Illness Data From the US Open Tennis Championships From 1994 to 2009

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Objective: To examine the incidence of illness and highlight gender differences in tennis players competing in a major professional tennis tournament over a 16-year period between 1994 and 2009.

Design: Descriptive epidemiology study of illness trends in professional tennis players.

Setting: Archival data from the US Open Tennis Championships.

Participants: Participants in the US Open Tennis Championships main draw from 1994 to 2009.

Main Outcome Measures: Illness data collected at the US Open Tennis Championships between 1994 and 2009 were classified using guidelines presented in a sport-specific consensus statement. Each case was categorized according to the medical system effected and impact on play availability during the tournament. Illness rates were determined based on the exposure of an athlete to a match event and were calculated as the ratio of illness cases per 1000 match exposures (ME).

Results: The average number of illness cases over the 16-year period analyzed was 58.19 ± 12.02 per year (36.74 per 1000 ME) requiring assistance by the medical staff. Statistical analyses showed a significant fluctuation in illness cases related to the dermatological (DERM), gastrointestinal, renal/urogenital/gynecological, neurological, ophthalmic and otorhinolaryngological (ENT), and infectious medical systems ($P < 0.05$). The ENT and DERM conditions were the most commonly reported types of illness for both men and women.

Conclusions: Numerous medical systems are susceptible to illness in tennis players. Sport-specific factors may influence susceptibility to common illnesses experienced by professional tennis players.

Key Words: ophthalmic, dermatological, trend analysis, tennis players

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INTRODUCTION

Tennis injuries are well documented.[1,2] However, illness rates in elite level tennis players are largely unknown despite the potential disruption it presents to training and competition. Documented instances of illness in professional or elite tennis players are limited to newspaper articles and case studies.[3,4] Approaches to determine potential health risks associated with elite level competitive tennis have focused primarily on injuries, infectious disease transmission, and heat-related complications.[1,2,5,6] No observational longitudinal data on illness trends in elite-level adult tennis players have been published.

The high volume of training, travel requirements, and year-long competitive schedule may predispose professional tennis players to a higher risk of illness than recreational athletes. Although playing tennis and regular conditioning may help improve physiological function,[7] the physicality of the modern game places a high degree of stress on the body, and may, along with excessive training and competition, increase players' risk of illness and reoccurring infection.[8–11] Anecdotal articles have documented conditions including allergies, respiratory and pulmonary issues, and viral infections in professional tennis players as being responsible for tournament withdrawal. Daily stresses experienced by elite athletes battling to balance athletic and personal commitments may also impact health.[12]

Information concerning illness trends in professional tennis players is scarce. The purpose of this study was to examine the illness rates experienced by professional tennis players and highlight gender differences in illness trends across a 16-year period at the US Open Tennis Championships. The results of this study will provide a better understanding of illness rates in competitive professional tennis players, which may help guide sport-specific prevention and treatment practices within medical and player education programs.

METHODS

In this cohort observational study, illness rates were examined in tennis players participating in the US Open Tennis Championships over a 16-year inclusive period from 1994 to 2009. Data of cases were included if a medical issue within a player required attention by the tournament medical staff and/or physician during the US Open Tennis Championships. Only cases involving men and women competing in the qualifying and main draws (singles, doubles, or mixed

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doubles) were included. All diagnoses and data classification were completed and verified by the United States Tennis Association (USTA) Medical Officer and Director of Player Medical Services for the US Open Tennis Championships at the time of occurrence. Before data recording and analysis, each case was assigned an identification number, and any study data recorded separately from the original paperwork with the player name and identifying information were removed.

Ethical Approval

Cases were identifiable by their identification number only. Approval for this study was obtained from the USTA Medical Office and the Institutional Review Board at Hofstra University.

Exposure, Onset, and Availability for Match Play

For data analysis, all cases were recorded using the systematic classification approach developed by Pluim et al[13] for exposure (match vs training) and manner of onset. Acute cases were defined as "… a condition resulting from a specific, identifiable event or … a sudden onset of (relatively severe) pain or disability" (p. 895). Gradual-onset cases were defined as conditions displaying a gradual onset of disability or pain (where an identifiable onset or cause may or may not be present).[13] No further information describing the circumstances leading to the condition were included in the current analysis because this information was not always known to the player, coaching staff, or medical staff or was not documented on the original medical form. All matches were played on hard courts (DecoTurf with asphalt base).

Given the tournament duration and changes in medical personnel responsible for overseeing player treatment and assessment, the approach suggested by Pluim et al[13] for reporting severity by duration of playing time lost was not documented.

Illness Classification by System

The primary medical system involved in each illness case was classified into one of the groupings for defining illness in the consensus statement developed by Pluim et al.[13] A summary of these classification groupings, abbreviations, and examples of illnesses for each grouping are presented in Table 1. The specific diagnosis was not included in this analysis.

