

OCCUPATIONAL DISABILITY AFTER HOSPITALIZATION FOR THE TREATMENT OF AN INJURY OF THE ANTERIOR CRUCIATE LIGAMENT

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Background: To date, no large population-based studies have focused on permanent occupational disability after injury of the anterior cruciate ligament as far as we know. The purpose of our study was to determine the risk factors for occupational disability after an injury of the anterior cruciate ligament.

Methods: We identified a cohort of 2192 active-duty personnel in the Army who had been hospitalized between 1989 and 1997 because of an injury of the anterior cruciate ligament and had completed a health risk-assessment survey. With use of the Total Army Injury and Health Outcomes Database, we retrospectively followed these individuals for up to nine years and collected clinical, demographic, occupational, and psychosocial data. These data were then evaluated with bivariate and proportional-hazards regression analyses to identify risk factors for receiving a disability discharge related to an injury of the anterior cruciate ligament.

Results: Overall, 209 (9.5%) of 2192 initial anterior cruciate ligament injuries resulted in a permanent disability discharge. In bivariate analyses, the following factors were related to a disability discharge: lower job satisfaction ($p < 0.0001$), lower education level ($p < 0.0001$), shorter length of service ($p < 0.0001$), lower pay grade or rank ($p < 0.0001$), occupational classification ($p < 0.0001$), older age ($p < 0.01$), cigarette-smoking ($p = 0.01$), and greater mental stress at work ($p = 0.02$). Associated cartilage injury ($p = 0.07$) and occupational physical demands ($p = 0.08$) approached significance; however, with the numbers available, other variables that were hypothesized to contribute to the development of disability, such as gender ($p = 0.85$), reconstruction of the anterior cruciate ligament ($p = 0.52$), and other secondary comorbidities of the knee, demonstrated no significant association. Proportional-hazards regression analysis confirmed that pay grade or rank, occupational classification, job satisfaction, age, and length of service were independent predictors of disability discharge.

Conclusions: In keeping with risk profiles of several other musculoskeletal disorders, such as low-back pain and carpal tunnel syndrome, the results revealed a multifactorial risk profile in which psychosocial factors were strongly associated with disability discharge from active military duty after injury of the anterior cruciate ligament.

Level of Evidence: Prognostic study, Level II-1 (retrospective study). See Instructions to Authors for a complete description of levels of evidence.

Musculoskeletal conditions are the major cause of occupational disability in adults of working age worldwide¹, accounting for >60% of the disorders

leading to an occupational disability². Disruption of the anterior cruciate ligament is among the most frequent major musculoskeletal injuries that affect physically active men and women. Each year in the United States, more than 100,000 new cases of anterior cruciate ligament injury are reported³ and an estimated 50,000 to 75,000 reconstructions of the anterior cruciate ligament are performed^{4,5}. Anterior cruciate ligament injury is ex-



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pensive in terms of treatment and postoperative rehabilitation, lost work, and high risk for disability. The clinical and nonclinical risk factors for disability after an anterior cruciate ligament injury may be useful data in the assessment of patients in a rehabilitation program after such an injury.

Multidimensional analyses of occupational disability have shown that nonclinical, psychosocial factors play a major role in predicting disability status for various musculoskeletal conditions⁶⁻¹². For example, Workers' Compensation benefits have been shown to adversely influence the outcome of several musculoskeletal disorders, such as low-back pain^{13,14}, carpal tunnel syndrome^{8,15}, rotator cuff disease¹⁶, and meniscal injury⁷.

Few reports of knee-related work disability following anterior cruciate ligament injury have used a multifactorial approach. Noyes et al.¹⁷ suggested that "non-knee-related" factors, such as educational and social factors, are necessary for the assessment of occupational limitations. Noyes and Barber-Westin⁹ studied the influence of Workers' Compensation status on outcomes after anterior cruciate ligament reconstruction and showed that the functional, subjective, and objective results for patients receiving Workers' Compensation and control subjects who were not receiving such compensation were the same, except that patients receiving Workers' Compensation were less likely to return to work. Wexler et al.¹⁸ retrospectively followed twenty-two patients receiving Workers' Compensation after anterior cruciate ligament reconstruction and concluded that Workers' Compensation claims do not adversely affect outcome, although there was no control group in that study.

To date, no large population-based studies that we know of have investigated long-term outcomes focusing on occupational disability after anterior cruciate ligament injury and reconstruction. Wojtys³ noted the shortcomings of existing long-term outcome studies. A number of single-institution surgical groups have reported their experience with postsurgical functional outcomes¹⁹⁻²⁵. However, those studies focused on small samples and homogeneous study populations, they often did not incorporate multivariate analysis, and they focused largely on sports-related disability rather than occupational disability. Our objective in the current study was to evaluate the role of clinical and nonclinical factors in the development of occupational disability in physically active men and women after an anterior cruciate ligament injury. The current study focused on occupational disability without consideration of typical clinical outcomes, such as stability or return to sport, and without a comparison of reconstruction and conservative treatment.

