A Meta-analysis of the Incidence of Anterior Cruciate Ligament Tears as a Function of Gender, Sport, and a Knee Injury–Reduction Regimen

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Purpose: The literature has shown that anterior cruciate ligament (ACL) tear rates vary by gender, by sport, and in response to injury-reduction training programs. However, there is no consensus as to the magnitudes of these tear rates or their variations as a function of these variables. For example, the female-male ACL tear ratio has been reported to be as high as 9:1. Our purpose was to apply meta-analysis to the entire applicable literature to generate accurate estimates of the true incidences of ACL tear as a function of gender, sport, and injury-reduction training. **Methods:** A PubMed literature search was done to identify all studies dealing with ACL tear incidence. Bibliographic cross-referencing was done to identify additional articles. Meta-analytic principles were applied to generate ACL incidences as a function of gender, sport, and prior injury-reduction training. **Results:** Female-male ACL tear incidences ratios were as follows: basketball, 3.5; soccer, 2.67; lacrosse, 1.18; and Alpine skiing, 1.0. The collegiate soccer tear rate was 0.32 for female subjects and 0.12 for male subjects. For basketball, the rates were 0.29 and 0.08, respectively. The rate for recreational Alpine skiers was 0.63, and that for experts was 0.03, with no gender variance. The two volleyball studies had no ACL tears. Training reduced the ACL tear incidence in soccer by 0.24 but did not reduce it at all in basketball. **Conclusions:** Female subjects had a roughly 3 times greater incidence of ACL tears in soccer and basketball versus male subjects. Injury-reduction programs were effective for soccer but not basketball. Recreational Alpine skiers had the highest incidences of ACL tear, whereas expert Alpine skiers had the lowest incidences. Volleyball may in fact be a low-risk sport rather than a high-risk sport. Alpine skiers and lacrosse players had no gender difference for ACL tear rate. Year-round female athletes who play soccer and basketball have an ACL tear rate of approximately 5%. **Level of Evidence:** Level IV, therapeutic case series. **Key Words:** Anterior cruciate ligament tear—Incidence—Gender variance—Knee injury reduction.

It is estimated that there will be more than 100,000 anterior cruciate ligament (ACL) tears in the United States this year.[1] The injury is usually quite painful. Treatment commonly entails surgery and significant time lost from work and sports. For these and other reasons, there is great interest in reducing the number of ACL tears. It is commonly reported that female subjects have a greater incidence of ACL tear than male subjects. This has been estimated to be as much as 8 to 9 times greater by sports medicine physicians.[2,3] It is also commonly reported that dedicated programs can reduce that incidence. Finally, varying claims are made as to which sports are high risk for ACL tear. Widely disparate representations are made because there has been no systematic study of the subject to establish what is really known. In addition,

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The authors report no conflict of interest.

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0749-8063/07/2312-0728$32.00/0
doi:10.1016/j.arthro.2007.07.003

Note: To access the supplementary tables accompanying this report, visit the December issue of *Arthroscopy* at www.arthroscopyjournal.org.

incidence data are technical and confusing to deal with, rendering cohesive understanding of the subject difficult from a casual reading of the literature. Before a problem can be adequately remedied, it is necessary to understand the nature of the problem. We believed that this subject lent itself well to meta-analysis. Therefore our purpose was to test the hypothesis that the incidence of ACL tears would show variation by sport, gender, and effect of ACL tear–reduction training program.

