

# 10-year trend in USA Cup soccer injuries: 1988–1997

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## ABSTRACT

ELIAS, S. R. 10-year trend in USA Cup soccer injuries: 1988–1997. *Med. Sci. Sports Exerc.*, Vol. 33, No. 3, 2001, pp. 359–367. **Objective:** To prospectively document the incidence of competition-related injury rates in an international youth soccer tournament and to analyze the type and location of injuries by age and gender. **Design:** A prospective injury report form completed for injured players presenting to a medical facility for evaluation by the medical staff. **Setting:** An international youth soccer tournament occurring annually during mid-July. **Participants:** 89,500 soccer players, ages 9–19. **Measurement/Main Results:** A total of 3840 new, play-related injuries were evaluated during 290,344 player-hours of competition from 1988 through 1997. New, play-related injuries per 1000-player-hours decreased from 19.87 in 1988 to 9.89 in 1997. Female injury rates ranged from a maximum of 20.11 in 1989 to a minimum of 10.23 in 1996 and the male injury rate ranged from a maximum of 20.04 in 1988 to a minimum of 7.60 in 1996. The lowest injury rate occurred in the under-19 females (10.64) and highest rates occurred in under-16 (17.68) and under-15 (16.92) females. Heat illness correlated with mean temperature. The aggregate rate of heat illness was 0.6 cases/1000 player-hours under "normal" conditions compared to a rate of 2.8/1000 player-hours during "hot" years. **Conclusions:** Injury rates for both genders declined over the 10-yr span of the USA Cup study. The aggregate rate of injury was slightly higher for females than males although the difference between male and female rates became less significant as the tournament matured. In conditions of extreme heat and humidity (1988 and 1995) the rate of new, heat illness increased compared with normal years and females were 1.6 times more likely to sustain heat illness than males. **Key Words:** YOUTH, TOURNAMENT, HEAT, AGE, GENDER, EPIDEMIOLOGY

The USA Cup Soccer Tournament, patterned after the Norway Cup Soccer Tournament, was started in 1985 by the Sons of Norway in Minneapolis, MN. Since the inaugural year with 68 teams, the USA Cup has grown into the fourth largest international youth tournament in the world with over 800 teams from 23 countries participating in age groups under-12 to under-19. All games are played at the National Sports Center/Blaine Soccer Complex, which has 55 fields on one site. The games are scheduled from 8 a.m. through 9 p.m. during the 6-d event occurring annually in mid-July.

Injuries occurring during the tournament were evaluated at a central medical facility staffed by volunteer medical personnel. The medical staff was comprised of an interdisciplinary group of physicians, athletic trainers, physical therapists, podiatrists, and nurses. A field staff of paramedical personnel managed on-field triage and transport. Most of the injuries were evaluated and treated in the on-site medical facility. Patients who required more extensive evaluation and treatment were transported to nearby hospitals. Radiology services were added to the on-site facility in 1992.

Starting with the second year of the tournament in 1986, injury records were kept to allow statistical analysis of injury type and rate. Medical records captured any tournament play-related event that resulted in admission to the USA Cup medical facility. Injury rates were normalized to units of 1000 player-hours of tournament competition. The rates of newly acquired injury during USA Cup competition

were calculated based on review of medical records and were used to profile the type and risk of injury.

The purpose of this paper is to present the rate and distribution of injury allowing for comparison with statistics from other soccer tournaments.

## METHODS

Competition at the USA Cup tournament was divided into two phases in World Cup fashion with group play followed by single elimination playoffs. The group-play phase occurred during the first 3 d of competition with three to four teams in each group; each team played one game against the other teams in the group. Every team played a minimum of three games during the group phase. (Groups that had only three teams played one game against a team from another group.) The top two teams in each group advanced to the A-level playoffs, the third place teams advanced to the B-level playoffs, and the 4th place teams advanced to the C-level playoffs.

All tournament games were played under FIFA rules with up to 18 players rostered per team. Unlimited substitutions were allowed in the 14-and-under age groups and younger. Teams in the older age groups were allowed a maximum of five substitutions per game, and no player was allowed to reenter the game once replaced by a substitute. Duration of the games varied by age group from 50 to 90 min. Game durations were shortened for conditions of extreme heat and humidity in 1988 and 1995. Quarterly water breaks, unlimited substitutions within all age groups and shortening of game times were phased in according to severity of heat stress. In 1997, games were shortened during the first two days of the tournament after flooding limited the number of playable fields.

Patient visits to the USA Cup medical facility were documented using a paper encounter form to record demographic

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and clinical information. The form remained relatively unchanged over the 10-yr span reported in this article. Patients presenting for care were identified as players, coaches, referees, staff, or spectators. Demographic data included home address, team identification, age, DOB, and gender. Teams were classified into groups of age and gender, e.g., under-16 male. Encounters were classified as NEW, FOLLOW-UP, or OLD. The NEW designation was reserved for those visits in which the presenting problem occurred during the current USA Cup tournament competition. The FOLLOW-UP field was checked when patients returned for reevaluation or treatment related to problem identified during a visit to the medical facility earlier in the week. When players presented with a preexisting problem such as an injury that occurred before the USA Cup, OLD was checked. These designations were not mutually exclusive; it was possible to characterize an encounter as being both NEW and OLD if a patient presented with a new, tournament-related injury with a history of a preexisting and related condition. Although it was possible to record time of injury and field where the injury or problem occurred, this information was not always reliably reported. Clinical information was reported in a standard subjective, objective, assessment, plan format.

Each year a separate database was maintained. Macintosh-based database applications were employed: OMNIS 3 (1988–1992), 4th Dimension (1993, 1994), and, most recently, Filemaker Pro (1995–1997). Each patient visit generated a separate entry into the database, and each paper record was stored with a unique sequence number in the database. Starting in 1995, team ID data enabled a link to team registration information imported for each player. In 1996, real-time registration was implemented: patient demographic data was directly entered when the patient presented to the medical facility. Diagnoses were recorded both in a free-form narrative field and also coded using a scheme that coded both the type and anatomic location for the injury. Multiple diagnoses could be assigned to each encounter. A MEDICAL field identified visits primarily devoted to medical problems such as asthma, rashes, upper respiratory infections, and gastroenteritis. These visits were not labeled as NEW, play-related problems unless the medical problem occurred during competition. For example, heat exhaustion, cramps, hyperventilation and exercise-induced asthma could be labeled as both MEDICAL and NEW. Injuries were classified according to the following categories for anatomic location: head and neck, trunk (chest including clavicles, back, abdomen, genitalia), upper extremity (distal to acromioclavicular joint including shoulder joint), and lower extremity (buttocks, thighs, and distal structures). Blisters were excluded from lower extremity classification. Multiple injury sites were specified when injuries extended beyond a single location category.