Statistical Analysis

Data were analyzed using frequencies, simple linear regression, nonparametric cross-tabulation procedures, and rate ratios and confidence intervals using PASW Statistics 17 software (SPSS Inc, Chicago, Illinois) and previously established methods.[1,14,15] Unless specified otherwise, $P < 0.05$ was used as an acceptable level of significance for all analyses.

Total match exposure (ME) during the US Open Tennis Championships, as opposed to playing hours, was used as an analysis tool to estimate illness rates. Tennis players are not required to train at the same facility during a tournament, and the data in this study were collected by medical personnel in a clinical setting with the goal of evaluation and treatment of the athlete's presenting complaints. Therefore, although Pluim et al[13] recommended reporting rates using playing hours, in the current study the calculation of illness rates based upon training versus competition hours was not possible. Match exposures were determined using 2 exposures for each singles match (2 players per match) and 4 exposures for each doubles match (4 players per match). Separate illness rates for men and women were determined using the aforementioned approach for MEs involving players in each sex only, instead of the overall denominator for both. The determination of injury rates per 1000 units (as opposed to playing hours) has been used in previous research.[16]

RESULTS

During 1994 and 2009, there were 931 documented reports of illness across the men's and women's qualifying and main draw players at the tournament, resulting in an overall rate of 36.73 per 1000 ME (Table 2). There were statistically significant increasing linear trends in the illness rates in women and overall ($P < 0.05$), but no significant changes in men (Figure 1).

Exposure, Onset and Availability for Match Play

The exposure and onset for a significant majority of illness cases was unknown ($P > 0.05$; Table 2). Only 27 cases (1.07 cases per 1000 ME) resulted in withdrawal from match play. Of these 27 cases, the ophthalmic and otorhinolaryngological (ENT) and respiratory (RESP) systems incurred the majority of cases (0.24 per 1000 ME for each),

TABLE 1. Illness Classification Grouping

Illness Classification	Abbreviation	Example of Potential Illness in Grouping
Gastrointestinal	GI	Viral gastroenteritis
Respiratory	RESP	Asthma
Cardiovascular	CV	Atrial fibrillation with bradyarrhythmia
Renal/urogenital/ gynecological	URO-GYN	Herpes simplex infection
Metabolic/ endocrinological	MET-ENDO	Hypoglycemia
Hematological	HEME	Iron deficiency anemia
Dermatological	DERM	Contact dermatitis
Neurological	NEURO	Vertigo
Psychiatric/behavioral	PSYCH	Depression
Ophthalmic/ otorhinolaryngological	ENT	Conjunctivitis, laryngitis, chronic oritis
Dental	Dental	Dental caries
Rheumatologic/ connective tissue disorder	RHEUM	Sacroiliitis
Allergic/immunological	ALLER	Seasonal rhinitis
Infectious	INF	Skin abscess

TABLE 2. Descriptive and Rate Data for Illness System Classification Overall and for Male and Female Players at the US Open Tournament Between 1994 and 2009