METHODS

A PubMed computerized literature search was performed to identify all English-language peer-reviewed research articles dealing with the incidence of ACL tears. A number of indexing terms were used to achieve this goal. The exact phrase "anterior cruciate ligament" with either the keyword "incidence" or "rate" was used initially. Each individual sport with the phrase "anterior cruciate ligament" was also indexed. We found 793 articles. Abstracts were then reviewed of each of these to identify those that had actual numeric data on the incidence of ACL tear. Reports that dealt with the incidence of ACL tears were obtained based on their abstracts for review. Of these, 33 were found to have usable ACL tear incidence data and are the basis of this study. The generally preferred and most commonly used method of ACL tear incidence measurement is "tears per 1,000 exposures," with an exposure being defined as a practice or a game. Of the 33 articles, 25 either reported their data via this method or were able to have their data converted into this format for purposes of comparison with other studies. The only exception to this convention is found in the Alpine skiing literature, in which a skier-day is used as an exposure. In all cases an exposure represents a usual day's participation for the given sport. These data are presented in Table 1 (online only, available at www.arthroscopyjournal.org). When conversions were made into the "tears per 1,000 exposures" format from data not originally presented that way, the assumptions that were used to make the conversion are listed. Most commonly, this involved converting "tears per hour of competition" into tears per exposure by converting hours into exposures by use of the length of practices in hours and minutes to substitute. The data in Table 1 (online only, available at www.arthroscopyjournal.org) are divided by sport and then subdivided by level of competition (i.e., high school or collegiate). Data from each subdivision level (e.g., high school soccer as a subdivision of soccer) were then pooled in Table 2 (online only, available at www.arthroscopyjournal.org). Table 3 (online only, available at www.arthroscopyjournal.org) lists the 8 studies that reported incidence data but not in, or convertible to, the "tears per 1,000 exposures" format.[4-11] Table 4 (online only, available at www.arthroscopyjournal.org) pools the data from studies that compared female with male injury rates. Only comparison studies were used, and weighted means were calculated for the female-male ratios thus obtained. Table 5 (online only, available at www.arthroscopyjournal.org) pools the data from studies that compared athletes who had been trained in ACL injury–reduction programs with athletes who had not. As with the female-male data, only comparison studies were used here to compute weighted means.

Statistical Analysis

The data from all of the articles were first pooled together by generating weighted means for all ACL incidence rates by sport. We then used the χ^2 test to compare weighted means across groups. The significance level was set at $P = .05$. All statistical analysis was performed with the S-PLUS program (Insightful, Seattle, WA).

RESULTS

In this section the sports are listed in descending order based on the number of exposures for each sport from the studies available.

Basketball

The collegiate basketball studies had 15,420,034 exposures.[12-16] The high school studies had 414,493 exposures.[17-20] The 2 professional studies had 115,221 exposures.[21,22] The female college incidence was 0.29, and the male rate was 0.08. The female-male ratio was 3.63. For high school, the female rate was 0.09 and the male rate was 0.02. The female-male ratio was 4.5. The female professional incidence was 0.20, and the male incidence was 0.21. The female-male ratio was 0.95.

Soccer

The collegiate soccer studies had 11,754,568 exposures.[12-16] The high school studies had 234,112 exposures.[18,20,23] The adult soccer studies had 66,810 exposures.[24-26] Two adult indoor game–only studies had 3,600 exposures.[27,28] Only the college and indoor soccer studies broke down incidence by gender. The mean female collegiate rate was 0.32, and the male rate was 0.12. The female-male ratio was 2.67. For indoor soccer, the female rate was 5.21 and the male rate was 1.88.[27,28] The female-male ratio was 2.77. Only high school soccer studies broke down incidence by the presence or absence of an ACL injury–reduction training regimen. The mean reduction for the 3 studies was −0.24 tears per 1,000 exposures.

Alpine Skiing

The two studies of ski lodge employee skiers by Oates et al.[29] and Viola et al.[30] have rates of 0.02 and 0.04, respectively. The two studies of general population skiers by Warme et al.[31] and Deibert et al.[32] have rates of 0.63 and 0.40, respectively. There was found to be no gender incidence difference in the study of Viola et al.

Lacrosse

The only available study regarding lacrosse was collegiate.[20] The total number of exposures was 1,783,903. The female ACL tear incidence was 0.18, and the male tear rate was 0.17. The female-male ratio was 1.06.

Football

The football studies had 1,227,469 exposures.[33,34] The athletes were all male. The overall ACL incidence was 0.08.