An on-site x-ray facility was added in 1992. X-rays were reviewed by a radiologist at a nearby hospital: results were subsequently recorded in the database. Follow-up reports from local emergency rooms were also entered into the database although the availability of this information varied from year to year.

Injury rates were calculated with a denominator of 1000 player-hours of tournament competition, the standard utilized in reporting results from the European soccer tournaments. Player-hours (PH) were determined based on tournament

records provided by the USA Cup administration. Sources of data included schedules reported in program books and scheduling reports directly obtained from tournament operations. From 1995 through 1997, game times were determined using a grid which listed each game by date, age group, and time slot. Calculation of player-hours reflected changes made to playing time under conditions of extreme weather.

On-site measurements of ambient and black globe temperature were made in extreme conditions and intermittently throughout the USA Cup tournaments. Black globe (BG) temperature measurements were made using a homemade apparatus allowing for a measure of radiant heat from the sun. Ambient temperature (dry bulb; DB) and relative humidity data were obtained from the National Weather Service and used to estimate the wet bulb (WB) temperature (from Relative Humidity and Dew Point Table, U.S. Department of Commerce, WSTA B-0–6D, 5–72). These data enabled a calculation for the Wet Bulb Globe Temperature:  $WBGT (^{\circ}F) = 0.1 * DB + 0.2 * BG + 0.7 * WB$ . This index, based on contribution from ambient temperature, radiant heat from the sun and humidity, is considered the standard for quantifying heat stress.

National Weather Service monitoring provided a more consistent and accurate record of climactic conditions from year to year during the 6-d span of USA Cup competition. Based on hourly measurements of dry bulb, wet bulb temperatures and relative humidity reported from the Minneapolis-St. Paul International Airport, it was possible to derive estimates of WBGT for the USA Cup site located approximately 20 miles north of the airport. Although airport measurements included cloud cover, there were no direct measurements of black globe temperature, allowing no direct calculation of WBGT. This was circumvented by the recent efforts of Coyle (4), who developed a method for conversion of airport monitoring to playing field estimates of WBGT (Airport Corrected Estimate: "ACE-WBGT"). The ACE-WBGT estimate provided a consistent method for comparison of heat stress from 1988 through 1997.

## RESULTS

From 1988 through 1997, 5373 teams played 13,643 games for 290,344 player-hours of USA Cup competition (Table 1). Within this 10-yr span 5911 patients were seen in the USA Cup medical facility. A total of 3840 visits were classified as new, play-related injury acquired by soccer players during tournament play. Over this same 10-year period, it is estimated that the USA Cup was attended by 89,500 soccer players, 10,700 coaches, 3500 referees, 5500 volunteers, 53,500 parents, and 21,400 spectators.

When analyzed by anatomic location the majority of injuries (65.5%) occurred in the lower extremity with ankle sprains being the most frequent injury. Head and neck injuries occurred in 13.6% of injured sites. Upper extremity and trunk injuries made up 12.3% and 8.6%, respectively. See Table 1 for numeric data on rates of new, play-related injuries classified by anatomic location. Injury rates for concussion, heat illness, and fractures are also displayed.

Head and neck injuries displayed a downward trend from 1988 to 1997 (Figure 1.2) with a decrease in value from 2.09 to 1.07 new, play-related injuries per 1000 PH. However,

TABLE 1. Injury Rate (Encounters/1000 PI-Hrs).