	Women (n = 453)			Men (n = 478)			Overall (N = 931)		
	Cases	Illness Rate per 1000 ME	95% Confidence Intervals	Cases	Illness Rate per 1000 ME	95% Confidence Intervals	Cases	Illness Rate per 1000 ME	95% Confidence Intervals
Average per year	28.31 ± 9.76	35.74	22.57-48.91	29.88 ± 6.51	37.73	24.33-24.33	58.19 ± 12.02	36.74	27.30-46.18
Illness onset									
Acute	27	2.13	1.33-2.93	33	2.60	1.71-3.49	60	2.37	1.77-2.97
Gradual onset	18	1.42	0.76-2.08	11	0.87	0.36-1.38	29	1.14	0.72-1.56
Unknown	408	32.20	29.08-35.32	434	34.25	31.03-37.47	842	33.22	30.98-35.46
Exposure									
Match	50	3.95	2.86-5.04	48	3.79	2.72-4.86	98	3.87	3.10-4.64
Training	1	0.08	−0.07-0.23	1	0.08	−0.07-0.23	2	0.08	−0.03-0.19
Unknown	402	31.72	28.62-34.82	429	33.85	30.65-37.05	831	32.79	30.56-35.02
Availability for match play									
Yes	434	34.25	31.03-37.47	456	35.98	32.68-39.28	890	35.12	32.81-37.43
No	19	1.50	0.83-2.17	22	1.74	1.01-2.47	41	1.62	1.12-2.12
Withdrawal from match play									
Yes	19	1.50	0.83-2.17	8	0.63	0.19-1.07	27	1.07	0.67-1.47
No	434	34.25	31.03-37.47	470	37.09	33.74-40.44	904	35.67	33.34-38.00
Retired from tournament									
Yes	3	0.24	−0.03-0.51	15	1.18*	0.58-1.78	18	0.71	0.38-1.04
No	450	35.51	32.23-38.79	463	36.54	33.21-39.87	913	36.02	33.68-38.36
Type of Illness†									
GI	24	1.89	1.13-2.65	48	3.79*	2.72-4.86	72	2.84	2.18-3.50
RESP	54	4.26	3.12-5.40	46	3.63	2.58-4.68	100	3.95	3.17-4.72
CV	6	0.47	0.09-0.85	4	0.32	0.01-0.63	10	0.40	0.16-0.64
URO-GYN	16	1.26‡	0.64-1.88	1	0.08	−0.07-0.23	17	0.67	0.35-0.99
MET-ENDO	1	0.08	−0.07-0.23	0	0	0	1	0.04	−0.04-0.12
DERM	109	8.60	6.99-10.21	111	8.76	7.13-10.39	220	8.68	7.53-9.83
NEURO	11	0.87	0.36-1.38	27	2.13	1.33-2.93	38	1.50	1.02-1.98
PSYCH	5	0.39	0.04-0.74	2	0.16	−0.06-0.38	7	0.28	0.08-0.48
ENT	143	11.28	9.43-13.13	125	9.86	8.13-11.59	268	10.57	9.30-11.84
Dental	11	0.87	0.36-1.38	6	0.47	0.09-0.85	17	0.67	0.35-0.99
ALLER	43	3.39	2.38-4.40	56	4.42	3.26-5.58	99	3.91	3.14-4.68
INF	12	0.95	0.41-1.49	16	1.26	0.64-1.88	28	1.10	0.69-1.51
ENVIR	18	1.42	0.76-2.08	36	2.84	1.91-3.77	54	2.13	1.56-2.70
Total	453	35.75	32.46-39.04	478	37.72	34.34-41.10	931	36.73	34.37-39.09

*Statistically higher than women ($P < 0.05$).
†For abbreviations, see Table 1.
‡Statistically higher than men ($P < 0.05$).

followed by environmental (ENVIR) (0.16 per 1000 ME), dermatological (DERM) and allergic/immunological (ALLER) (0.12 per 1000 ME for each), gastrointestinal (GI; 0.08 per 1000 ME), and cardiovascular (CV), renal/urogenital/gynecological (URO-GYN), and psychiatric/behavioral (PSYCH) groupings (0.04 per 1000 ME). There was a significant increasing linear trend in rate of withdrawal between 1994 and 2009 ($P < 0.05$). The rates attributed to withdrawal from match play as a result of illness were consistently lower than those for muscle or tendon-related injury across the same tournament and timeframe[17] (Figure 2). Significantly more cases were attributed to acute onset versus gradual onset [2.37 vs 1.14 per 1000 ME, rate ratio = 2.08, 95% confidence interval (CI) = 1.34-3.24; Table 3].

Illness Classification

There was a significantly higher rate of ENT illness compared with all other categories of illness ($P < 0.05$). DERM conditions were significantly higher than all other categories, with the exception of ENT conditions ($P < 0.05$), followed by RESP and ALLER (Table 2). No cases for hematological and rheumatologic/connective tissue disorder were documented.

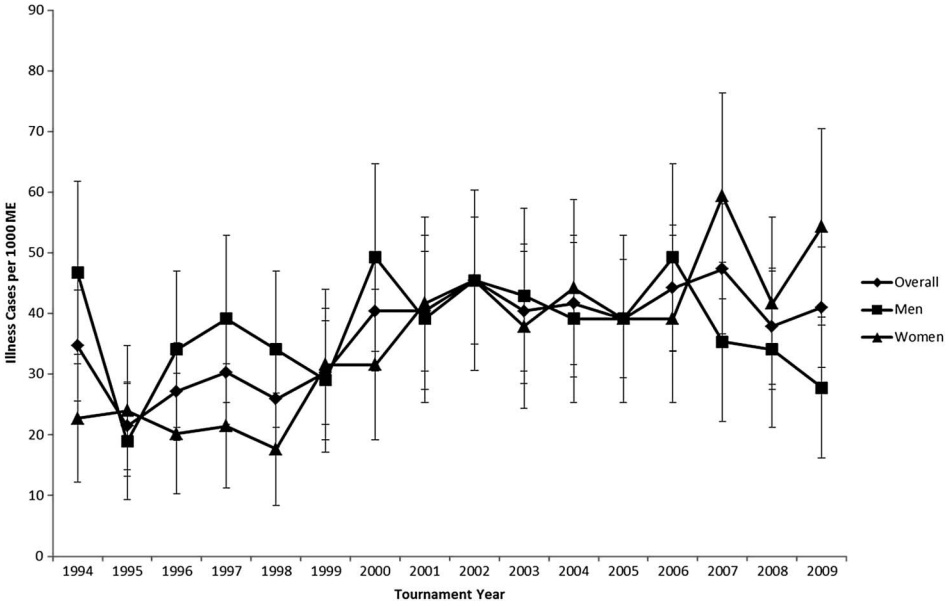

FIGURE 1. Illness rates in male and female players at the US Open Tennis Championships between 1994 and 2009.