Handball

The three included studies regarding handball have total exposures of 154,035.[35-38] In two of these studies, the female and male rates are 0.86 and 0.24, respectively (female-male ratio, 3.59),[37] and 0.56 and 0.11, respectively (female-male ratio, 5.01),[35] and in the third study, the female-only cohort had a rate of 1.26.[36] The study by Petersen et al.[36] showed a nonsignificant trend toward reduction of ACL tears in the trained group.

Australian-Rules Football

The one included study of Australian-rules football has total exposures of 100,820.[39] This is a male-only cohort with an ACL tear rate of 0.04.

Rugby

The two collegiate studies of rugby had total exposures of 89,559.[15,40] The incidences in female and male subjects were 0.36 and 0.18, respectively, for a female-male ratio of 2.

Volleyball

The two high school volleyball studies had total exposures of 28,657.[17,21] There were no torn ACLs.

Wrestling

The college wrestling study had exposures of 11,888.[14] The ACL tear rate was 0.77 in female subjects and 0.19 in male subjects. The female-male ratio was 4.1.

Female Versus Male Tear Rate

In descending order the female-male ratios are as follows: wrestling, 4.05; basketball, 3.5; indoor soccer, 2.77; soccer, 2.67; rugby, 1.94; lacrosse, 1.18; and alpine skiing, 1.00.

Training Effect

ACL injury–reduction programs resulted in a reduced incidence of ACL tears in soccer of −0.24 tears per 1,000 exposures for the trained versus untrained group. For basketball, the trained group had an increased rate of ACL tear of 0.25. For volleyball, there were no tears in either group.

Exposures by Sport

The exposures by sport in descending order are as follows: basketball, 15,949,748; soccer, 13,892,946; alpine skiing, 8,114,373; lacrosse, 1,783,903; football, 1,227,469; handball, 154,035; rugby, 89,559; volleyball, 28,657; and wrestling, 11,888.

DISCUSSION

This is the only study to our knowledge that evaluates the overall relative risks of ACL tears as a function of sport, gender, and injury-reduction training. It is also the only study to use meta-analytic methods to arrive at these conclusions for all three parameters. The data analysis provides a number of interesting observations.

Before these observations are discussed, it should be pointed out that there is great variation in the number of exposures among the available studies. The largest group had over 8 million exposures, whereas the smallest had only 625. It is therefore imperative that the reader always be cognizant of the number of exposures attendant to given ACL tear incidence rates because the reliability of the incidence is directly proportional to the number of exposures. The meta-analytic method is particularly well suited to analyses in which such large variations exist because it weights aggregated rates proportionately according to the number of exposures and thus minimizes the effect of low exposure cohorts. Thus Table 2 (online only, available at www.arthroscopyjournal.org), which provides these weighted means, provides the most reliable numbers. Although this weighting eliminates outlier effects within groups of studies for a specific sport, it cannot eliminate this effect for comparisons between sports when there are few exposures for one of them.

The National Collegiate Athletic Association Injury Surveillance System provided the data for the large studies of Arendt and Dick,[13] Harmon and Dick,[15] Agel et al.,[12] and Mihata et al.[16] These studies used National Collegiate Athletic Association Injury Surveillance System data from 1989-1993, 1989-1997, 1989-2002, and 1989-2004, respectively. The injury rates were quite similar among these large exposure studies even though they look at different time periods. For example, the basketball and soccer data are dominated by the large exposure studies of Mihata et al., Agel et al., and Arendt and Dick. The female injury rates for basketball were 0.28, 0.29, and 0.30 from these 3 different studies, respectively. For soccer, the rates were 0.32, 0.33, and 0.31, respectively. For male subjects, the corresponding rates were 0.08, 0.08, and 0.07 for basketball and 0.12, 0.12, and 0.13 for soccer. The fact that this consistency was maintained over time can best be interpreted as indicating a very high level of reliability of these data. However, the rates for wrestling, volleyball, and indoor soccer, all of which are very high, have much lower reliability, given the very small number of exposures. The remaining sports have intermediate numbers of exposures and thus intermediate reliability.