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Slope	AGGREGATE DATA: 1988-1997.			
												Total Number	Aggregate Rate*	Ratio M/F Rate	
Total Teams	252	316	405	412	496	584	656	664	804	784		5373			Total Teams
Male Teams	172	204	258	272	320	360	408	396	506	474		3370			Male Teams
Female Teams	80	112	147	140	176	224	248	268	298	310		2003			Female Teams
Total Games	618	888	1053	1063	1254	1458	1623	1637	2060	1969		13643			Total Games
Male Games	422	598	693	720	822	906	1012	980	1311	1194		8658			Male Games
Female Games	196	290	360	343	432	552	611	657	769	775		4985			Female Games
Total PI-Hrs/1000	13.887	20.266	23.641	22.383	26.386	30.771	33.095	31.218	47.733	40.964	3.09	290.344			Total PI-Hrs/1000
Male PI-Hrs/1000	9.382	13.454	15.490	15.045	17.270	19.122	20.629	18.657	30.140	24.904	1.76	184.093			Male PI-Hrs/1000
Female PI-Hrs/1000	4.505	6.812	8.151	7.338	9.116	11.649	12.467	12.561	17.593	16.060	1.33	106.251			Female PI-Hrs/1000
Total Encounters*	27.87	20.58	23.81	24.62	23.61	21.94	20.76	21.14	14.10	16.48	-1.06	5911	20.36	0.98	Total Encounters
Male Encounters*	28.14	15.68	22.47	24.33	23.28	23.74	22.01	22.08	13.24	16.66	-0.78	3725	20.23		Male Encounters
Female Encounters*	27.30	30.24	26.38	25.21	24.24	18.97	18.69	19.74	15.57	16.19	-1.58	2186	20.57		Female Encounters
Total New, Play*	19.87	14.06	16.07	16.93	15.16	14.69	13.05	13.52	8.57	9.89	-0.93	3840	13.23	0.90	Total New, Player
Male New, Play*	20.04	11.00	14.20	16.42	15.40	15.58	12.60	13.51	7.60	9.20	-0.83	2337	12.69		Male New, Player
Female New, Play*	19.53	20.11	19.63	17.99	14.70	13.22	13.80	13.53	10.23	10.96	-1.16	1503	14.15		Female New, Player
Total Head/Neck*	2.09	1.78	1.73	2.46	1.97	1.92	1.75	1.31	1.26	1.07	-0.10	475	1.64	0.89	Total Head/Neck
Male Head/Neck*	1.60	1.49	1.55	2.73	1.97	2.09	1.45	1.18	1.26	0.96	-0.08	288	1.56		Male Head/Neck
Female Head/Neck*	3.11	2.35	2.09	1.91	1.97	1.63	2.25	1.51	1.25	1.25	-0.16	187	1.76		Female Head/Neck
Total Concussion*	0.14	0.05	0.21	0.49	0.23	0.32	0.27	0.19	0.21	0.27	0.01	71	0.24	1.47	Total Concussion
Male Concussion*	0.11	0.07	0.19	0.66	0.29	0.47	0.15	0.16	0.30	0.28	0.01	51	0.28		Male Concussion
Female Concussion*	0.22	0.00	0.25	0.14	0.11	0.09	0.48	0.24	0.06	0.25	0.01	20	0.19		Female Concussion
Total UE*	1.37	1.43	1.61	2.50	1.45	1.98	1.45	1.22	1.03	1.34	-0.05	432	1.49	1.04	Total UE
Male UE*	1.17	1.11	1.68	2.92	1.62	2.46	1.16	1.39	0.73	1.41	-0.04	278	1.51		Male UE
Female UE*	1.78	2.06	1.47	1.64	1.21	1.20	1.93	0.96	1.53	1.25	-0.06	154	1.45		Female UE
Total Trunk*	1.22	1.04	1.14	1.38	1.93	1.33	1.03	1.06	0.48	0.54	-0.07	800	1.03	1.06	Total Trunk
Male Trunk*	1.17	0.82	1.03	1.26	1.97	1.62	1.07	1.29	0.66	0.60	-0.05	194	1.05		Male Trunk
Female Trunk*	1.33	1.47	1.35	1.64	1.86	0.86	0.96	0.72	0.68	0.44	-0.12	106	1.00		Female Trunk
Total LE*	11.81	8.04	10.53	10.05	9.10	8.97	8.40	6.73	5.32	5.76	-0.59	2295	7.90	0.96	Total LE
Male LE*	13.43	6.84	9.62	9.04	9.15	9.10	8.73	7.29	4.94	5.42	-0.59	1435	7.79		Male LE
Female LE*	8.44	10.42	12.27	12.13	9.00	8.76	7.86	5.89	5.97	6.29	-0.58	860	8.09		Female LE
Total Knee*	4.18	2.32	2.75	2.77	2.46	2.24	1.87	1.60	1.49	1.71	-0.22	619	2.13	0.74	Total Knee
Male Knee*	4.69	1.78	2.13	2.39	2.37	2.04	1.75	1.50	1.06	1.41	-0.24	348	1.89		Male Knee
Female Knee*	3.11	3.38	3.93	3.54	2.63	2.58	2.09	1.75	2.22	2.18	-0.19	271	2.55		Female Knee
Total Sprain Ankle*	3.17	2.52	2.45	2.32	1.78	1.82	2.75	1.73	1.26	1.56	-0.15	577	1.99	0.68	Total Sprain Ankle
Male Sprain Ankle*	3.41	1.64	1.94	1.66	1.80	1.67	2.57	1.50	0.96	1.20	-0.15	312	1.69		Male Sprain Ankle
Female Sprain Ankle*	2.66	4.26	3.44	3.68	1.76	2.06	3.05	2.07	1.76	2.12	-0.19	265	2.49		Female Sprain Ankle
Total Heat*	2.59	1.33	0.72	0.49	0.23	0.36	0.27	3.11	0.38	0.98	-0.06	272	0.94	0.44	Total Heat
Male Heat*	2.03	0.59	0.32	0.20	0.23	0.21	0.24	2.47	0.23	0.68	-0.02	118	0.64		Male Heat
Female Heat*	3.77	2.79	1.47	1.09	0.22	0.60	0.32	4.06	0.63	1.43	-0.15	154	1.45		Female Heat
Total Fracture*	0.22	0.10	0.42	0.40	0.61	0.94	0.69	0.86	0.44	0.59	0.06	164	0.56	1.48	Total Fracture
Male Fracture*	0.21	0.07	0.45	0.53	0.23	1.31	0.68	1.02	0.53	0.88	0.08	118	0.64		Male Fracture
Female Fracture*	0.22	0.15	0.37	0.14	1.32	0.34	0.72	0.64	0.28	0.12	0.01		0.43		Female Fracture

the rate of concussion remained relatively stable with a mean rate of 0.24. Most concussions were mild to moderate using the Cantu scale of classification.

Lower extremity injuries also showed a downward trend with values decreasing from 11.81 in 1988 to 5.76 in 1997 (Fig. 1.3) with ankle sprains declining from 3.17 to 1.56 (Fig. 1.4) and knee injuries declining from 4.18 to 1.71 (Fig. 1.5).

As the USA Cup tournament grew from 252 teams in 1988 to a high of 804 teams in 1996, the rate of new, play-related injuries for all soccer players decreased from 19.87 to 8.57 per 1000 PH (Fig. 1.1). For females, rates declined from a maximum of 20.11 in 1989 to a minimum of 10.23 in 1996. In males, rates declined from a maximum

of 20.04 in 1988 to a minimum of 7.60 in 1996. The 1996 tournament was the largest USA Cup to date, with 804 teams and 47,733 PH. In 1997, the number of teams decreased to 784 with a total of 40,964 PH.

When encounter rates were analyzed (Table 2) for specific age groups (U-19, U-16, U-14, and U-12), a wider variation was apparent compared with rates based on gender alone without age stratification. For each group of age and gender, the yearly number of new, play-related encounters was totaled and divided by the total number of player-hours to yield an aggregate encounter rate for the 10-yr span of competition. The lowest aggregate encounter rate for new, play-related encounters occurred in the under-19 females (10.64/1000 PH) rate followed by rates for under-12 males (11.22) and under-14

