 37-40} were used to calculate tennis injury rates for each study year. Statistical analyses included linear regression, χ^2 analysis and calculation of relative risk (RR) with 95% confidence intervals (CIs). The level of significance for all statistical tests was $\alpha=0.05$.

ETHICAL CONSIDERATIONS

This study was approved by the IRB of the Research Institute at Nationwide Children's Hospital.

RESULTS

Demographics

From 1990 through 2011, an estimated 492,002 people (95% CI: 364668-619336) were treated in U.S. EDs for tennis-related injuries. Patient age ranged from 5 to 94 years with a mean and median age of 37.3 (95% CI: 32.9-41.7) and 35 years, respectively. Injuries to children (5-18 years) accounted for 29.2% of all injury cases (Table 1). The majority of tennis-related injuries involved males (56.5%). Most patients were treated and released from the ED (96.2%), while 3.4% of patients were admitted to the hospital. Among admitted cases, two-thirds (65.6%) involved patients 56 years of age or older. Most injuries occurred at a sport/recreation facility (83.4%) or a school/public property (10.6%).

Injury Trend

The number of tennis-related injuries decreased markedly over the 22-year study period. An estimated 30,595 cases (95% CI: 20,458-40,732) were reported in 1990 compared with 17,933 cases (95% CI: 8,632-27,233) in 2011, representing a 41.4% reduction in the number of injuries (Figure 2). Between 1990 and 2011, the annual injury rate also decreased significantly by 53.4% ($m=-0.22$, $p<0.01$) from 13.3 (95% CI: 8.9-17.7) cases to 6.2 (95% CI: 3.0-9.3) cases per 100,000 U.S. residents age five years or older. Children ages 5-18 years had a higher mean annual injury rate, averaging 11.9 (95% CI: 10.1-13.7) cases per 100,000 children than adults 19 years or older, who averaged 7.7 (95% CI: 5.3-10.12) cases per 100,000 adults. Using tennis participation data to calculate injury rates, the mean annual injury rate per 100,000 tennis players ≥ 12 years also decreased significantly by 45.2% from 135.9 (95% CI: 90.1-181.7) in 1990 to 74.5 (95% CI: 43.0-106.0) in 2007 ($m=-3.14$, $p<0.001$), averaging 95.7 (95% CI: 73.4-118.0) (Figure 3).

Body Region of Injury

The most commonly injured body regions were the lower extremities (42.2%), followed by the upper extremities (26.7%), with the ankle representing 47.2% of lower extremity injuries and the wrist representing 34.8% of upper extremity injuries (Figure 1). Males (RR=1.52, 95% CI: 1.37-1.67) and patients ages 5-10 years (RR=3.91, 95% CI: 3.4-4.49) were more likely to sustain an injury to the head or neck than female patients or other age groups, respectively. Patients 11-40 years of age were more likely to sustain an ankle injury (RR=2.60, 95% CI: 2.21-3.07) than other age groups. Male patients were more likely to sustain an eye injury (RR=1.74, 95% CI: 1.38-

2.18), while female patients were more likely to injure the wrist (RR=1.59, 95% CI: 1.26-2.00) or the ankle (RR=1.45, 95% CI: 1.34-1.56) compared with the other gender.

Injury Diagnosis

Strains or sprains were the leading type of injury (44.1%), followed by fractures (14.6%) and soft tissue injuries (13.9%). Strains or sprains were the most commonly diagnosed lower extremity (72.3%) and trunk (45.2%) injury, while fractures (33.8%) were the most frequent diagnosis for upper extremity injuries. Lacerations (39.8%) and soft tissue injuries (30.3%) accounted for most of the injuries sustained to the head and neck. Male patients were more likely to sustain a laceration (RR=2.31, 95% CI: 1.98-2.71) than females. Females (RR=1.30, 95% CI: 1.11-1.54) and patients age 56 years or older (RR=1.80, 95% CI: 1.53-2.12) were more likely to be diagnosed with a fracture than males or other age groups, respectively. Patients ages 5-10 years were more than three times more likely to sustain a laceration or soft tissue injury than other age groups (RR=3.12, 95% CI: 2.83-3.43).