The female-to-male ACL injury rate has been the aspect of ACL tear incidence that has attracted the most recent interest. The basketball ratio of 3.5 and soccer ratio of 2.66, as described, give a reliable picture of this relative risk. This roughly 3-fold gender disparity is somewhat lower than the 6-fold increased risk that is often quoted. Rugby and handball also showed significantly increased risk among female subjects, though with less reliable numbers because of the smaller number of exposures.

It is interesting that alpine skiing had no difference in injury rates between male and female subjects in very high exposure studies for both the ski lodge employee expert skiers and the general population non-expert skiers. We have no explanation for this lack of gender disparity. This would indicate, however, that any injury-reduction efforts in snow skiing would best be directed at both male and female subjects.

In addition, the overall skiing data showed snow skiing to indeed be the high-risk sport that it is commonly thought to be for the general public. The 0.49 rate is the highest recorded for large exposure studies, especially given that half of the subjects are male. However, among the ski lodge employees, presumably expert skiers, the 0.03 rate is the lowest for any large exposure study. Both cohorts have very large exposures, indicating high reliability. Thus the low tear rate group benefited dramatically from increased skill in their sport without specific injury-reduction training. This obviously highlights the benefit of novice skiers obtaining proper instruction. In fact, the diminution in ACL tear incidence as a function of this difference in skill level is the largest such effect seen in the study. It should be pointed out, however, that the actual risk to recreational skiers, despite the high incidence, is actually quite low because most recreational skiers have very few exposures per year compared with those playing competitive organized sports such as soccer and basketball.

There was also no gender disparity regarding lacrosse. It has been suggested that the carrying of the stick is in some way ACL-protective, but if so, it would only be protective for female subjects because the 0.17 male rate is slightly higher than that found for male subjects in soccer, basketball, and football.

Despite the relatively small number of exposures, we think it is potentially of interest that no volleyball ACL tears occurred among 4 cohorts from studies by 2 different groups. Volleyball is routinely classified as a "high-risk sport."[41] These data indicate that it may be a much lower-risk sport for ACL tear than has been previously thought.

Football, with a male injury rate of 0.11, had a very similar rate to that of soccer, at 0.12, and basketball, at 0.08. All 3 sports are subject to noncontact ACL tears. Football is often thought to have higher risk because its players are subject to a much higher risk of contact ACL tear as well as noncontact tear. The fact that the overall incidence in football is not higher indicates that the noncontact mechanism of injury is likely much more prevalent than the contact mechanism for ACL tears overall.

Three separate soccer studies showed significant reductions in ACL tear rate as a result of specific injury-reduction training programs. Surprisingly, however, the two basketball studies showed no reduction in tear rate and indeed both showed double-digit increases in tear rate. Although it is unlikely that the programs actually significantly increased tear rate, it would appear that the ACL tear–reduction training programs extant are effective for soccer but ineffective for basketball.

The data in this study can be used to provide at least a rough estimate of the overall chance of injury for high-risk sports. Hewett et al.[41] found a 4.4% 1-year incidence of ACL tear in a prospective study of such female athletes. The combined college soccer and basketball female ACL tear rate per 1,000 exposures is roughly 0.3—that is, a given athlete would have a 30% risk of ACL tear after 1,000 exposures. Year-round players easily participate in 167 exposures per calendar year; 167/1,000 (17%) multiplied by this 30% risk equals 5%. Thus there may be roughly a 5% chance of ACL tear for a female high-level soccer/basketball athlete for each year of participation. This number is in reasonably close agreement with the 4.4% figure of Hewett et al. The risk would be higher or lower depending on the actual number of exposures. We think this may be a reasonable ballpark number that may be useful for counseling of athletes interested in the risks of participation. If men are assumed to have one third this risk, this would translate to a roughly 1.7% yearly risk, again depending on the number of exposures.

This report has many weaknesses inherent to a large meta-analysis. Because the inclusion and exclusion criteria vary from article to article, there is significant selection bias. In addition, not all of the articles reported the incidence data in the same format; assumptions were made that again may lead to bias. Also, most of the studies were retrospective studies. In addition, we made assumptions as to the length of practices and games in some cases, where noted, to allow the comparison of data in the per-hour format to data in the preferred and more widely used per-exposure format.