Materials and Methods

Study Design and Cohort Definition

A retrospective cohort design was used to follow all active-duty United States Army personnel with an injury of the anterior cruciate ligament who had an initial hospitalization for treatment of the injury between 1989 and 1997. A total of 8236 anterior cruciate ligament-related hospitalizations occurred during this period, but the study group was limited to

the patients who completed the Health Risk Appraisal, a self-administered questionnaire²⁶. The Health Risk Appraisal has been used in numerous studies to assess health-related behaviors such as smoking and alcohol use in relation to motor vehicle accidents, acute injuries, and suicide²⁷⁻³¹. It consists of seventy-five items derived from the Carter Center Health Risk Assessment and the Rhode Island Wellness Survey and is quite similar to the Centers for Disease Control behavior risk factor surveys³¹⁻³³. The Health Risk Appraisal has been shown to be externally valid as the Army population at large is nearly identical to the Army personnel who complete the Health Risk Appraisal³¹⁻³⁴. The Health Risk Appraisal is not administered randomly, but it is generalizable³¹. It is most frequently administered when a soldier is initially in-processing to the service or to a new post, and it may also be administered during periodic physical fitness examinations that typically occur twice a year, as part of standard physical health examinations, when a soldier presents to an outpatient clinic, or for other reasons. In the current study, 1172 patients (53.5%) completed the Health Risk Appraisal before the injury and 1020 patients (46.5%) completed it after the injury.

To be included in the study, cohort subjects met the following criteria: (1) they were on active duty at the time of a hospitalization related to an injury of the anterior cruciate ligament, (2) they were hospitalized with an injury of the anterior cruciate ligament during the period from 1989 to 1997, and (3) they completed a Health Risk Appraisal during the same period. Patients who were hospitalized for the same condition before 1989 or who had a disability rating preceding the initial hospitalization for the injury of the anterior cruciate ligament were disqualified and eliminated from the cohort. The study cohort consisted of 2192 individuals who met the criteria for inclusion.

Data Sources

The United States Army Total Army Injury and Health Outcomes Database (TAIHOD) was used in the present study in an effort to investigate a true population-based cohort in which subjects had a full range of jobs, full employment, absence of geographical or other bias, and full access to health care. The TAIHOD is a collection of Army administrative databases that was recently compiled for injury prevention and health research²⁶. For the current study, five of the databases—those related to personnel, hospitalization, disability, loss from service, and health risk appraisal—were linked. The Health Risk Appraisal database provided information on health practices and stress levels. The other databases included information on demographics, clinical parameters, outcomes, and length of service. Unique identifiers (encrypted Social Security numbers) enabled us to link information across databases, which allowed us to track the history of a subject's condition from the initial hospitalization related to an anterior cruciate ligament injury to long-term disability. The administrative databases provided excellent follow-up data with minimal loss of cohort subjects.

Diagnosis and Procedure Codes

The diagnostic codes of the ICD-9-CM³⁵ (International Classification of Diseases, Ninth Revision, Clinical Modification) were used to identify potential subjects with disruption of the anterior cruciate ligament. Subjects with diagnostic codes indicating multiple ligament injuries were excluded, leaving only those who had unilateral, single ligament injury as the primary diagnosis. Determination of a knee-related comorbidity (nonligamentous) was based on the presence of a secondary diagnostic code indicating a meniscal injury, cartilage injury, or synovitis in the remaining seven diagnostic fields. These secondary diagnoses were grouped into five clinically relevant categories: medial meniscal injury, lateral meniscal injury, both medial and lateral meniscal injuries, cartilage injury, or synovitis. It is possible that subjects with a partial tear of the anterior cruciate ligament were miscoded as having a complete tear and were included in the study, but it is also possible that these subjects were coded under another diagnosis such as meniscal tear and were excluded from the study.

ICD-9-CM procedure codes were used to identify surgical intervention, including therapeutic arthroscopy, anterior cruciate ligament reconstruction, and other common related surgical procedures, such as 80.6 (excision of semilunar cartilage of the knee), 80.86 (other local excision or destruction of lesion of joint), and 81.47 (other repair of the knee). The majority of the subjects (96.1%) underwent at least one of these anterior cruciate ligament-related procedures.

Outcome

The outcome of interest was the development of disability following the initial hospitalization related to an anterior cruciate ligament injury. Occupational disability has been defined as termination of employment, inability or impaired ability to work, or the awarding of compensation benefits³⁶. Long-term disability has been defined on the basis of pensions¹¹. In the current study, the determination of long-term disability was based on the findings of a medical evaluation board of physicians and the ruling of a physical evaluation board of Army officers. We considered long-term disability status to be represented by the following conditions: (1) a permanent disability or retirement (a knee-related disability rating of $\geq 30\%$, regardless of length of service, or any disability in an individual with at least twenty years of service) and (2) involuntary Army separation without benefits (a knee-related disability rating of $< 30\%$ in an individual with less than twenty years of service)³⁷. The standardized Army disability evaluation relies on fitness for duty and considers whether the medical condition precludes the reasonable performance of the duties of the office, grade, rank, or rating³⁸. This disability definition minimized biases resulting from geographic variation.

Time-to-Event Analysis

Survival analysis techniques were used to measure the risk of a disability discharge related to an anterior cruciate ligament injury over time. The starting point for the analysis was the date of the initial hospitalization related to the anterior cruciate lig-

ament injury, and the end point was the date of the outcome of interest (a disability discharge related to the anterior cruciate ligament injury), the date of discharge for another reason, or the end of the follow-up period (1997). For example, if a subject was hospitalized because of an injury of the anterior cruciate ligament on the first day of the study and remained in the Army during the nine-year study period without becoming disabled, the duration of follow-up for that subject would be nine years. If that same subject were to receive a disability discharge two years after hospitalization related to an injury of the anterior cruciate ligament, the duration of follow-up would be two years. For a subject who had a hospitalization because of an anterior cruciate ligament injury in the third year of the study with only two months remaining in his or her commitment and who consequently left the Army two months later for reasons unrelated to the knee injury, the duration of follow-up is two months before this subject is censored. These techniques accommodate variable durations of follow-up by censoring subjects who reach an end point before the outcome of interest is experienced^{39,40}.