Mechanism of Injury

Nonspecific mechanisms of injury occurring during tennis play were the most common cause of injury (37.9%), followed by trips or falls (23.8%), and twists (11.7%). Male patients (RR=1.43, 95% CI: 1.28-1.59) and children ages 5-10 years (RR=4.80, 95% CI: 4.04-5.71) were at greater risk for being struck by a racket or ball than females or other age groups, respectively. Injuries due to twists were more likely to occur among female patients (RR=1.45, 95% CI: 1.29-1.62) than males and among patients ages 11-40 years (RR=2.79, 95% CI: 2.08-3.74) than other age groups. Female patients (RR=1.25, 95% CI: 1.14-1.37) and those 56 years of age or older

(RR=2.50, 95% CI: 2.29-2.73) were more likely to sustain an injury from a trip or fall than males and other age groups, respectively. A twist injury was twice as likely to cause a strain or sprain (RR=2.08, 95% CI: 1.92-2.25) compared with other mechanisms of injury. Among all injured patients, racket or ball contact was more likely to cause a laceration or soft tissue injury (RR=5.02, 95% CI: 4.57-5.51) and injury to the head or neck (RR=8.43, 95% CI: 7.65-9.29) than other mechanisms of injury. In addition, ball contact was more than one hundred times more likely to cause injury to the eye (RR=101.2, 95% CI: 71.67-143.00) than other injury mechanisms.

Net Involvement

Most injuries were not explicitly associated with tennis nets (97.7%). However, patients ages 5-18 were seven times more likely to sustain a net-related injury than other age groups (RR=7.13, 95% CI: 4.65-10.93), and male patients were at greater risk than females (RR=1.78, 95% CI: 1.30-2.43) for a net-related injury. Patients with a net-related injury were also more likely to sustain an injury to the head or neck (RR=2.44, 95% CI: 1.70-3.49) than other body regions.

DISCUSSION

This study is the first to examine tennis-related injuries using a nationally representative dataset. Over the study period, the number of tennis-related injury cases decreased by more than 40%, and the rate of tennis-related injuries decreased by 45-53% during a 12-to-18-year period in the US, despite a 46% increase in tennis participation over the past decade. Though the reason for this decrease is unknown, an emphasis should continue to be placed on injury prevention due to the increasing popularity of the sport. Continued increases in tennis participation, especially

among younger age groups, will place a larger portion of the population at risk for tennis-related injuries.

The main results of this study are consistent with previous epidemiological studies in the literature. The number of lower extremity injuries was greater than the number of upper extremity injuries, which is comparable to other studies.^{10, 11, 16, 24} The preponderance of injuries to key joint areas, such as the ankle, shoulder, elbow, and wrist, as well as the high frequency of sprains or strains is also well documented.¹⁸⁻²⁰ In contrast with the previous literature, fractures were a common injury of the upper extremities in this study. Though rare in experienced or elite tennis players,^{19, 20} these injuries are more likely to be seen in an ED patient population, which tends to include more severe types of injuries; this observation has been noted in a similar study.¹⁶ Overall, despite differences in study design, the injury profile of tennis players appears to follow similar trends across several types of study populations and injury definitions.

The most common mechanism of injury was nonspecific in nature (37.9%), incurred during tennis play without clear cause. Many tennis injuries, especially among younger age groups, have been attributed to microtrauma-related overuse.^{9, 10} Repetitive arm movements and vibrations from ball to racket contact place stress on the upper extremities while pivots, sprints, and sudden stops place stress on the lower extremities.²⁰ Though an acute injury usually can be linked to a mechanism of injury, many overuse injuries cannot be traced to an unambiguous mechanism. This is because subacute or chronic injuries occur over an extended time period and can manifest not only at the stressed site but also in adjacent joints and muscles through a linked kinetic chain mechanism.¹⁰