CONCLUSIONS

Female subjects had a roughly 3 times higher incidence of ACL tears in soccer and basketball than male subjects. Injury-reduction programs were effective for soccer but not basketball. Recreational Alpine skiers had the highest incidences of ACL tear, whereas expert Alpine skiers had the lowest incidences. Volleyball may in fact be a low-risk sport rather than a high-risk sport. Alpine skiers and lacrosse players had no gender difference for ACL tear rate. Year-round female soccer and basketball athletes have an ACL tear rate of approximately 5% per year.

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Table 1. *ACL Tear Rate by Sport, Level, Gender, and Injury Training*

Sport	Level	Subgroup	First Author	Male and Female			Female			Male			
				Incidence	ACL Tear	Exposures	Incidence	ACL Tear	Exposures	Incidence	ACL Tear	Exposures	Female-Male Ratio
Basketball	Professional	WNBA	Trojian[22]				0.20	9	45,036.00				
	Professional	NBA	Lombardo[21]							0.21	15	70,185.00	
	College	NCAA	Mihata[16]*	0.17	1,393	8,068,016.00	0.28	1,061	3,733,209.00	0.08	332	4,334,807.00	3.50
		NCAA	Agel[12]*	0.18	682	3,889,954.00	0.29	514	1,797,730.00	0.08	168	2,092,224.00	3.63
		Collegiate	Harmon[15]*	0.18	359	1,972,170.00	0.30	275	925,501.00	0.08	84	1,046,669.00	
		NCAA	Arendt[13]*	0.17	238	1,375,974.00	0.30	189	639,898.00	0.07	49	736,076.00	4.29
		Naval—collegiate	Gwinn[14]	0.28	6	21,734.00	0.48	5	10,452.00	0.09	1	11,282.00	5.33
		Naval—intramural	Gwinn	0.14	5	35,226.00	0.00	0	1,360.00	0.15	5	33,866.00	0.00
		Naval—all levels	Gwinn	0.19	11	56,960.00	0.42	5	11,812.00	0.13	6	45,148.00	3.23
	High school		Gomez[17]				0.13	11	84,341.66				
			Messina[19]*	0.07	15	223,566.15	0.12	11	92,885.38	0.03	4	130,680.77	4.50
		Untrained	Pfeiffer[20]				0.11	2	18,076.00				
		Trained					0.48	3	6,302.00				
		Untrained	Hewett[18]				0.29	3	10,370.00				
		Trained					0.42	2	4,767.00				
Soccer	Adults	German National League	Faude[24]				0.65	11	16,830.00				
	Adults	Competitive—trained	Soderman[26]				0.18	4.00	22,134.00				
	Adults	Competitive—untrained					0.04	1.00	27,846.00				
	Adults	Recreational	Bjordal[24]*	0.07	131	1,837,455.83							
	College	NCAA	Mihata*	0.21	1,295	6,283,785.00	0.32	871	2,736,615.00	0.12	424	3,547,170.00	2.67
		NCAA	Agel*	0.21	586	2,840,568.00	0.33	394	1,208,994.00	0.12	192	1,631,574.00	2.75
		Collegiate	Harmon*	0.20	317	1,605,004.00	0.32	194	604,430.00	0.12	123	1,000,574.00	
		NCAA	Arendt*	0.19	178	934,971.00	0.31	97	308,748.00	0.13	81	626,223.00	2.38
		Naval—collegiate	Gwinn	0.32	6	18,916.00	0.77	5	6,508.00	0.08	1	12,408.00	9.63
		Naval—intramural	Gwinn	0.46	12	26,204.00	2.70	2	742.00	0.39	10	25,462.00	6.92
		Naval—all levels	Gwinn	0.40	18	45,120.00	0.97	7	7,250.00	0.29	11	37,870.00	3.34
	High school	Untrained	Mandelbaum[23]*				0.49	67	137,448.00				
		Trained					0.09	6	67,860.00				
		Untrained	Pfeiffer				0.11	1	9,357.00				
		Trained					0.00	0	5,913.00				
		Untrained	Hewett				0.22	2	9,017.00				
		Trained					0.00	0	4,517.00				
Alpine skiing	All ages	General population	Deibert[32]*	0.40	1,448	3,641,041.00							
	Adults	General population	Warme[31]*	0.63	1,615	2,550,000.00							
	Employees		Oates[29]*	0.02	19	1,196,496.00							
	Employees		Viola[30]*	0.04	31	726,836.00	0.04	10	227,766.00	0.04	21	499,070.00	1.00