Product-limit (Kaplan-Meier) estimates of survival time were used to assess the risk of disability discharge related to an anterior cruciate ligament injury among different groups. Log-rank tests for equality and for linear trend were used to determine whether there were significant differences (defined as $p < 0.05$) between the groups with respect to the time to outcome (a disability discharge related to the anterior cruciate ligament). Cox proportional-hazards regression was used to assess the concurrent influence of multiple variables on survival. This analysis produces a relative hazard, which is a measure of the influence that a covariate has on the outcome while controlling for the other covariates in the model.

Variables considered for modeling were either categorical (for example, gender, age-group, race, or pay grade) or continuous (health practice index⁴¹ or number of dependents). Categories for age-group and other demographic characteristics are consistent with those of the 1992 Worldwide Survey of Substance Abuse and Health Behaviors Among Military Personnel^{41,42}. The age-groups reflect the Army population in terms of new recruits, early career, mid-career, and full-career military personnel. Occupations were defined according to the United States Army military occupational classification system, and occupational physical demands were categorized as light to very heavy on the basis of the maximum upper-body strength requirements as defined by the Army⁴³. The categories of occupation and occupational physical demands are applicable only to enlisted personnel (1775 of 2192 subjects). All other categories applied to all subjects in the study.

Proportional hazard models were fitted to study variables with use of a forward-conditional stepwise method ($P_{\text{entry}} = 0.10$, and $P_{\text{removal}} = 0.15$). The proportional-hazards regression model assumes that the effects of the covariates are constant over time and that censoring occurs independent of outcome. Plots of log minus log functions against time and partial residuals against time were used to check for violations of this pro-

TABLE I Bivariate Analysis of Demographic Factors and Disability After Hospitalization for Treatment of Anterior Cruciate Ligament Injury in 2192 United States Army Personnel from 1989 to 1997*

Covariate	No. (%) of Patients	No. (%) of Patients Disabled†	Log-Rank Test‡ (Equality)
Gender			
Male	2001 (91.3)	193 (9.6)	0.85
Female	190 (8.7)	16 (8.4)	
Age-group			
<21	207 (9.4)	9 (4.3)	0.01§
21 to 25	710 (32.4)	76 (10.7)	
26 to 34	899 (41.0)	105 (11.7)	
≥35	376 (17.2)	19 (5.1)	
Marital status			
Single	845 (41.2)	108 (12.8)	0.0006
Married	1205 (58.8)	93 (7.7)	
Race			
White	1442 (65.8)	136 (9.4)	0.96
Black	552 (25.2)	54 (9.8)	
Hispanic	92 (4.2)	11 (12.0)	
American Indians	9 (0.4)	1 (11.1)	
Asian	35 (1.6)	4 (11.4)	
Other	60 (2.7)	4 (6.7)	
Total	2192 (100)	209 (9.50)	NA

*Data were not available for all subjects. †Per 100 hospitalizations. ‡The values are given as the p value. NA = not applicable. §Test for trend.

portional assumption. All analyses were performed with SPSS for Windows (release 9; SPSS, Chicago, Illinois). Significance was defined as a p value of <0.05.

Results

The current cohort of 2192 subjects was generally young (mean age, twenty-eight years; range, eighteen to fifty-five years), male (91%; 2001 subjects), white (66%; 1442 subjects), and educated (74%; 1622 subjects were high-school graduates). The median duration (and standard deviation) of follow-up was 32.9 ± 27.3 months.

Of the 2192 study subjects, 2107 (96.1%) underwent at least a diagnostic arthroscopy because of an anterior cruciate ligament injury. A total of 1239 subjects (57%) underwent reconstruction of the anterior cruciate ligament, and 953 (43%) did not. Three hundred and two subjects (14%) who had reconstruction had an articular cartilage injury, and 996 subjects (45%; 1178 diagnoses) who had reconstruction had a meniscal injury (627 medial and 551 lateral meniscus). Other procedures included excision of the semilunar cartilage of the knee (780 subjects), other local excision of destruction or lesion (419 subjects), and other repair of the knee (214 subjects). These data are included in the analyses.

The results of the bivariate analysis for the study population are presented in terms of demographic (Table I), clinical (Table II), and occupational or psychosocial factors (Table

III). The overall rate of disability discharge related to anterior cruciate ligament injury was 9.5% of the initial injuries of the anterior cruciate ligament.

Survival curves for the factor levels provided estimates of the risk of disability discharge over an extended follow-up period. Analyses of demographic factors revealed that two age-groups (twenty-one to twenty-five and twenty-six to thirty-four years old) were at greater risk for a disability discharge related to an injury of the anterior cruciate ligament ($p = 0.01$) than were the other age-groups and that individuals who were single were at higher risk for such a disability discharge ($p = 0.0006$) than were those who were married. No significant difference in the time to a disability discharge related to an anterior cruciate ligament injury was detected with respect to gender ($p = 0.85$) or race ($p = 0.96$).

Many occupational and psychosocial factors were strongly associated with a disability discharge related to an anterior cruciate ligament injury. Greater risk was evident with lower job satisfaction ($p < 0.0001$), shorter length of service ($p < 0.0001$), lower pay or rank ($p < 0.0001$), no college education ($p < 0.0001$), greater mental stress at work ($p = 0.02$), and cigarette-smoking ($p = 0.01$).