Although the exact cause of injury may be difficult to characterize, subacute and chronic injuries are more preventable than certain acute traumatic injuries. Previous research by Blackwell has linked faulty stroke mechanics to differences in wrist kinematics, where novice players are more likely to hit a tennis ball with the wrist flexed rather than extended, possibly influencing injury manifestation.¹⁵ Correlations between type of racket grip and type of wrist injury have also been described in the literature.²⁷ Players therefore may be able to reduce the likelihood of wrist and other types of injuries through proper training and refinement of technique. Furthermore, negative adaptations, such as reduced flexibility and asymmetric hypertrophy, can occur after repeated tennis play, increasing the risk of injury.^{9, 10, 13} Poor physical conditioning, especially among groups such as females and younger players,¹⁰ can increase player susceptibility to high energy stressors during match play. In a study by Kibler, tennis players who underwent a stretching and conditioning program demonstrated increased range of motion in key injury areas such as the shoulder and back.⁴¹ Further study is warranted regarding whether a comprehensive conditioning program, involving both joint and muscle flexibility and strength training, can reduce the risk of injury.

Children aged 5-10 were more likely to be struck by a racket or ball than other age groups. Though this finding may be related to aggressive play, children in this age group may not possess fully developed motor and perceptual skills necessary to execute proper stroke technique or controlled volleys. These factors may be compounded by the improper use of tennis equipment. The ITF specifies a separate set of tennis guidelines and equipment for children ages ten and younger.⁶ Instead of the standard yellow tennis ball, younger players are encouraged to use several types of introductory balls based on age and skill level, which may be softer and have

slower speeds and lower rebound heights.^{6, 42} Junior rackets, which are smaller and lighter, allow for improved ball control and reduce the risk of injury to self and others.⁶ Other ITF stipulations, such as smaller courts and lower nets, not only create a more enjoyable tennis experience for young children but also may prevent injuries. Since these rules were recently implemented in the beginning of 2012,⁷ many may not be aware of these alterations to tennis play for children. Parents, tennis instructors, and school officials should be encouraged to adopt these guidelines.

Although children 5-18 years of age had a higher mean annual injury rate than adults, two-thirds of patients requiring admission to the hospital were 56 years of age or older, indicating that older patients experienced injuries of higher severity compared with younger individuals. Pre-existing co-morbidities also may have contributed to the higher number of admissions in this older age group.

This study has several limitations. The number of tennis-related injuries was under-estimated in this study, because only injuries treated in the ED setting were included. Patients treated in urgent care and physicians' offices, as well as those who were injured but did not seek treatment, are not captured in the NEISS database. This study also may not be representative of all tennis-related injuries. Furthermore, completeness of NEISS case narratives is limited by the amount of detail included by NEISS professional coders and the amount of information contained in ED records. Narratives, therefore, may have been missing information concerning involvement of the tennis net in injury, injury mechanism, or factors contributing to the injury event. Despite these limitations, the strength of this study lies in its large, nationally representative sample and the study period, which spans 22 years.

CONCLUSIONS

Despite the decrease in tennis-related injuries, the growing popularity of this sport warrants increased efforts to prevent injuries, especially among child and older adult participants.

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TABLE AND FIGURE LEGENDS

Table 1. Characteristics of tennis-related injuries treated in U.S. emergency departments, 1990-2011

Figure 1. Body region injured: upper extremity, lower extremity, head/neck, all body regions

Figure 2. Estimated number and rate of tennis-related injuries in the U.S. population, 1990-2011

Figure 3. Estimated number and rate of tennis-related injuries among tennis players ≥ 12 years of age, 1990-2007