Table 1. *Continued*

				Male and Female			Female			Male			
Sport	Level	Subgroup	First Author	Incidence	ACL Tear	Exposures	Incidence	ACL Tear	Exposures	Incidence	ACL Tear	Exposures	Female-Male Ratio
Lacrosse	College	NCAA	Mihata*	0.18	315	1,783,903.00	0.18	146	799,611.00	0.17	169	984,292.00	1.06
Football	Adults	Professional	Scranton[34]							0.07	61	895,908.00	
	High school		DeLee[33]*							0.11	37	331,561.00	
Handball	Adults	Elite athletes	Myklebust[35]	0.33	28	84,690.00	0.56	23	40,799.00	0.11	5	43,891.00	5.09
	Adults	Recreational	Seil[37]							0.24	5	20,462.67	
	Adults	Untrained	Petersen[36]				0.43	5	11,671.34				
		Trained					0.08	1	12,254.90				
	Young adults	Competitive	Wedderkopp[38]				0.09	4	42,442.42				
Australian football	Adults	Professional—2001	Orchard[39]*							0.82	83	100,820.00	
Rugby	College	Collegiate	Levy[40]				0.36	21	58,296.00				
		Naval—collegiate	Gwinn	0.22	7	31,263.00	0.35	3	8,475.00	0.18	4	22,788.00	1.94
Volleyball	High school	Untrained	Pfeiffer				0.00	0	11,229.00				
		Trained					0.00	0	5,739.00				
		Untrained	Hewett				0.00	0	3,751.00				
		Trained					0.00	0	7,938.00				
Wrestling	College	Naval—collegiate	Gwinn	0.25	3	11,888.00	0.77	1	1,306.00	0.19	2	10,582.00	4.05
Indoor soccer	All ages	General population	Lindenfeld[27]	2.78	10	3,600.00	5.21	8	1,536.00	0.97	2	2,064.00	5.37
		General population	Putukian[28]				5.30	1	190.00	5.00	3	600.00	1.04

NOTE. Incidences are expressed as complete ACL tears per 1,000 exposures.
Abbreviations: WNBA, Women's National Basketball Association; NBA, National Basketball Association; NCAA, National Collegiate Athletic Association.
*High-exposure study.