Occupation was strongly associated with disability discharge related to an anterior cruciate ligament injury among enlisted personnel ($p < 0.0001$). Those in the classification of direct combat, communications or intelligence, and craftsmen

TABLE II Bivariate Analysis of Clinical Factors and Disability After Hospitalization for Treatment of Anterior Cruciate Ligament Injury in 2192 United States Army Personnel from 1989 to 1997

Covariate	No. (%) of Patients	Disability Rate*	Log-Rank Test† (Equality)
Knee comorbidity			
Medial meniscal injury	627 (28.6)	8.0	0.13
Lateral meniscal injury	551 (25.1)	10.0	0.64
Medial and lateral meniscal injury	182 (8.3)	9.3	0.98
Synovitis	154 (7.0)	9.7	0.69
Cartilage injury	302 (13.8)	11.9	0.07
Reconstruction of anterior cruciate ligament			
Yes	1239 (56.5)	9.3	0.52
No	953 (43.5)	9.9	
Total	2192 (100)	9.50	NA

*Per 100 hospitalizations. †The values are given as the p value. NA = not applicable.

had higher disability rates (Table III). Multivariate analysis confirmed that occupation was an independent predictor of disability, with greater risk for those involved in direct combat (relative hazard, 1.73; 95% confidence interval = 1.09 to 2.73) and communications or intelligence (relative hazard, 1.88; 95% confidence interval = 0.98 to 3.62). Occupational physical demands only approached significance ($p = 0.08$).

With regard to clinical factors, we found no significant difference between patients who underwent reconstruction of the anterior cruciate ligament and those who did not ($p = 0.52$). Further stratification based on gender, age, body-mass index, occupational physical demands, pay grade or rank, job satisfaction, and comorbid knee conditions also showed no significant difference, with the data available, with respect to reconstruction of the anterior cruciate ligament. The presence of one or more knee comorbidities was not strongly associated with a greater risk of disability related to anterior cruciate ligament injury. In unadjusted analyses, cartilage injury was not associated with disability discharge ($p = 0.07$); however, after adjusting for age, cartilage injury in patients who were less than thirty years old was associated with disability discharge ($p = 0.01$).

For the entire study population, the final multivariate model identified the covariates of pay grade or rank, job satisfaction, age, and length of service as significant independent predictors of a disability discharge related to an injury of the anterior cruciate ligament. The most dramatic difference in risk was found among subjects at the lowest pay grade, whose risk of a disability discharge related to an anterior cruciate ligament injury was nearly seven times higher than that for higher-ranking subjects. The survival curves based on this model for pay grade (Fig. 1), job satisfaction (Fig. 2), age (Fig. 3), and length of service (Fig. 4) are also adjusted for the effects of gender, anterior cruciate ligament reconstruction, and a secondary diagnosis of cartilage injury. A final model including only enlisted personnel added occupational classification to the list of significant predictors.

Discussion

This study yielded a broad view of many covariates that were suspected of affecting the risk of disability discharge after anterior cruciate ligament injury. The overall disability discharge rate for those who were hospitalized for surgery related to the anterior cruciate ligament was nearly 10% of the subjects (9.5/100 initial hospitalizations). This number is markedly lower than that reported in a United States Navy study²⁴ (23%) and substantially higher than that found in a study of Army aviators, in which 2.3% of the subjects were medically terminated after nonrevision reconstruction of the anterior cruciate ligament²⁵. Cullison et al.²⁴ reviewed the cases of 120 patients with an injury of the anterior cruciate ligament from a single naval institution and found that twenty-eight had received a medical discharge after surgical reconstruction. They concluded that reconstruction of the anterior cruciate ligament offered a “higher likelihood of return to full military duty” than did nonoperative management, on the basis of a historical control group from a previous study by Barrack et al.⁴⁴ that showed fair to poor results with nonoperative management. We found no significant difference ($p = 0.52$) in risk between patients who underwent reconstruction of the anterior cruciate ligament and those who did not. The overall rate of disability discharge of 9.5% is similar to the overall rate of musculoskeletal disability reported by Lincoln et al. for a wide range of common musculoskeletal disorders⁴⁵.

In one of the few epidemiological studies investigating outcomes of operative compared with nonoperative treatment for injury of the anterior cruciate ligament, Daniel et al. studied a group of 292 patients at the Kaiser Medical Center and found no significant differences in return to work between the operative and the nonoperative group⁴⁶. That descriptive study did not control for operative intervention and was not randomized; its findings were likely influenced by surgical technique, activity level, and comorbidities. However, the findings suggested that patients who receive nonoperative treatment for an injury of the anterior cruciate ligament may do as well

TABLE III Bivariate Analysis of Occupational and Psychosocial Factors and Disability After Hospitalization for Treatment of Anterior Cruciate Ligament Injury in 2192 United States Army Personnel from 1989 to 1997*