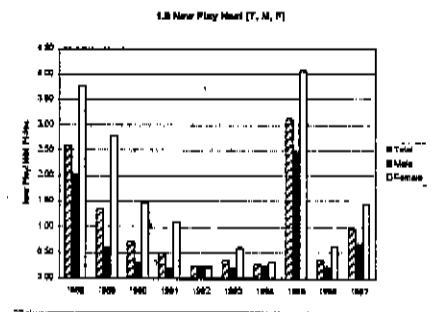
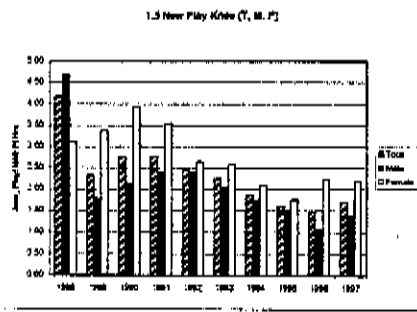
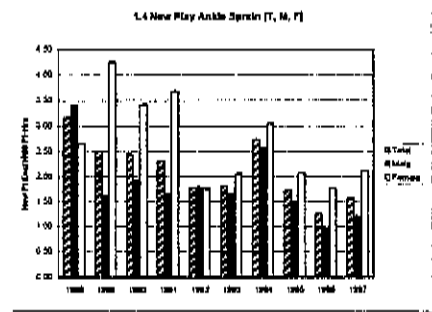
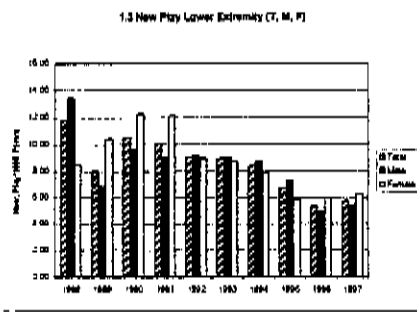
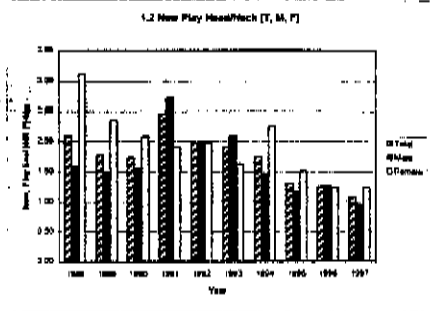
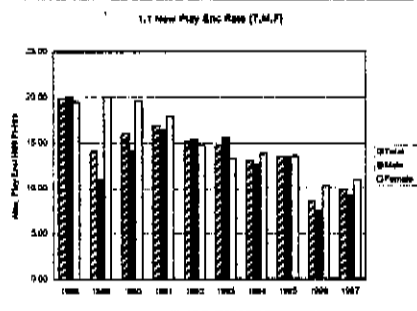


Figure 1. Rate (per 1000 PH) displayed for all New Play-related Encounters (1.1) and for selected injury types: Head and Neck (1.2), Lower Extremity (1.3), Ankle Sprain (1.4), Knee (1.5), and Heat Illness (1.6) [See Table 1 for numerical values. Total (cross-hatched); Male (black); Female (white)]

males (11.81). The highest rates occurred in the under-16 (17.68) and under-14 (16.92) female age groups.

The anatomic distribution of injuries was also reported for each age group. Table 3 lists the number and rate of new, play-related injuries; highest and lowest rates for each gender are displayed in bold and italic, respectively. These data suggest that high (or low) injury rates within a particular age group are reflected by high rates at multiple anatomic sites. For example, the low aggregate rate of injuries for under-19 females represents the lowest rates for head and neck, upper extremity, trunk, and lower extremity injuries for all female players. Similarly, under-12 males have the lowest rates at multiple sites consistent with an aggregate low rate for male players.

The aggregate rate of heat illness (heat exhaustion, hyper-ventilation, heat cramps) for the entire 10-yr span of the study was 0.94 cases per 1000 PH in the period between 1988 and 1997. No cases of heat stroke were documented. Females showed a greater tendency for heat illness with a rate of 1.45 compared with an aggregate rate for males of 0.64 (Table 1).

Conditions of extreme heat and humidity were a significant problem in 1988 and 1995. Climactic data obtained from the National Weather Service at the Minneapolis-St. Paul International Airport showed that although 1988 was hotter than 1995, 1995 was more humid. The average mean daily ambient (dry bulb) temperature was 83.3°F in 1988 (range: 67–99°F) and 81.3°F in 1995 (range: 66–101°F). Average humidity was

TABLE 2. Injury Rate (Encounters/1000 PH-Hrs).

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Slope	Total	Aggregate	Rank
Under-19 Male	12.95	7.69	12.98	15.76	17.77	14.55	14.32	15.13	8.58	10.59	-0.1	638	13.46	5
Under-16 Male	24.94	13.90	17.14	16.71	17.34	19.12	13.93	17.71	9.87	10.63	-1.0	809	16.05	6
Under-14 Male	19.04	8.50	14.51	17.27	12.88	16.47	11.49	9.56	6.69	6.65	-1.0	582	11.81	3
Under-12 Male	25.35	16.69	11.03	14.91	12.71	9.27	9.33	12.35	3.43	8.84	-1.5	310	11.22	2
<b>Total Male</b>	<b>20.04</b>	<b>11.00</b>	<b>14.33</b>	<b>16.42</b>	<b>15.40</b>	<b>15.58</b>	<b>12.60</b>	<b>13.51</b>	<b>7.60</b>	<b>9.20</b>	<b>-0.8</b>	<b>2339</b>	<b>13.39</b>	
Under-19 Female	10.36	7.18	11.81	10.75	13.33	8.99	12.63	8.74	11.03	6.94	-0.1	290	10.64	1
Under-16 Female	22.37	18.80	19.62	19.99	16.66	14.27	16.64	22.39	12.97	13.37	-0.7	631	17.68	8
Under-14 Female	34.99	35.18	30.99	21.96	12.11	17.56	15.76	11.45	9.29	12.62	-3.0	479	16.92	7
Under-12 Female	12.22	38.57	12.10	20.89	17.81	11.04	8.65	12.28	6.68	9.31	-1.8	204	12.64	4
<b>Total Female</b>	<b>19.53</b>	<b>20.11</b>	<b>19.75</b>	<b>17.99</b>	<b>14.70</b>	<b>13.22</b>	<b>13.80</b>	<b>13.53</b>	<b>10.23</b>	<b>10.96</b>	<b>-1.2</b>	<b>1504</b>	<b>14.78</b>	

TABLE 3. Distribution of injuries by anatomic location, gender and age group.