TABLE 2. *Weighted Means for Groups*

Sport	Level	Male and Female			Female			Male			
		Incidence	ACL Tears	Exposures	Incidence	ACL Tears	Exposures	Incidence	ACL Tears	Exposures	Total Exposures
Basketball	Professional				0.20	9.00	45,036.00	0.21	15.00	70,185.00	15,949,747.66
	Collegiate	0.17	2,694.00	15,420,034.00	0.29	2,049.00	7,119,962.00	0.08	645.00	8,300,072.00	
	High school—untrained				0.10	27.00	233,538.66	0.02	4.00	169,885.00	
	High school—trained				0.45	5.00	11,069.00				
Soccer	German National League				0.65	11.00	16,830.00				13,892,945.83
	Adult competitive—untrained				0.04	1.00	27,846.00				
	Adult competitive—trained				0.18	4.00	22,134.00				
	Adult recreational	0.07	131.00	1,837,455.83							
	Collegiate	0.21	2,412.00	11,754,568.00	0.32	1,570.00	4,873,287.00	0.12	842.00	6,881,281.00	
	High school—untrained				0.45	70.00	155,822.00				
	High school—trained				0.08	6.00	78,290.00				
Alpine skiing	Employees	0.03	50.00	1,923,332.00	0.04	10.00	227,766.00	0.04	21.00	499,070.00	8,114,373
	General population	0.49	3,063.00	6,191,041.00							
Lacrosse	Collegiate	0.18	315.00	1,783,903.00	0.18	146.00	799,611.00	0.17	169.00	984,292.00	1,783,903
Football	Professional							0.07	61.00	895,908.00	1,227,469
	High school							0.11	37.00	331,561.00	
Handball	Elite athletes	0.33	28.00	84,690.00	0.56	23.00	40,799.00	0.11	5.00	43,891.00	154,035.09
	Adult recreational—untrained				0.86	5.00	5,815.00	0.24	5.00	20,462.67	
	Adult recreational—trained				1.60	1.00	625.00				
	Young adults				0.09	4.00	42,442.42				
Australian football	Professional							0.82	83.00	100,820.00	100,820
Rugby	Collegiate	0.22	7.00	31,263.00	0.36	24.00	66,771.00	0.18	4.00	22,788.00	89,559
Volleyball	High school—untrained				0.00	0.00	14,980.00				28,657
	High school—trained				0.00	0.00	13,677.00				
Wrestling	Collegiate	0.25	3.00	11,888.00	0.77	1.00	1,306.00	0.19	2.00	10,582.00	11,888
Indoor soccer	General population	2.78	14.00	3,600.00	5.21	9.00	1,726.00	1.88	5.00	2,664.00	4,390

NOTE. Incidences are expressed as complete ACL tears per 1,000 exposures.

TABLE 3. *Studies With Data Not Expressed in ACL Tears per 1,000 Exposures*

First Author	Yr	Level	Details	Sex	Total ACL Injury	Total No. of Participants	No. of Yrs	Total Player Seasons	Total Player Game Hours	Total Player Practice Hours	Total Player Game and Practice Hours
Basketball											
Deitch[4]	2006	NBA and WNBA		M and F	36	1,145	6				
Deitch	2006	NBA	1996-2002	M	22	702	6				
Deitch	2006	WNBA	1997-2002	F	14	443	6				
Soccer											
Heidt[5]	2000	High school	Aged 14-18 yrs	F	8	258	1	516			
Handball											
Myklebust[7]	2003	Amateur/semiprofessional	1998-1999	F	29	942	1	942	15,447	193,389	208,836
Myklebust[8]	1997	Amateur/semiprofessional	1989-1991	M and F	87	3,392	2	6,784			
Myklebust	1997	Amateur/semiprofessional	1989-1991	M	33	1,696	2	3,392			
Myklebust	1997	Amateur/semiprofessional	1989-1991	F	54	1,696	2	3,392			
American football											
Lambson[6]	1996	High school	1989-1991	M	42	3,119	3				
Powell[11]	1992	NFL	1980-1989	M					123,156		
Australian football											
Orchard[10]	2001	AFL	1992-2000	M			9				
Orchard[9]	1999	AFL	1992-1998	M		2,239	7				

Abbreviations: NBA, National Basketball Association; WNBA, Women's National Basketball Association; NFL, National Football League; AFL, Australian Football League.