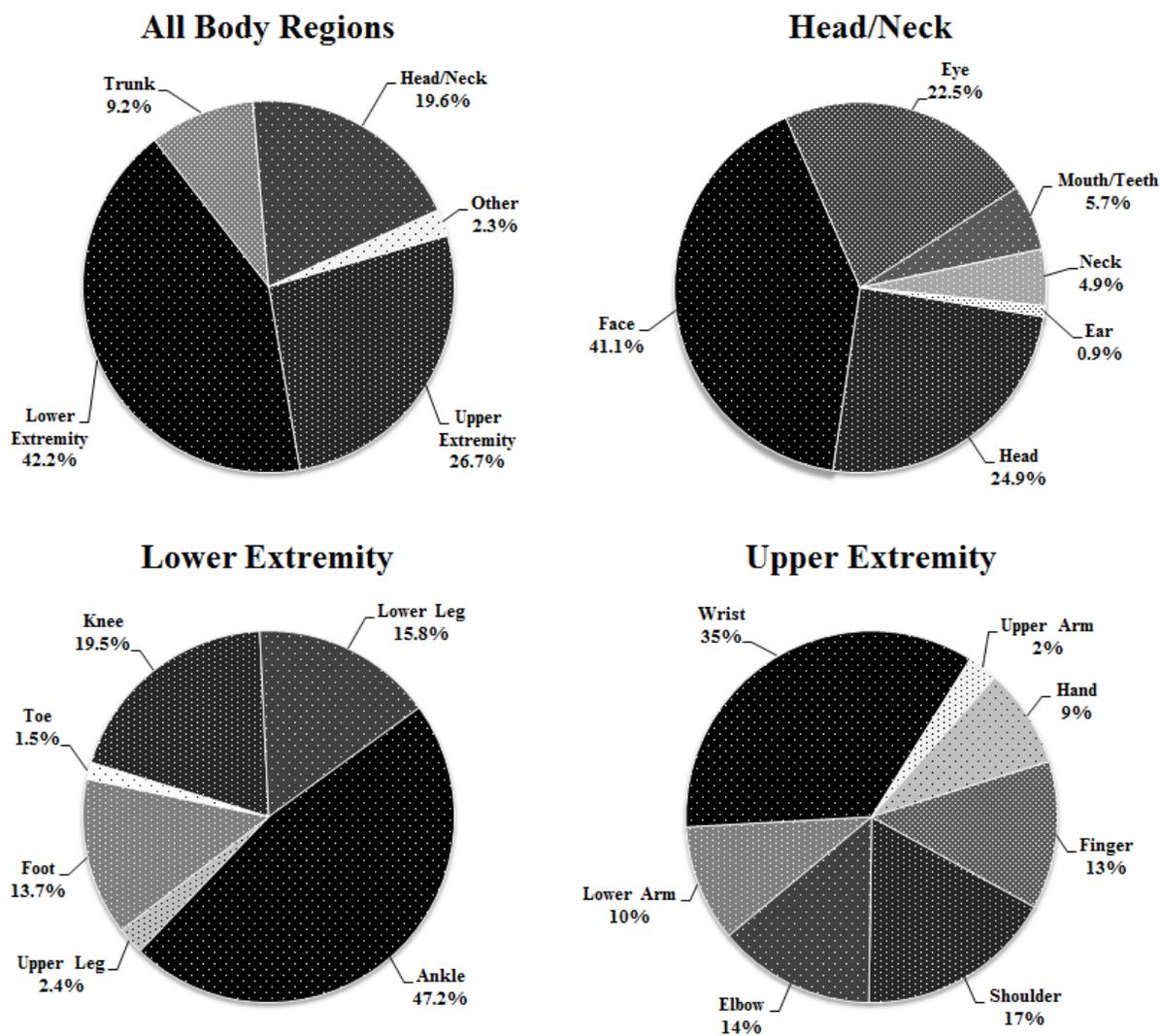
Table 1. Characteristics of tennis-related injuries treated in U.S. emergency departments, 1990-2011

