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

Chadwick C. Prodromos, M.D., Yung Han, M.D., Julie Rogowski, B.S., Brian Joyce, B.A., and Kelvin Shi, M.S.

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,

From the Illinois Sports Medicine & Orthopaedic Centers (C.P., J.R., B.J.), Glenview, Illinois, U.S.A.; Rush University Medical Center (C.P.), Chicago, Illinois, U.S.A.; McGill University Orthopaedic Surgery Residency Program (Y.H.), Montreal, Quebec, Canada' and Forest Labs (K.S.), New York, New York, U.S.A.

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Address correspondence and reprint requests to Chadwick C. Prodromos, M.D., Illinois Sports Medicine & Orthopaedic Centers, 1720 N Milwaukee, Glenview, IL 60025, U.S.A. E-mail: research@ismoc.net

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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