Covariate	No. (%) of Patients	Disability Rate†	Log-Rank Test‡	
			Equality	Trend
Pay grade§				
E1-E3	337 (15.4)	18.4	<0.0001	<0.0001
E4-E7	1286 (58.7)	10.6		
E8-E9	152 (6.9)	2.0		
W1-W5	42 (1.9)	0		
O1-O3	266 (12.1)	3.0		
O4-O10	80 (3.6)	0		
Cadets	29 (1.3)	0		
Length of service				
<1 yr	82 (3.7)	19.5	<0.00	<0.0001
1 to 4 yr	932 (42.6)	12.3		
5 to 10 yr	704 (32.2)	8.4		
>10 yr	469 (21.4)	3.6		
Work stress				
Often	170 (7.9)	16.5	<0.0001	0.02
Sometimes	495 (22.9)	10.3		
Seldom	877 (40.7)	7.9		
Never	615 (28.5)	9.6		
Job satisfaction				
Not satisfied	254 (14.4)	15.4	<0.00	<0.0001
Somewhat	435 (24.7)	10.3		
Mostly	692 (39.3)	8.2		
Totally	381 (21.6)	3.1		
Cigarette-smoking				
Nonsmoker	1606 (73.3)	8.7	0.01	NA
Smoker	586 (26.7)	11.8		
Education				
No college	1641 (76.2)	11.9	<0.0001	NA
College	512 (23.8)	2.5		
Occupational class				
Direct combat	604 (28.3)	13.7	<0.0001	NA
Electronic equipment repair	34 (1.6)	2.9		
Communications or intelligence	116 (5.4)	19.0		
Health care	29 (1.4)	10.3		
Other technical	91 (4.3)	8.8		
Support or administration	220 (10.3)	11.4		
Electrical or mechanical repair	218 (10.2)	6.4		
Craftsman	64 (3.0)	14.0		
Service or supply	375 (17.6)	9.6		
Nonoccupational	380 (17.8)	2.1		
Total	2192 (100)	9.50		

*Data were not available for all subjects. †Per 100 hospitalizations. ‡The values are given as the p value. NA = not applicable. §E1 to E3, private to private first class; E4 to E7, corporal to sergeant first class; E8 to 9 master sergeant to sergeant major; W1 to W5, warrant officer level 1 to 5; O1 to O3, junior officers; and O4 to O11, senior officers.

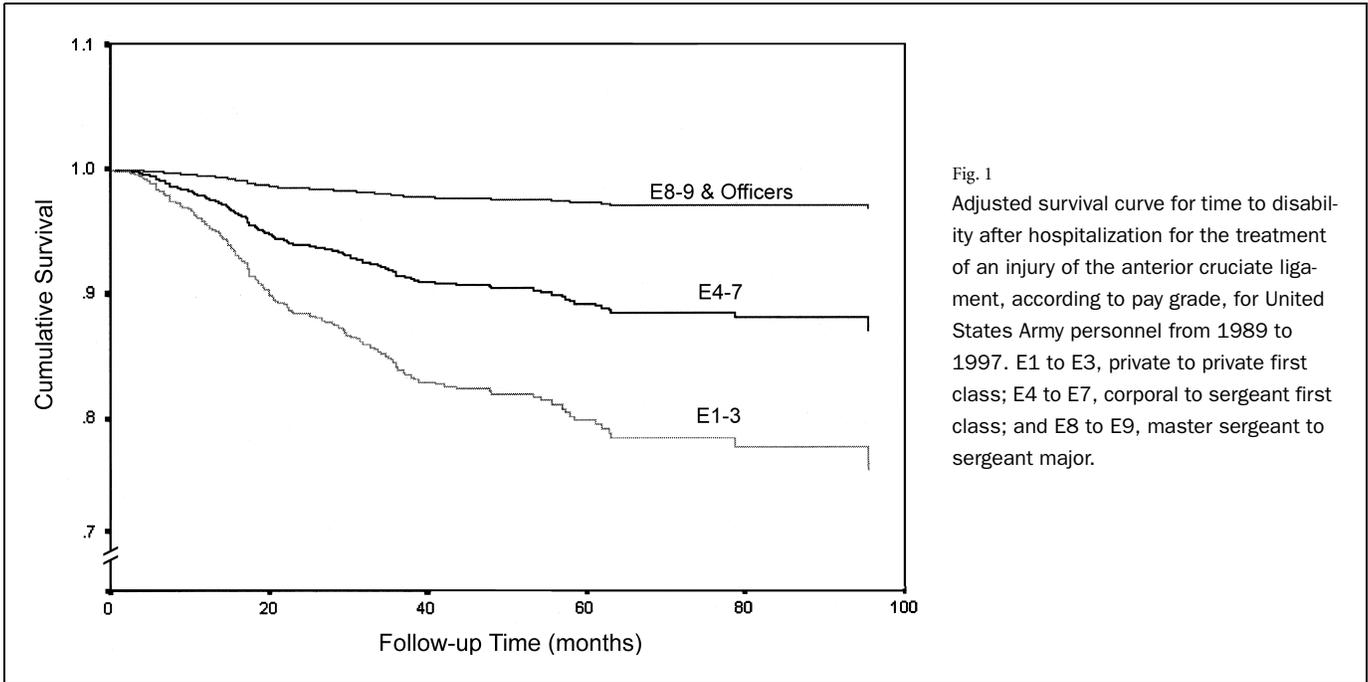


Fig. 1
Adjusted survival curve for time to disability after hospitalization for the treatment of an injury of the anterior cruciate ligament, according to pay grade, for United States Army personnel from 1989 to 1997. E1 to E3, private to private first class; E4 to E7, corporal to sergeant first class; and E8 to E9, master sergeant to sergeant major.

as those who receive operative treatment, on the basis of data for return to work and other indicators.

Cullison et al.²⁴ also found that clinical parameters, such as concomitant Outerbridge stage-III and IV chondromalacia, subsequent reoperation, and Lysholm scores of <80 points, were associated with medical discharge. The inclusion of such clinical parameters is desirable, but this was not possible in our retrospective cohort study, where only administrative data from hospitalization records were available. Our inability to grade the

severity of cartilage injury may have biased our findings toward the null, resulting in only marginal significance associated with the comorbidity of cartilage injury.