Description	Cases (n)	National Estimate (%)*	95% Confidence Interval
Age (years)			
5-10	965	30206 (6.1)	(25015 - 35397)
11-18	3136	113769 (23.1)	(95104 - 132433)
19-40	3325	134411 (27.3)	(109411 - 159411)
41-55	2354	96595 (19.6)	(70321 - 122869)
56+	2435	116952 (23.8)	(45940 - 187964)
Gender			
Male	6894	277744 (56.5)	(206044 - 349445)
Female	5318	214144 (43.5)	(157601 - 270688)
Diagnosis			
Laceration	1224	48018 (9.8)	(36732 - 59303)
Soft tissue injury	1752	68461 (13.9)	(55237 - 81685)
Concussion/closed head injury	358	12173 (2.5)	(7956 - 16390)
Dislocation	267	10125 (2.1)	(7133 - 13117)
Fracture	1828	71844 (14.6)	(50721 - 92967)
Strain/sprain	5170	216802 (44.1)	(157396 - 276208)
Other	1606	64118 (13.0)	(42718 - 85519)
Body Region Injured			
Trunk	1060	45077 (9.2)	(28895 - 61259)
Head/neck	2636	96292 (19.6)	(76204 - 116380)
Upper extremities	3199	131470 (26.7)	(94176 - 168765)
Lower extremities	5055	207262 (42.1)	(156809 - 257714)
Other/non-specific	251	11417 (2.3)	(3315 - 19519)
Disposition from ED**			
Released	11766	473137 (96.2)	(353072 - 593202)
Hospitalized	389	16539 (3.4)	(9027 - 24052)
Left against medical advice	49	1806 (0.4)	(894 - 2719)
Location			
School/public property	1039	39913 (10.6)	(30765 - 49061)
Sports/recreation place	7190	313924 (83.4)	(196783 - 431065)
Other	576	22420 (6.0)	(17423 - 27417)
Mechanism of Injury			
Twist	1427	57651 (11.7)	(47010 - 68291)
Fall/trip	2751	117098 (23.8)	(73352 - 160843)
Hit with racket	1081	38594 (7.8)	(32760 - 44429)
Hit with ball	951	33223 (6.8)	(26775 - 39671)
Play	4607	186320 (37.9)	(133273 - 239366)
Other	1399	59116 (12.0)	(39822 - 78410)
Net Involvement			
No	11906	480585 (97.7)	(354237 - 606933)
Yes	310	11417 (2.3)	(9317 - 13517)

*Percentages may not sum to 100.0%, because of rounding error.

**ED = Emergency Department

Figure 1: Body region injured: upper extremity, lower extremity, head/neck, all body regions



Percentages may not sum to 100.0%, because of rounding error.

Figure 2. Estimated number and rate of tennis-related injuries in the U.S. population, 1990-2011