There were statistically significant increasing linear trends for GI, RENAL, DERM, NEURO, and ENT ($P < 0.05$), and a significant decreasing trend for infectious medical system (INF; $P < 0.05$) (Figure 3). ALLER and RESP also showed a nonsignificant linear decrease in average annual change ($P > 0.05$). Several spikes in ENVIR-attributed illness were observed in 2001, 2002, 2005, and 2007, although increases in temperature or overall heat index were not apparent (Figure 4).

There was no significant difference in illness rates for men compared with women ($P > 0.05$; Table 2). For both men and women, ENT and DERM conditions were the most frequently documented, followed by RESP in women and ALLER in men. Men demonstrated significantly higher rates of GI (3.79 vs 1.89 per 1000 ME, rate ratio = 2.01, 95% CI = 1.23-3.28), whereas women demonstrated significantly higher URO-GYN rates (1.26 vs 0.08 per 1000 ME, rate ratio = 15.75, 95% CI = 2.09-118.66). Although not statistically different, men were over twice as likely to exhibit cases related to NEURO (2.13 vs 0.87 per 1000 ME, rate ratio = 2.45, 95% CI = 1.22-4.94), PSYCH (0.39 vs 0.16 per 1000 ME, rate ratio = 2.44, 95% CI = 0.47-12.57), and ENVIR (2.84 vs 1.42 per 1000 ME, rate ratio = 2.00, 95% CI = 1.14-3.52) causes. Women were more likely to demonstrate CV (0.47 vs 0.32 per 1000 ME, rate ratio = 1.47, 95% CI = 0.42-5.20) or DENTAL concerns (0.87 vs 0.47 per 1000 ME, rate ratio = 1.85, 95% CI = 0.68-5.00) (Table 2).

DISCUSSION

To the authors' knowledge, this is the first study to examine illness trends in professional tennis players. Before this study, minimal research[3,10] was available to medical practitioners indicating the physiological systems of the body most likely to experience illness-related concerns in professional tennis players treated by the medical staff during competition. The main findings of this study were a significant fluctuation in illness rates between 1994 and 2009, an average illness rate of 36.74 per 1000 ME, and rates highest in the ENT and DERM systems for both men and women. The rates attributed to withdrawal from match play as a result of illness were lower than previously documented injury-related rates in

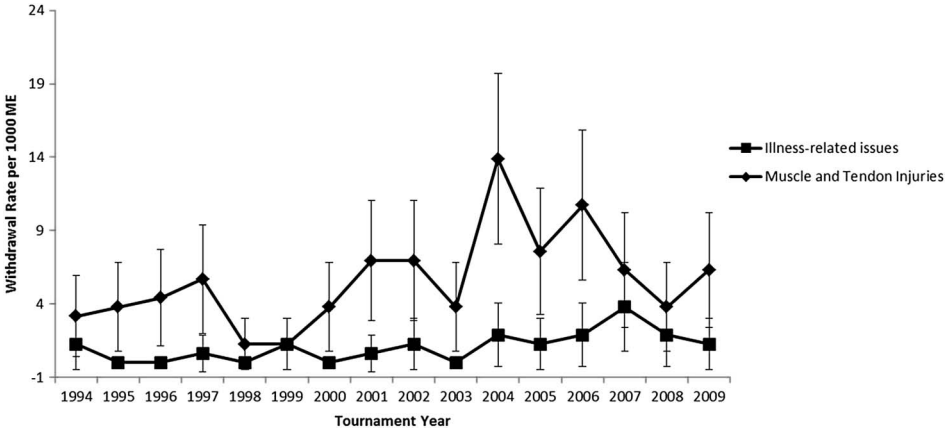

FIGURE 2. Comparison of withdrawal from match-play rates for illness-related issues and muscle or tendon injuries in players at the US Open Tennis Championships between 1994 and 2009.