Table 4. *Ratios of Female-to-Male ACL Tear Rates*

				Female			Male				
Sport	Level	Subgroup	First Author	Incidence	ACL Tear	Exposures	Incidence	ACL Tear	Exposures	Female-Male Ratio	*P* Value
Basketball	College	NCAA	Mihata[16]	0.28	1,061	3,733,209.00	0.08	332	4,334,807.00	3.50	
		NCAA	Agel[12]	0.29	514	1,797,730.00	0.08	168	2,092,224.00	3.63	
		Collegiate	Harmon[15]	0.30	275	925,501.00	0.08	84	1,046,669.00	3.75	
		NCAA	Arendt[13]	0.30	189	639,898.00	0.07	49	736,076.00	4.29	
		Naval—collegiate	Gwinn[14]	0.48	5	10,452.00	0.09	1	11,282.00	5.33	
		Naval—intramural	Gwinn	0.00	0	1,360.00	0.15	5	33,866.00	0.00	
		Naval—all levels	Gwinn	0.42	5	11,812.00	0.13	6	45,148.00	3.23	
			Mean	0.29			0.08			3.63	
	High school		Messina[19]	0.09	11	120,751.00	0.02	4	169,885.00	4.50	
			Mean	0.28			0.08			3.50	< .0001
Soccer	College	NCAA	Mihata	0.32	871	2,736,615.00	0.12	424	3,547,170.00	2.67	
		NCAA	Agel	0.33	394	1,208,994.00	0.12	192	1,631,574.00	2.75	
		Collegiate	Harmon	0.32	194	604,430.00	0.12	123	1,000,574.00	2.67	
		NCAA	Arendt	0.31	97	308,748.00	0.13	81	626,223.00	2.38	
		Naval—collegiate	Gwinn	0.77	5	6,508.00	0.08	1	12,408.00	9.63	
		Naval—intramural	Gwinn	2.70	2	742.00	0.39	10	25,462.00	6.92	
		Naval—all levels	Gwinn	0.97	7	7,250.00	0.29	11	37,870.00	3.34	
			Mean	0.32			0.12			2.67	< .0001
Alpine skiing	Employees		Viola[30]	0.04	10	227,766.00	0.04	21	499,070.00	1.00	.91
Lacrosse	College	NCAA	Mihata	0.18	146	799,611.00	0.17	169	984,292.00	1.06	
			Mean	0.18			0.17			1.05	.59
Handball	Adults	Elite athletes	Myklebust[35]	0.56	23	40,799.00	0.11	5	43,891.00	5.09	< .0001
Rugby	College	Naval—collegiate	Gwinn	0.35	3	8,475.00	0.18	4	22,788.00	1.94	.36
Wrestling	College	Naval—collegiate	Gwinn	0.77	1	1,306.00	0.19	2	10,582.00	4.05	.25
Indoor soccer	All ages	General population	Lindenfeld[27]	5.21	8	1,536.00	0.97	2	2,064.00	5.37	
		General population	Putukian[28]	5.20	1	190.00	5.00	3	600.00	1.04	
			Mean	5.21			1.88			2.77	.07

NOTE. Incidences are expressed as complete ACL tears per 1,000 exposures.
Abbreviation: NCAA, National Collegiate Athletic Association.

Table 5. *Effect of ACL Reduction Training Program on Tear Rate*

Sport	Level	First Author	Untrained Female Subgroup Incidence	Untrained Female Subgroup ACL Tear	Untrained Female Subgroup Exposures	Trained Female Subgroup Incidence	Trained Female Subgroup ACL Tear	Trained Female Subgroup Exposures	Change (Trained − Untrained)	*P* Value
Basketball	High school	Hewett[18]	0.29	3	10,370.00	0.42	2	4,767.00	0.13	
		Pfeiffer[20]	0.11	2	18,076.00	0.48	3	6,302.00	0.37	
		Mean	0.18			0.45			0.25*	.15
Soccer	Competitive adults	Soderman[26]	0.04	1	27,846.00	0.18	4	22,134.00	0.14	
	High school	Hewett	0.22	2	9,017.00	0.00	0	4,517.00	−0.22	
		Mandelbaum[25]	0.49	67	137,448.00	0.09	6	67,860.00	−0.40	
		Pfeiffer	0.11	1	9,357.00	0.00	0	5,913.00	−0.11	
		Mean	0.45			0.08			−0.24†	.0001
Volleyball	High school	Hewett	0.00	0	3,751.00	0.00	0	7,938.00	0.00	
		Pfeiffer	0.00	0	11,229.00	0.00	0	5,739.00	0.00	
		Mean	0.00			0.00				
Handball	Competitive adults	Petersen[36]	0.43	5	11,671.34	0.08	1	12,254.90	−0.35	‡

NOTE. Incidences are expressed as complete ACL tear rate per 1,000 exposures.
*The trained group had a trend toward more ACL tears than the untrained group.
†The trained group had a significant reduction in ACL tears versus the untrained group.
‡No *P* value reported. Reported odds ratio of 0.17 insignificant as per Petersen et al.[36]