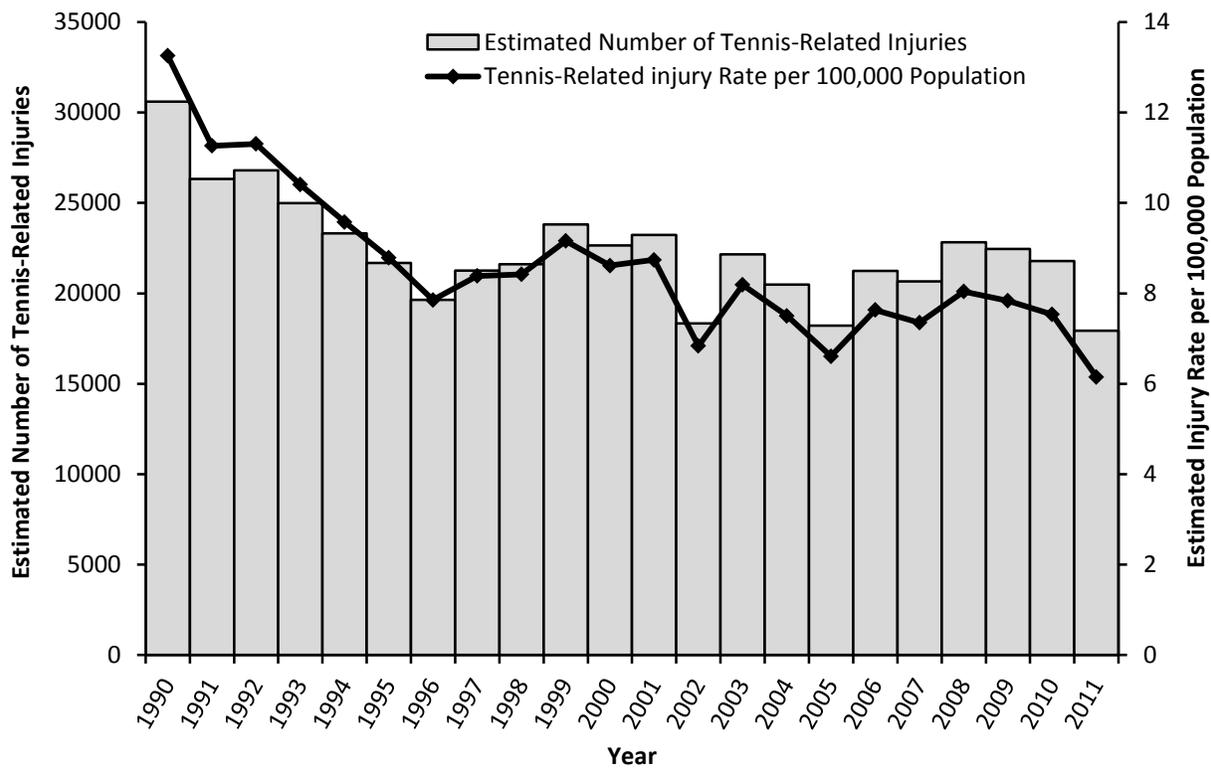
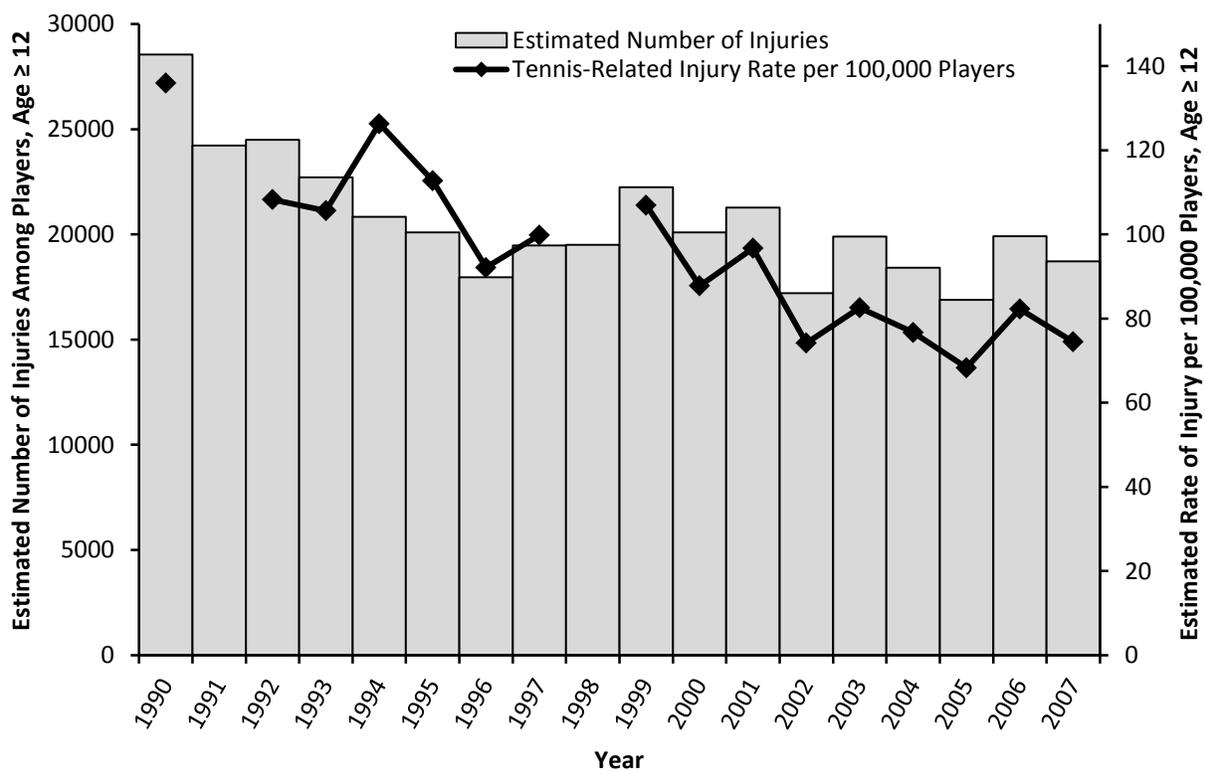


Figure 3: Estimated number and rate of tennis-related injuries among tennis players ≥ 12 years of age, 1990-2007



Estimates of tennis participation for ages ≥ 12 was not available for 1991 and 1998.