TABLE 3. Descriptive Data for Known Acute and Gradual-Onset Illness in Tennis Players at the US Open Tournament Between 1994 and 2009

	Acute Illness (n = 60)			Gradual-Onset Illness (n = 29)		
	Cases	Illness Rate per 1000 ME	95% Confidence Intervals	Cases	Illness Rate per 1000 ME	95% Confidence Intervals
Type of illness*						
GI	7	0.28	0.08-0.48	2	0.08	−0.03-0.19
RESP	7	0.28	0.08-0.48	4	0.16	0.01-0.31
CV	3	0.12	−0.01-0.25	0	0	0
URO-GYN	0	0	0	1	0.04	−0.11-0.19
MET-ENDO	0	0	0	0	0	0
DERM	7	0.28	0.08-0.48	10	0.40	0.16-0.64
NEURO	3	0.12	−0.01-0.25	6	0.24	0.05-0.43
PSYCH	0	0	0	0	0	0
ENT	20	0.79†	0.44-1.14	3	0.12	−0.01-0.25
Dental	0	0	0	0	0	0
ALLER	7	0.28	0.08-0.48	1	0.04	−0.11-0.19
INF	0	0	0	0	0	0
ENVIR	6	0.24	0.05-0.43	2	0.08	−0.03-0.19
Total	60	2.37†	1.77-2.97	29	1.14	0.72-1.56

*For abbreviations, see Table 1.
†Statistically higher than gradual-onset cases ($P < 0.05$).

adults and youth players in high-level competition.[16,18] The low overall rate of illness-attributed withdrawal is consistent with previous trends in withdrawals because of isolated illnesses (eg, heat illness).[16] The lack of previous research on illness trends in tennis players makes comparisons with current literature challenging, but numerous behavioral, seasonal, and epidemiological risk factors may provide insight into the illness trends observed and identify areas for ongoing study.

The understanding and application of professional practice related to sports science has improved considerably over the past 2 decades.[19–21] Tennis demands a high level of physical fitness and exerts both a physical and mental strain on players[20–22]—acute bouts of high-intensity training have been shown to suppress immune function and facilitate glycogen depletion.[3,10] High training loads coupled with insufficient recovery and nutritional replenishment may increase the likelihood of "overreaching,"[9,23] which if not adequately managed may impact the quality of sleep and increase the risk of minor infections.[3,24] Ongoing developments in sport-specific training[19,21] and better management of certain medical conditions (eg, asthma, seasonal allergies) have improved the quality of training and nutritional practices,[25,26] much of which may have contributed to a decreased risk of or susceptibility to illnesses in the ALLER, RESP, and PSYCH systems.

In the current study, cases classified as INF showed a significant change over the timeframe analyzed but were only documented in 4 years: 1994 (13 cases), 1995 (7 cases), 1996 (4 cases), and 2000 (4 cases). The significant fluctuation

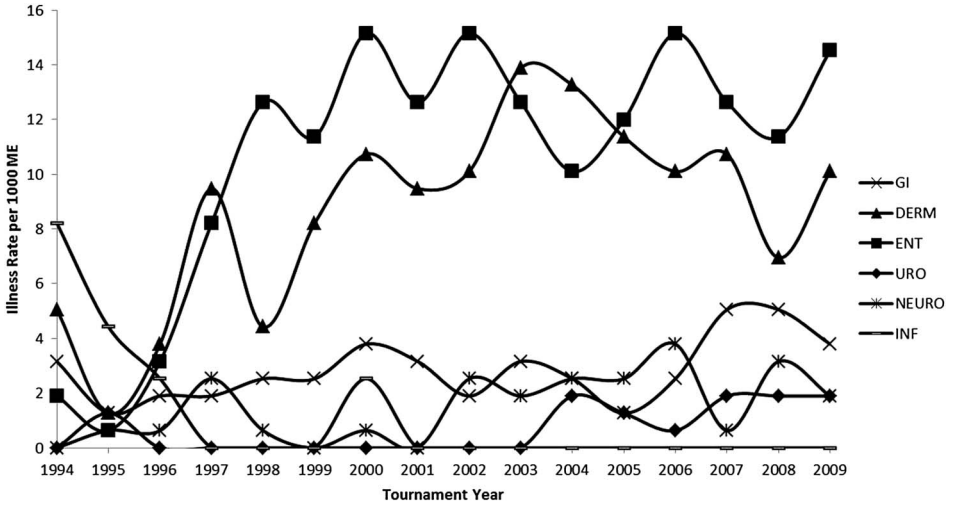

FIGURE 3. Distribution of illness rates by medical system that showed significant fluctuations from 1994 to 2009.

in INF rates may be because of high single-year rates. Decreases in INF rates may have been enhanced by better implementation of preventable strategies (eg, hand washing) and implementation of immunizations to the more prevalent indigenous infectious diseases[6] in a given region before international travel.