In the current study, three of the four clinical covariates—anterior cruciate ligament reconstruction, secondary meniscal injury, and secondary synovitis—were not associated with disability related to anterior cruciate ligament injury. A secondary diagnosis of cartilage injury in patients who were less than thirty years old was significantly associated with a

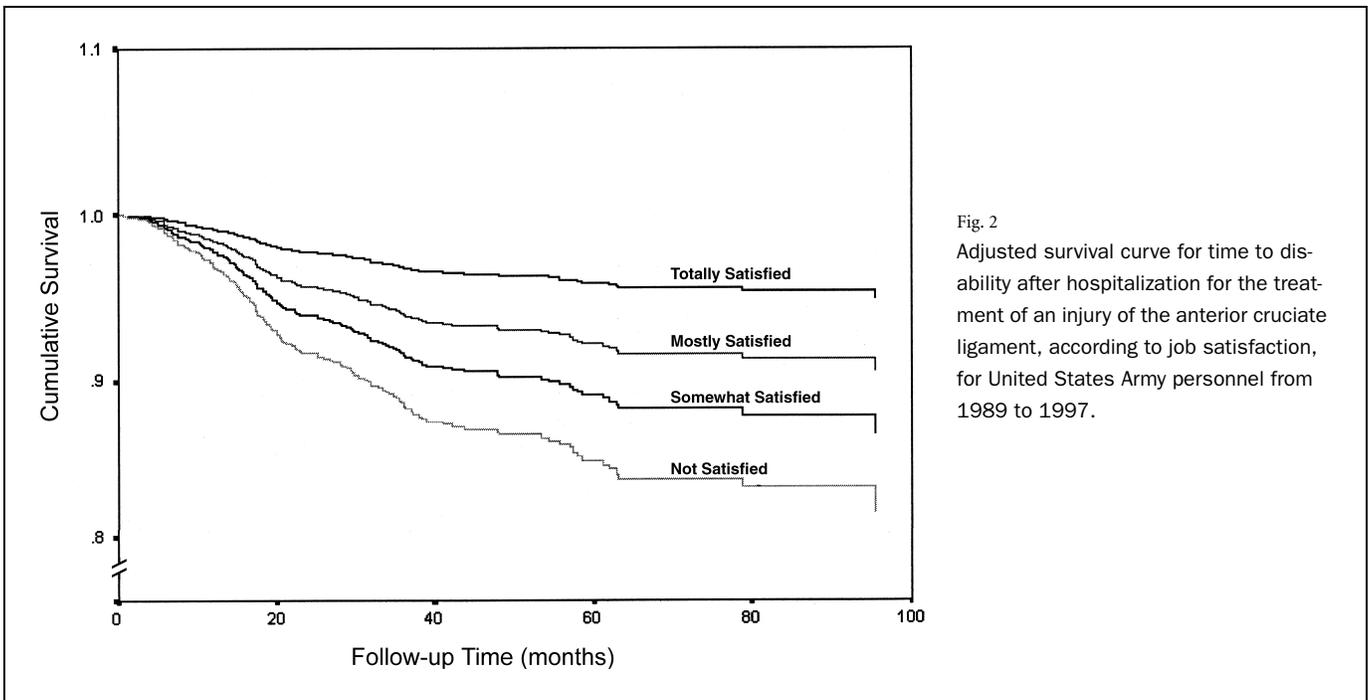


Fig. 2
Adjusted survival curve for time to disability after hospitalization for the treatment of an injury of the anterior cruciate ligament, according to job satisfaction, for United States Army personnel from 1989 to 1997.