Male	# Injuries (1988-1997)				Male Injury Rates (per 1000 PH)				Range	Male Rate
	U12	U14	U16	U19	U12	U14	U16	U19		
Head	43	66	99	80	1.48	1.29	1.85	1.59	[1.29-1.85]	1.56
Concussion	6	7	22	16	0.21	0.14	0.41	0.32	[0.14-0.41]	0.28
UE	36	90	92	60	1.24	1.76	1.72	1.79	[1.19-1.76]	1.51
Shoulder	5	9	26	20	0.17	0.18	0.49	0.40	[0.18-0.49]	0.33
Trunk	22	66	65	41	0.76	1.29	1.22	0.81	[0.89-1.70]	1.05
LE	180	362	485	408	6.18	7.07	9.08	8.11	[6.01-8.75]	7.79
Thigh	32	77	117	78	1.10	1.50	2.19	1.55	[0.93-1.85]	1.65
Knee	57	76	118	97	1.96	1.48	2.21	1.93	[1.48-2.21]	1.89
Leg	25	58	70	63	0.86	1.13	1.31	1.25	[0.86-1.31]	1.56
Ankle	48	95	135	124	1.65	1.85	2.53	2.46	[1.65-2.53]	2.18
Foot	24	60	55	57	0.82	1.17	1.03	1.13	[0.82-1.17]	1.06
Total LE	180	362	485	408	6.18	7.07	9.08	8.11	[6.01-8.75]	7.79
Blister	6	6	17	20	0.21	0.12	0.32	0.40	[0.12-0.40]	0.27
PI-Hrs/1000	29.14	51.23	53.40	50.33						

BOLD: highest rate for U12-U19 males; ITALIC: lowest rate for U12-U19 males

Female	# Injuries (1988-1997)				Female Injury Rates (per 1000 PH)				Range	Female Rate
	U12	U14	U16	U19	U12	U14	U16	U19		
Head	28	75	62	22	1.69	2.56	1.97	0.76	[0.76-2.56]	1.76
Concussion	1	6	12	1	0.06	0.20	0.38	0.03	[0.03-0.38]	0.19
UE	30	54	50	20	1.81	1.84	1.59	0.69	[0.69-1.84]	1.45
Shoulder	4	11	6	3	0.24	0.38	0.19	0.10	[0.10-0.38]	0.28
Trunk	14	41	35	16	0.85	1.40	1.11	0.55	[0.66-1.74]	1.00
LE	110	252	327	171	6.65	8.60	10.41	5.90	[5.79-10.28]	8.09
Thigh	12	33	38	23	0.73	1.13	1.21	0.79	[0.60-1.08]	1.00
Knee	43	82	96	50	2.60	2.80	3.05	1.72	[1.72-3.05]	2.55
Leg	12	27	37	28	0.73	0.92	1.18	0.97	[0.73-1.18]	0.98
Ankle	33	94	124	57	1.99	3.21	3.95	1.97	[1.97-3.95]	2.90
Foot	13	19	38	16	0.79	0.65	1.21	0.55	[0.55-1.21]	0.81
Total LE	110	252	327	171	6.65	8.60	10.41	5.90	[5.79-10.28]	8.09
Blister	4	16	19	13	0.24	0.55	0.60	0.45	[0.24-0.60]	0.49
PI-Hrs/1000	16.55	29.29	31.42	28.99						

BOLD: highest rate for U12-U19 females; ITALIC: lowest rate for U12-U19 females

61.7° in 1988 and 71.5° in 1995. Average cloud cover was similar for both years: 0.4 in 1988 and 0.5 in 1995.

On site measurement of wet bulb globe temperature (WBGT) revealed nearly identical indexes of heat stress for both years. WBGT were based on measurements of dry bulb (ambient) and black globe (radiant) temperatures over the first 4 days of each tournament. The average value for WBGT from 10 a.m. through 4 p.m. was 85.7°F for both 1988 and 1995. Only the first 4 of 6 days were compared because conditions moderated over the last 2 days for both years and on-site data collection was incomplete. When comparing the average hourly ACE-WBGT for the same daytime, 4-day periods as specified above, the value was 87.9° for 1988 and 85.2° for 1995. For the entire span of the 6-day event, the value for 1988 was 84.4° compared with 84.0° for 1995. Values for average ACE-WBGT for the other 8 years range from a low of 70.1° in 1992 to 79.1° in 1997.

During the "hot" years, 1988 and 1995, the average rate of heat illness was 2.85; females were 1.7 times more likely to sustain heat illness than their male counterparts (3.92 female/2.25 male). Under "normal" (more moderate) conditions during the remaining 8 years, the average rate of heat illness was 0.59 and the female/male ratio was 3.2 (1.07 female/0.34 male). When the yearly rate of heat illness (1988-1997) was compared with average mean temperature for the USA Cup site each year during the weeks of the tournament, a correlation of 0.89 was obtained. No significant correlation was found between the rate of new, play-related encounters and average mean ambient temperature (correlation: 0.12).

Statistics from USA Cup 1988 indicated 36 cases of new, play-related heat illness out of a total number of 276 new, play-related visits. The rate of heat illness was 2.59 visits per 1000-player hours. The ratio of female to male play-related heat illness rates was 1.9 (3.77 female/2.03 male). Analysis of the distribution of heat injuries by age group in 1988 showed that under-16 and under-14 females sustained the highest rate of heat illness with rates of 7.20 and 6.49 respectively. The highest rate for males was 4.67 in the under-12 age group. The under-12 and under-19 females had the lowest rates of heat illness: 0.00 and 0.58 respectively, followed by under-19 males: 1.36 (Table 4).

In 1988, playing conditions were modified to reduce the risk of heat illness, although these modifications were not implemented until the third day of the tournament. Modifications included reduction in playing time, mandatory water breaks and unlimited substitutions. In 1995, similar changes were instituted earlier because of contingency planning for extreme heat and humidity although length of play was not reduced since regularly scheduled games were already shorter in comparison with 1988.

In 1995, a total of 141 cases of heat illness (heat exhaustion, hyperventilation, cramps) occurred out of a total number of 660 patient visits to the medical facility. This total represents visits from all patients—coaches, staff, spectators, parents, and soccer players. Soccer players sustained 97 new, play-related cases of heat exhaustion accounting for 23% of the total of 422 new, play-related problems. The new, play-related rate of heat illness

TABLE 4. Heat illness [Heat exhaustion, Hyperventilation, Cramps] 1988, 1995.

	88 N	PI Hrs	88 Rate*	88 Rank	95 N	PI Hrs	95 Rate*	95 Rank
U19 Male	4	1.36	1	5	1.16	1		
U16 Male	5	1.66	3	14	2.88	3		
U14 Male	3	1.54	2	12	2.05	2		
U12 Male	7	4.67	4	15	4.12	4		
<b>TOTAL M</b>	<b>19</b>	<b>2.08</b>		<b>46</b>	<b>2.47</b>			
U19 Female	1	0.58	2	7	2.11	1		
U16 Female	9	6.49	3	15	4.94	3		
U14 Female	7	7.20	4	16	4.16	2		
U12 Female	0	0.00	1	13	5.51	4		
<b>TOTAL F</b>	<b>17</b>	<b>3.77</b>		<b>51</b>	<b>4.06</b>			
<b>TOTAL M + F</b>	<b>36</b>	<b>2.59</b>		<b>97</b>	<b>3.11</b>			

\* Encounters/1000 PI-Hrs.

was 3.11 per 1000-PH. Females sustained heat illness with a rate of 4.06–1.6 times the male rate of 2.47 cases per 1000 PH. For both male and female players, the under-12 age group sustained the greatest rate of heat illness with a value of 5.51 for females and 4.12 for males. The lowest rate of heat illness occurred in the under-19 age group: 2.11 for females and 1.16 for males (Table 4).