Given the physical nature of tennis, it is not surprising that players may be predisposed to various dermatological conditions, such as blisters, calluses, and nail dystrophies (eg, "tennis toe")[27] and that the rate of these conditions has shown an average increase over time. Excessive exposure to the sun, recurrent friction or frictional trauma, mechanical stresses, acute sheering forces, and certain medications [eg, nonsteroidal anti-inflammatory drugs (NSAIDs)] are several documented risk factors for dermatological health issues.[27,28] Although the reasons for the significant fluctuation in DERM cases in the current study are not entirely known, changes in equipment, grip quality, and playing surface composition at the US Open may have impacted incidence. Further research on trends in the location (eg, hand, foot) of DERM-related issues is needed.

The ENT system was the most frequent medical system affected by illness in tennis players over the 16-year timeframe. Research has suggested that the ENT system in outdoor athletes can be sensitive to changes in ambient air conditions, especially the unpredictable interaction between various air pollutants (eg, ozone, sulfur dioxide, carbon monoxide, particulate matter) and environmental variables (eg, precipitation, temperature), which are often unpredictable. Given the proximity of the US Open tournament to several major airports, highways, and the metropolitan climate of New York City, air quality or ambient conditions unfamiliar to the athlete (or which they have elevated sensitivity) may have evoked unwanted effects on the ENT system and impacted work capacity.[29,30] Further investigation into the causes of ENT issues and Centers for Disease Control and Prevention and US Environmental Protection Agency data to identify trends in various air pollutants and airborne allergens specific to the tournament timeframe and location is highly warranted.

However, issues related to the ENT system are sometimes considered a normal response to training at a high intensity or for prolonged periods of time.[8] For example, in elite level tennis players, a significant relationship has been found between training load, training duration, and incidence of upper respiratory infection (URI).[11] The risk of URI increases during periods of overtraining and immunosuppression.[9,10] Furthermore, adverse respiratory responses involving ENT systems during or after exercise should not necessarily be confused with asthma[8,31,32]; however, undiagnosed cases showing early symptomology may have been included in the ENT classification. Future research is needed to examine the etiology of ENT issues in tennis players to identify those with elevated risk of ENT irritation and to define more clearly the parameters for classification in this grouping in surveillance studies.

Symptoms of GI issues, although often mild, may impact athletic performance.[2,33] Dehydration or inadequate fuel or fluid replenishment during or after play may seriously compromise metabolic, thermoregulatory, and circulatory function and impair concentration, increase fatigue, and delay recovery rate.[34] Tennis players may also be susceptible to additional factors, such as the use of NSAIDs, and consuming food that has not been properly stored or prepared (typical preventive strategies related to GI conditions to which adherence may be challenging). Risk factors such as the arduous travel commitments inherent in professional tennis, as well as the unpredictability of professional competitive tennis, may interfere with optimal physical conditioning, practice, access to treatment facilities and personnel, circadian rhythm (and sleep patterns), and optimization of recovery. For example, although the heat index experienced by players at other tournaments may eclipse the US Open tournament, heat and humidity may still present a thermoregulatory challenge, especially when coupled with high levels of physical exertion. Risk factors for ENVIR illness include, but are not

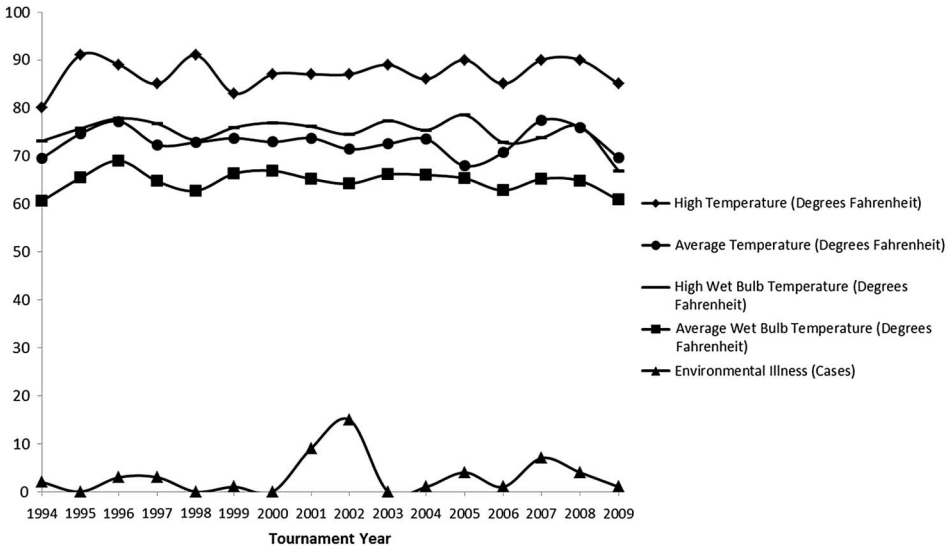

FIGURE 4. Comparison of environmental illness cases and measures of heat index at the US Open Tennis Championships between 1994 and 2009.