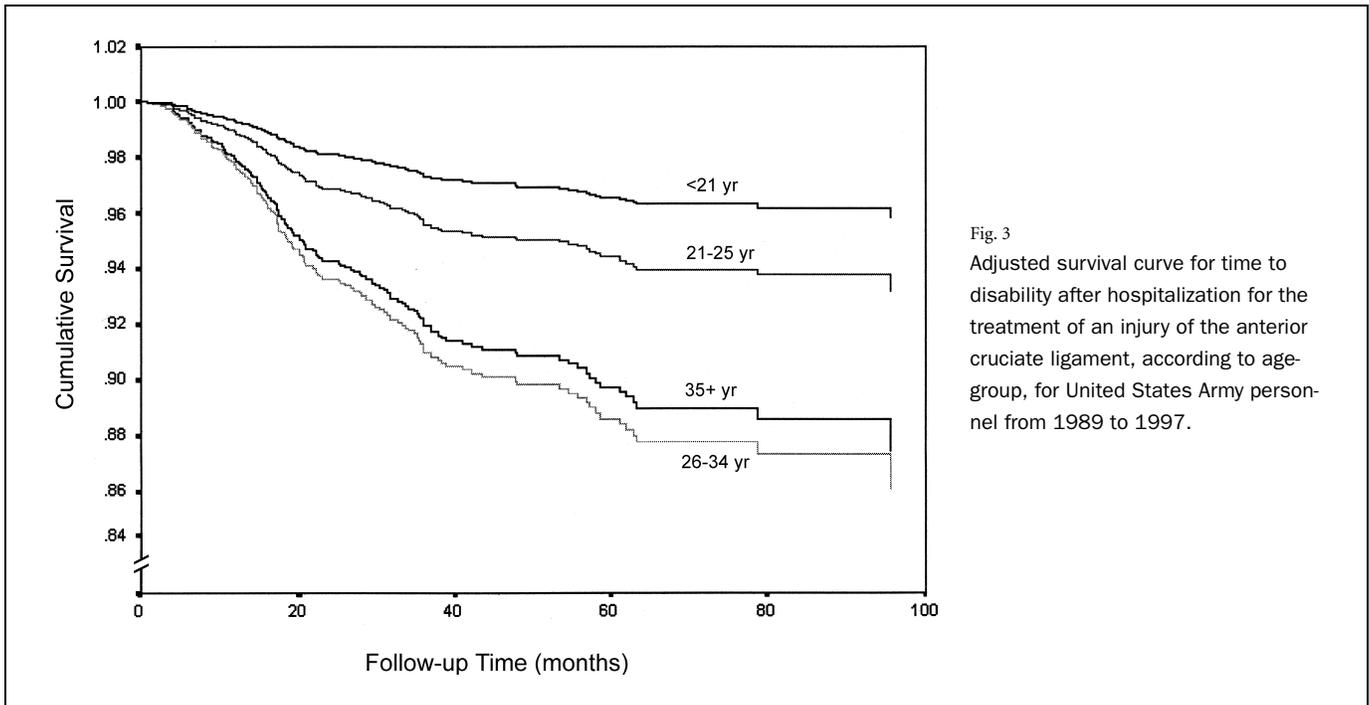


Fig. 3
Adjusted survival curve for time to disability after hospitalization for the treatment of an injury of the anterior cruciate ligament, according to age-group, for United States Army personnel from 1989 to 1997.

greater risk of a disability discharge related to an injury of the anterior cruciate ligament. Overall, demographic, occupational, and psychosocial covariates demonstrated much stronger associations with the disability discharge rate than did clinical covariates. This finding is consistent with those in other studies in which occupational and psychosocial factors have been found to be associated with musculoskeletal disability^{6,8,9,13,15}. Similarly, the results of this investigation sup-

port those in the study by Berkowitz et al.⁴⁷, who found that disability risk factors among Army personnel are multifactorial. As Noyes et al. noted, sports-related and occupational knee problems are distinctly different¹⁷. Occupational knee problems are more difficult to address objectively and are likely influenced more by nonclinical factors over which the orthopaedist has little control. This observation reflects the complex nature of occupational disability, which is influenced

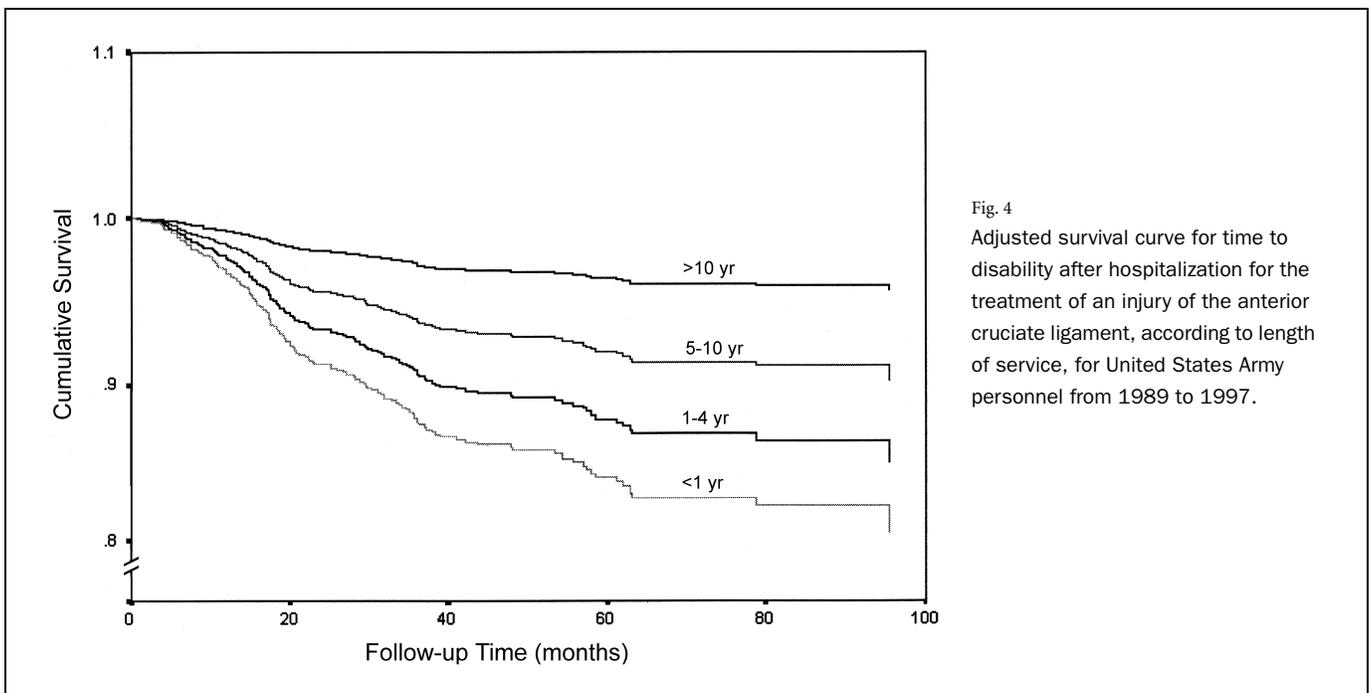


Fig. 4
Adjusted survival curve for time to disability after hospitalization for the treatment of an injury of the anterior cruciate ligament, according to length of service, for United States Army personnel from 1989 to 1997.

by elements other than simply the medical condition^{10-12,48}, and might explain why several authors have noted a lack of association between objective findings (e.g., laxity) and outcome after anterior cruciate ligament reconstruction^{9,21,49,50}.

Rank or pay grade was the strongest predictor of disability discharge among the many variables analyzed for this population. These findings are consistent with those of other studies in which wages have been shown to be highly associated with outcome^{6,8,45,51}. An analysis of medical discharges from the British Army also found lower discharge rates among officers⁵².