The incidence of heat illness was analyzed by geographic distribution for the 1995 USA Cup tournament. A total of 87 cases of heat illness occurred in teams from latitudes greater than 40° from the equator (rate: 3.42 new, play related heat illness/1000 PH) with the remaining 10 cases occurring in teams from warmer climates from latitudes less than or equal to 40° (rate: 1.74 new, play related heat illness/1000 PH) (Table 5). When analyzed by gender, heat illness occurred with a rate of 2.71 for males from latitudes greater than 40° compared with a rate of 1.64 for males from warmer latitudes. In females, the rate was 4.33 from latitudes greater than 40° compared with a rate of 1.47 from warmer latitudes. Generally, the rate was higher within each specific age group for teams from cooler climates. A notable exception was a rate of 22.0 for under 12 females because of two cases occurring in female players from Littleton, CO, where the climate is cooler due to higher altitude.

## DISCUSSION

### Youth Tournament Studies

The Norway Cup, held annually during the first week in August, is the largest international youth soccer tournament. This six-day event served as a model for the development of the USA Cup with comparable age groups and competitive

format. Table 6 compares Norway Cup injury statistics with data from the USA Cup and the Bluegrass Invitational Soccer Tournament in Lexington, Kentucky.

Three studies are cited documenting a decline in Norway Cup injury rates from 1975 through 1997. Injury rates were first published by Nilsson and Roaas (10) in 1978 for tournaments in 1975 and 1977. They reported mean injury rates of 23.0/1000 PH in boys and 44.0/1000 PH for girls. (When minor skin abrasions and blisters were excluded from the analysis, the injury rate decreased to 14 for boys and 32 for girls). The mean injury rate for both genders was not reported. Maehlum, Dahl, and Daljord (8) studied type and frequency of injury in the 1984 Norway Cup with a total of 1,348 teams (1,016 male and 332 female) playing 3001 games with 35,154 player-hours. The mean injury rate for males declined to 9.9 injuries/1000 PH while the rate for females declined to 17.6 injuries per 1000 PH. The overall mean injury rate was 11.7. Injuries were classified by type and anatomic location: 60% lower extremity, 17% head and neck, and 14% upper extremity. Forty-seven percent of the injuries were contusions with 22% sprains, 18% lacerations, and 6% fractures. The most recent study, conducted by Maehlum, Daljord and Hansen (9) in 1999, reported injury statistics from the 1993 and 1997 Norway Cup tournaments and showed a further decline in injury rates.

Kibler (7) analyzed injuries occurring in the Bluegrass Invitational Soccer Tournament held in Lexington, Kentucky, in late May over a 4-year period from 1987 through 1990. Statistics reflected an aggregate of 480 games and 74,900 PH. An injury rate of 23.8/10,000 PH was reported. Injuries were classified by degree (severity) of injury, site of injury, type of injury, and playing status. Sixty-two point five percent of the injuries were classified as mild. The lower extremity was the most common site of injury (21% thigh, 15.8% knee, 13% ankle, and 12.8% foot). Eight percent of the injuries occurred in the head and neck region, and 10.9% involved the torso (abdomen, spine, and genital areas). Injury type included 32% contusions, 24.5% muscle strains, 21.8% sprains, 9% fractures, 1.5% concussions, and a 4.5% rate of heat illness. Thirty-seven percent of the injuries allowed return to play; 43.7% returned to play with intervention and 19.3% missed the remainder of the tournament.

The USA Cup definition of injury included any competition-related event resulting in a visit to the medical facility. Rates were

TABLE 5. Geographic distribution of heat illness

Age Groups	All Teams		Teams ≤ 40° Latitude				Teams > 40° Latitude			
	PI-Hrs	Teams	# Teams	PI-Hrs ≤40°	#Cases New, Play Heat	Rate ≤40°	# Teams	PI-Hrs >40°	# Cases New, Play Heat	Rate >40°
U19 Male	4.30	83	20	1.04	0	0.00	63	3.26	5	1.53
U16 Male	4.86	100	21	1.02	3	2.94	79	3.84	11	2.87
U14 Male	5.86	128	28	1.28	1	0.78	100	4.58	11	2.40
U12 Male	3.64	82	21	0.93	3	3.21	61	2.71	12	4.43
<b>TOTAL MALE</b>	<b>18.66</b>	<b>393</b>	<b>90</b>	<b>4.27</b>	<b>7</b>	<b>1.64</b>	<b>303</b>	<b>14.38</b>	<b>39</b>	<b>2.71</b>
U19 Female	3.32	64	9	0.47	0	0.00	55	2.85	7	2.45
U16 Female	3.04	64	6	0.28	0	0.00	58	2.75	15	5.46
U14 Female	3.84	84	14	0.64	1	1.56	70	3.20	15	4.68
U12 Female	2.36	52	2	0.09	2	22.02	50	2.27	11	4.84
<b>TOTAL FEMALE</b>	<b>12.68</b>	<b>264</b>	<b>31</b>	<b>1.47</b>	<b>3</b>	<b>2.03</b>	<b>233</b>	<b>11.08</b>	<b>48</b>	<b>4.33</b>
<b>TOTAL M + F</b>	<b>31.22</b>	<b>657</b>	<b>121</b>	<b>5.75</b>	<b>10</b>	<b>1.74</b>	<b>536</b>	<b>25.47</b>	<b>87</b>	<b>3.42</b>