limited to, lack of sleep, improper nutrition or supplementation, dehydration, poor acclimatization, use of medications, and overtraining.[5,35,36]

The rate of GI and ENVIR health conditions in the current study were considerably higher in men compared with women, which may be related to the accumulation of risk factors previously discussed.[37,38] For example, although the average duration of a game on hard courts is marginally longer for men compared to women (4:20 and 4:18 minutes, respectively),[39] the duration of men's matches is usually longer at the US Open Tennis Championships because men's singles matches are best of 5 sets, whereas the women's matches are best of 3 sets. Although researchers and practitioners have developed a more thorough understanding of the physical demands of tennis over the past few decades, coaches and players may need to pay particular attention to these variables, especially in preparation for the possibility of hot and humid conditions at the US Open. Training and recovery practices should be carefully monitored to check for signs and symptoms of overtraining or compromised physiological function.

The primary purpose of the current study was to identify illness trends among elite level tennis players. However, several attributes of this study may limit the generalizability of these findings. The information collected in this study was from 1 tournament in the second half of an 11-month competitive season. Illness rates across physiological systems may differ throughout the year. Accurate gauges of the total number of men and women participating in the tournament between 1994 and 2009 are not available, which limits the ability to determine rates per player volume as suggested by Pluim et al.[13] Changes in medical staffing over the 16-year period may have impacted diagnosis. This potential limitation is minimized by use of a medical system classification approach[13] and verification by the current USTA Medical Officer. Players may also have been accompanied by their own medical staff, have visited an off-site physician, or not reported any medical issues they were having because of personal reasons (eg, embarrassment about condition), as opposed to using the USTA medical staff. Although all these scenarios are fairly uncommon, they would have resulted in an underreporting of cases. This study also highlights the need for more detailed explanation of illness classifications and ongoing surveillance studies that include a detailed diagnosis in addition to a broad classification grouping to reduce the potential for misclassification.

CONCLUSIONS

Although many risk factors for the conditions identified in this study overlap to other sports, other factors such as extensive international travel and reoccurring racket-to-hand friction are more sport specific. Preventive measures can be developed from research ascertaining the magnitude of illness cases and identification of potential risk factors that influence susceptibility for analysis in ongoing research. These data may assist medical professionals, players, and coaches in the development of interventions or programs to help decrease exposure to preventable sport-specific risk factors and facilitate treatment in professional tennis players at the US Open Championships (and possibly other similar professional tennis tournaments). Although surveillance studies need to be conducted on players throughout the year and address sport-specific risk factors in greater detail, this study is the first to highlight illness trends in professional tennis players at a major competition.

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REFERENCES

1. Ellenbecker TS, Pluim B, Vivier S, et al. Common injuries in tennis players: exercises to address muscular imbalances and reduce injury risk. *Strength Cond J.* 2009;31:50–58.
2. Pluim BM, Staal JB, Windler GE, et al. Tennis injuries: occurrence, aetiology, and prevention. *Br J Sports Med.* 2006;40:415–423.
3. Nieman D. Exercise infection and immunity. *Int J Sports Med.* 1994;15:131.
4. Leone JE, Gray KA, Massie JE, et al. Celiac disease symptoms in a female collegiate tennis player: a case report. *J Athl Train.* 2005;40:365–369.
5. Howe AS, Boden BP. Heat-related illness in athletes. *Am J Sports Med.* 2007;35:1384–1395.
6. Turbeville SD, Cowen LD, Greenfield RA. Infectious disease outbreaks in competitive sports. *Am J Sports Med.* 2006;34:1860–1865.
7. Groppel J, DiNubile N. Tennis: for the health of it. *Phys Sportsmed.* 2009;37:40–50.
8. Spence L, Brown WJ, Pyne DB, et al. Incidence, etiology, and symptomatology of upper respiratory illness in elite athletes. *Med Sci Sports Exerc.* 2007;39:577–586.
9. Budgett R. Overtraining and chronic fatigue: the unexplained underperformance syndrome (UPS). *Int Sport Med J.* 2000;1:1–10.
10. Nimmo MA, Ekblom B. Fatigue and illness in athletes. *J Sports Sci.* 2007;25:S93–S102.
11. Novas AM, Rowbottom DG, Jenkins DG. Tennis incidence of URTI and salivary IgA. *Int J Sports Med.* 2003;24:223–229.
12. Anderson L, Triplett-McBride T, Foster C, et al. Impact of training patterns on incidence of illness and injury during a women's collegiate basketball season. *J Strength Cond Res.* 2003;17:734–738.
13. Pluim BM, Fuller CW, Batt ME, et al. Consensus statement on epidemiological studies of medical conditions in tennis, April 2009. *Br J Sports Med.* 2009;43:893–897.
14. Knowles SB, Marshall SW, Guskiewicz KM. Issues in estimating risks and rates in sports injury research. *J Athl Train.* 2006;41:207–215.
15. Le Gall F, Carling C, Reilly T, et al. Incidence of injuries in elite French youth soccer players: a 10-season study. *Am J Sports Med.* 2006;34:928–938.
16. Jayanthi NA, O'Boyle J, Durazo-Arvizu RA. Risk factors for medical withdrawals in United States Tennis Association junior national tennis tournaments: a descriptive epidemiologic study. *Sports Health.* 2009;1:231–235.
17. Sell K, Hainline B, Yorio M, et al. Injury trend analysis from the US Open tennis championships between 1994 and 2009 [published online ahead of print September 24, 2012]. Clin J Sport Med. doi: 10.1097/JSM.0b013e31826b7e52.
18. Spreen D. Injury statistics and injury trends of ATP players. *Med Sci Tennis.* 2001;6. http://www.stms.nl. Accessed June 5, 2012.
19. Kovacs MS. Applied physiology of tennis performance. *Br J Sports Med.* 2006;40:381–386.
20. Fernandez-Fernandez J, Sanz-Rivas D, Mendez-Villanueva A. A review of the activity profile and physiological demands of tennis match play. *Strength Cond J.* 2009;31:15–26.
21. Kovacs MS. Energy system-specific training for tennis. *J Strength Cond.* 2004;26:10–13.
22. Ferrauti AG, Neumann G, Weber K, et al. Urine catecholamine concentration and psychophysical stress in elite tennis under practice and tournament conditions. *J Sports Med Phys Fitness.* 2001;41:269–274.