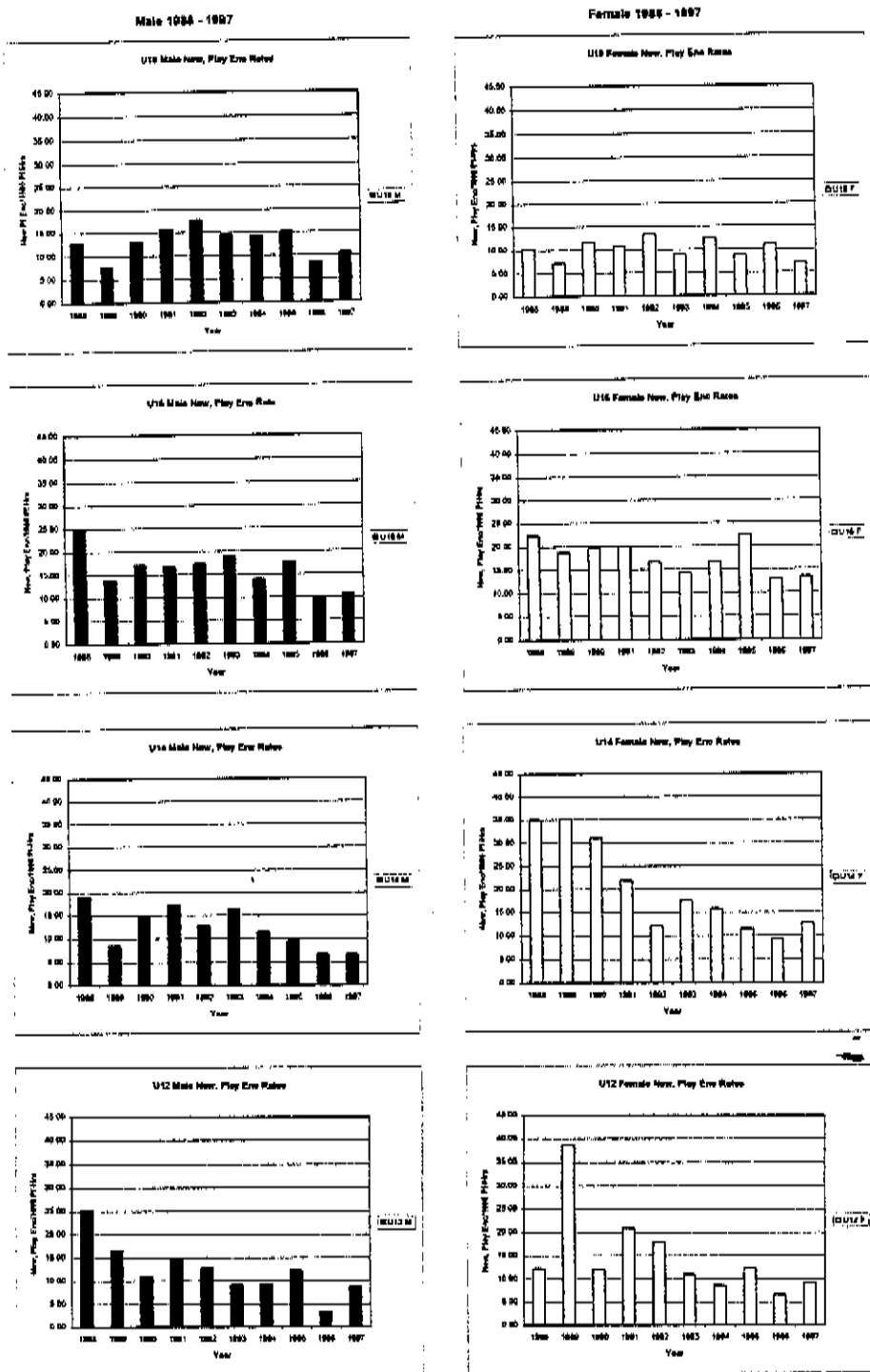


Figure 2. Injury rates (New, Play-related Encounters/1000 PH) graphed according to groups of age and gender. See Table 2 for numerical values. Legend: Male (black); Female (white)

reported per 1000 hours of USA Cup competition allowing for comparison with injury rates in other similar studies. Severity of injury was not recorded. The 10-year span of the study, lack of consistent standards for definition of severity, and a large number and variety of medical personnel involved in delivering care made a uniform assignment of severity impractical. Post-tournament follow-up, which would have allowed for a more precise assessment of diagnosis and playing status after injury, was not carried out due to limited resources and large number of injured participants.

USA Cup statistics show a downward trend in the rate of new, play-related encounters in the interval from 1988 through 1997. Injury rates are now consistent with those reported from the European tournaments. Most recent statistics from the Norway Cup show a similar downward trend in injury rates and also reveal an injury rate for females slightly higher than the rate for males.

The lower extremity was the most common location for injury (64%) followed by head and neck (14%), upper extremity (12%), and trunk (10%). The overall distribution of injuries

TABLE 6. Youth tournament studies.

Tournament	Year(s)	Number Games	Number Teams	Player-Hours	Mean Injury Rate/1000 PH	Male Injury Rate/1000 PH	Female Injury Rate/1000 PH	Study (Reference)
Norway Cup (Oslo, Norway)	1975, 1977	2987	1549	NR (not reported)	NR	23.0 (14.0)	44.0 (32.0)	Nilsson, Roaas 1978 (10)
Norway Cup	1984	3001	1348	35,154	11.7	9.9	17.6	Maehlum, Dahl, Daljord 1984 (8)
Norway Cup	1993	NR	[1016 M, 332 F]	36,036	7.7	7.6	8.1	Maehlum, Daljord, Hansen 1999 (9)
Norway Cup	1997	NR	NR	40,779	7.3	6.9	8.3	Maehlum, Daljord, Hansen 1999 (9)
Bluegrass (Lexington, KY)	1987-1990	480	NR	74,900	2.38	NR	NR	Kibler 1993 (7)
USA Cup (Blaine, MN)	1988-1997	13,643	5373 [3370 M, 2003 F]	290,344 [20,266-47,733]*	13.23 [8.57-19.87]*	12.69 [7.60-20.04]*	14.15 [10.23-20.11]*	Elias 2001

\* Range: min-max.

by anatomic location was consistent with statistics from the Norway Cup. Review of individual encounters during the entire span of USA Cup competition reveals that severe injuries were limited to fractures, concussions, ACL and meniscus tears, as well as rare spleen and liver lacerations.

### Gender and Susceptibility to Injury

USA Cup analysis shows that females sustain fractures and concussions at lower rates than their male counterparts but have a greater rate of knee injuries and ankle sprains. Females are also significantly more vulnerable to heat illness during the years of significant heat stress. As noted above, overall female injury rates during USA Cup participation are greater than rates for males. The difference in rates, is becoming less significant, possibly due to improved conditioning and greater experience. There are also gender differences in style of play, which might play an important role in susceptibility to injury. Furthermore, there are physiological factors discussed below in the context of specific types of injury.

In a retrospective 1997 study (2) of ACL injuries in Norwegian soccer players the incidence for women was 0.10 injuries per 1000 game hours and the incidence for men was 0.057. In 1998 Wojtyls (12) reported anterior cruciate injuries four to eight times higher in women than men and found a significant statistical association between stage of menstrual cycle and incidence of ACL injuries. In a 1997 review article on female athletes (11), musculoskeletal injuries in sports were not considered to be gender specific while acknowledging the increased prevalence of ACL injuries in women soccer and basketball players. Huston and Wojtyls (6) analyzed neuromuscular performance characteristics in elite female athletes and demonstrated differences in strength, endurance, and laxity.

When history of concussion was evaluated for elite soccer players in 1998 (1), it was predicted that male players had odds of 50% of sustaining a concussion within a 10-year period whereas female players had odds of 22%. Men had a risk 2.26-fold higher risk of sustaining a concussion. In this survey of 72 men and 72 women, men sustained more concussions (74 male; 38 female). Male concussions were more severe and men were more likely to sustain multiple concussions. Men reported different symptoms than women and these differences were attributed to "women's smaller

mass, greater ball-to-head-size ratio and possible lesser neck strength, as well as a subjective impression that there is more heading in women's games than in men's."

Endocrine status is another important factor distinguishing males from females although the impact on performance remains to be defined. Both endogenous and exogenous hormones impact cardiovascular, respiratory, and metabolic physiology, but are felt to have a "minimal impact" at the recreational level (5). In 1988, Carpenter (2) reported that "endogenous hormones subtly alter women's response to heat stress." At higher levels of competition, especially under conditions of extreme heat and humidity, this may be at least one important factor explaining the increased female incidence of heat illness seen in USA Cup competition.

### Age

When USA Cup rates are analyzed by age and gender (Fig. 2) it is apparent that the decrease in female encounter rates in the under-16 and under-14 age brackets contributes significantly to an overall downward trend in injury rates.

Analysis of age-stratified injury rates in the USA Cup study show that the under-19 females have been consistently low (10.64/1000 PH) even during the early years of the study (Table 2). The next lowest group was under-12 males (11.22/1000 PH). The under-19 female group may have had a longer experience with soccer competition and play with more skill compared to younger players. The low rate in under-12 males is likely explained by lower body mass and possibly less aggressive style of play compared to older males.

The highest aggregate injury rates occurred in under-16 (17.68/1000 PH) and under-14 female (16.92/1000 PH) age brackets. This may reflect differences in degree of conditioning and experience. The overall downward trend in female injury rates (slope -1.2 new, play enc/1000 PH per year) was influenced by decreases in these age groups. Under-14 females showed the most dramatic downward trend (slope -3.0) from 1988 through 1997; under-12 (slope -1.8) and under-16 (slope -0.7) females also demonstrated less significant downward trends. One explanation for these trends might be improved conditioning and greater involvement and experience with soccer within this span of time.

Injury rates for males show a similar downward trend (slope -0.8 new, play enc/1000 PH per year) with a maximum

aggregate rate of new, play-related encounters declining from 20.0 in 1988 to a minimum rate of 7.60 in 1996. Under-12 males had the lowest 10-year aggregate injury rate with 11.22 new, play-related encounters/1000 PH followed by under 14 males (11.81) then under-19 males (13.46) with the greatest rate occurring in under-16 males (16.05). When trends within each age group are examined, a downward trend is most evident in the under-12 males (slope -1.5) suggesting that wider participation in soccer from 1988 through 1997 has led to improvements in conditioning and experience. Similar factors might account for downward trends in the under-14 (slope -1.0) and under-16 (slope -1.0) age groups. Under-19 males showed no significant downward trend (slope -0.1); the trend for under-19 females showed a similar trend (slope -0.1).

It must be acknowledged that proposed explanations for observed variation in injury rates are speculative in nature and not corroborated by USA Cup data.

## Heat

This study focuses on the risk of injury with age and gender as independent variables. Heat stress is likely to be another important variable, although an analysis of its full impact has yet to be determined. Certainly conditions of extreme heat and humidity lead to an increased incidence of heat illness. The high correlation between average ACE-WBGT and the rate of heat illness is consistent with this expectation. It can be hypothesized that heat stress impacts susceptibility to all injuries through impairment of judgement and neuromuscular coordination. The lack of significant correlation between our approximation of heat stress and overall injury rate might suggest that heat stress does not contribute to risk of injury. However, the design of this study does not allow for the more complex multivariate analysis required to test this hypothesis.

Instead of using an average measurement of ACE-WBGT to approximate heat stress during an entire tournament, a more accurate approach might entail measurement of cumulative heat exposure for individual players based on monitoring of WBGT on-site. Current technology now allows for nearly continuous on-site monitoring and recording of WBGT throughout the entire duration of the tournament. Accurate estimates of heat exposure during tournament-related competition can be accomplished, but the task requires extensive data collection for a tournament of this size. Theoretically, it is possible to calculate a cumulative heat exposure prior to the date and time of each new, play-related injury. An analysis of

injury risk could then be carried out using age, gender, and cumulative heat exposure as independent variables.

Medical encounter forms used throughout the duration of the current study, in fact, have fields for recording of place, date, and time for each injury. In reality, due to size of the tournament, number of injuries, and large number of medical staff participating, these data have not been consistently recorded.

The definitive analysis of the role of heat stress in injury will likely require a smaller number of subjects monitored over the span of a single tournament with extensive resources applied for data collection and analysis. There are obviously many additional factors affecting injury rates: field conditions, conditioning, acclimatization, officiating style, changes in rules, number of years of soccer experience, style of play, total number of games played, and number of games played per day in addition to inequalities in level of skill and style of play. This problem is further complicated by the relationship between gender and susceptibility to heat stress.

## SUMMARY

An analysis of USA Cup injuries from 1988 through 1997 demonstrates a downward trend in youth soccer injuries during international competition with exposure rates now comparable to the European international youth tournaments. The USA Cup study also indicates that although females are injured at a rate slightly greater than males, there is a trend suggesting that the overall difference is becoming less significant. Nevertheless, there may be age and gender differences in susceptibility to certain injuries. USA Cup data shows an increased susceptibility to heat illness in females. Females also have increased rates of knee injuries and ankle sprains with decreased fracture rates compared to males. Finally, epidemiological studies of youth soccer indicate that catastrophic injuries are relatively rare and that most injuries are minor. USA Cup experience is consistent with this observation.

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