23. Rossi SJ, Buford TW, McMillan J, et al. Nutritional strategies and immune function. *Strength Cond J.* 2010;32:65–70.
24. Derman W, Schwellnus MP, Lambert MI, et al. The "worn-out athlete": a clinical approach to chronic fatigue in athletes. *J Sports Sci.* 1997;15: 341–351.
25. Christmass MA, Richmond SE, Cable NT, et al. Exercise intensity and metabolic response in singles tennis. *J Sports Sci.* 1998;16: 739–747.
26. Konig D, Huonker M, Schmid A, et al. Cardiovascular, metabolic, and hormonal parameters in professional tennis players. *Med Sci Sports Exerc.* 2001;33:654–658.
27. Adams BB. Dermatologic disorders of the athlete. *Sports Med.* 2002;32: 309–321.
28. Grouios G. Corns and calluses in athletes' feet: a cause for concern. *The Foot.* 2004;14:175–184.
29. Bernard SM, Samet JM, Gramsbsch A, et al. The potential impacts of climate variability and change on air pollution-related health effects in the United States. *Environ Health Perspect.* 2001;109: 199–209.
30. Folinsbee LJ. Effects of air pollutants on exercise. In: Garrett WE, Kirkendall DT, eds. *Exercise and Sport Science*. Philadelphia, PA: Lippincott Williams & Wilkins; 2000:285–298.
31. Stephors N. Self-reported symptoms and bronchial hyperresponsiveness in elite cross-country skiers. *Respir Med.* 2010;104:1760–1763.
32. Turcotte H, Langdeau JB, Thibault G, et al. Prevalence of respiratory symptoms in an athlete population. *Respir Med.* 2003;97:955–963.
33. Wright H, Collins M, Schwellnus MP. Gastrointestinal (GIT) symptoms in athletes: a review of risk factors associated with the development of GIT symptoms during exercise. *Int SportMed J.* 2009;10: 116–123.
34. Shoor S. Athletes, nonsteroidal anti-inflammatory drugs, coxibs, and the gastrointestinal tract. *Curr Sports Med Rep.* 2002;1:107–115.
35. Coris EE, Ramirez AM, Van Durme DJ. Heat illness in athletes. *Sports Med.* 2004;34:9–16.
36. Ristow M, Zarse K, Oberbach A, et al. Antioxidants prevent health-promoting effects of physical exercise in humans. *Proc Natl Acad Sci U.S.A.* 2009;106:8665–8670.
37. Morante SM, Brotherhood JR. Air temperature and physiological and subjective responses during competitive singles tennis. *Br J Sports Med.* 2007;41:773–778.
38. Morante SM, Brotherhood JR. Thermoregulatory responses during competitive singles tennis. *Br J Sports Med.* 2008;42:736–741.
39. Brown E, O'Donoghue PG. Gender and surface effect on elite tennis strategy. *ITF Coach Sport Sci Rev.* 2008;15:9–11.