It is generally accepted that musculoskeletal disability increases with increasing age⁶. The overall trend in our data supported this idea. However, patients who were between twenty-six to thirty-four years old in our study population were at greater risk than were those who were more than thirty-five years old in both adjusted and unadjusted analyses. Barber et al.⁵³ concluded that disability after reconstruction of the anterior cruciate ligament in patients who were more than forty years old was not significantly different from that in younger control subjects. Our subanalysis of the 1239 individuals who underwent reconstruction of the anterior cruciate ligament demonstrated no difference in outcome when stratified by age ($p = 0.78$). The inconsistency between the increased risk of disability discharge with increasing age in the people who were between twenty-six and thirty-four years old may partly reflect the overall high level of fitness across the study group or the lower functional demand in the older subjects.

Although it is known that women are at increased risk for injury of the anterior cruciate ligament^{3,54}, it has not been shown previously whether this translates to an increased risk of disability. Feuerstein et al.⁵⁵ found that the risk of musculoskeletal-related disability was higher for women than for men in their study population. Several authors^{12,45,51,56} have noted a higher risk for occupational disability in women, whereas others⁶ have found no difference overall for musculoskeletal disability on the basis of gender. In addition, men seem to be at increased risk for specific musculoskeletal disorders, such as low-back pain, but less so for other musculoskeletal disorders, such as arthritis^{6,56}. To our knowledge, the current investigation is the first large population-based study to address the role of gender in occupational disability related to injury of the anterior cruciate ligament. We found no significant difference ($p = 0.85$) between disability discharge rates for women (8.4%) and men (9.6%). Although multivariate analysis of risk confirmed this finding, this conclusion is limited by the predominance of males in the study population.

Occupation for enlisted personnel was significantly associated with disability discharge rates. This information is of interest, although further investigation is needed to determine the reasons for the association. The occupational categories used in the current study encompass hundreds of different jobs, each with its own rating for occupational physical demands and other factors. Additional studies are needed to investigate the occupational classifications with a significant association with disability in greater detail.

Results for occupational physical demands were ex-

pected to be significantly associated with disability discharge, but they only approached significance ($p = 0.08$). A potential association between physical demands and disability may have been masked by a relationship that likely exists between more stringent physical activity and lower rank. The highest level of occupational physical demands ("very heavy") included approximately 70% (939) of the 1340 enlisted subjects for whom data were available. The ceiling effect in this category may have prevented the identification of a significant association between physical demands and disability. Indeterminate or missing data for approximately 25% (435) of the 1775 total enlisted subjects in this category also limited the analysis.

At the time of the current study, it was common practice for the Army to hospitalize individuals for injuries that prevented them from carrying out daily activities. Thus, some subjects were included in the current study who might otherwise not have been hospitalized. In general, however, this study was not able to capture subjects who had an anterior cruciate ligament injury but were not hospitalized. The current study was also limited to those who completed the Health Risk Appraisal because psychosocial factors were of critical interest.

The timing of the administration of the Health Risk Appraisal varied in the study period. A sensitivity analysis was done to determine the effect on the results of the timing of the administration of the Health Risk Appraisal with regard to the time of injury. For example, a response to the Health Risk Appraisal question on job satisfaction might be interpreted as contributing to the disability if the questionnaire was administered before the injury and as an effect of the disability if it was administered after the injury. The sensitivity analysis showed no changes in the significance of the predictors or in their magnitude in a model that included only subjects who completed the Health Risk Appraisal prior to the injury.

The administrative database used in the current study did not include data on injury severity. Some investigators have considered hospitalization to be an indicator of severity⁵⁶, but this assumption may not be valid for the current population as Army practice may have required hospitalization for the injury period and convalescence. Disease stratification with use of knee comorbidities had little prognostic value in the current study, although the use of ICD-9-CM coding may have played a part in this lack of significant association. However, a lack of association between return to work and injury severity has been noted by other investigators^{9,51}.

ICD-9 coding was used for primary and secondary diagnoses in the current study, and the use of these diagnosis codes introduces the possibility of error to the study. In one report on the frequency of discrepancies between the original diagnosis coding and the reabstracting, the rate of correct coding for the principal diagnosis was found to be 65.2% for fourteen target diagnoses⁵⁷. The same study found ICD reliability ranging from 30.2% for chronic ischemic heart disease to as high as 97% for surgical diagnoses. It is possible that error rates for diagnosis coding may have improved since the time of the reliability study, yet this remains a potential source of error in the current study. Furthermore, the current study did not review

hospital operative reports to verify the accuracy of diagnosis coding in the administrative database. Such a review is desirable and might reveal coding errors.

In conclusion, our results showed an overall occupational disability rate following injury of the anterior cruciate ligament of approximately 10% in this young, active population. The current study also showed that men and women had similar rates of disability discharge and that anterior cruciate ligament reconstruction did not affect the likelihood of occupational disability after an injury of the anterior cruciate ligament. The type of occupation for the enlisted personnel was found to be associated with disability discharge after hospitalization related to an anterior cruciate ligament injury, with the highest risk associated with those in direct combat. Psychosocial risk factors were strongly associated with disability discharge after hospitalization for the treatment of an anterior cruciate ligament injury, and they resembled the risk profiles of several other musculoskeletal disorders, such as low-back pain and overuse syndromes of the upper extremity. ■

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References

1. **Bernard BP, editor.** *Musculoskeletal disorders and workplace factors. A critical review of the epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back.* 2nd ed. Cincinnati, OH: United States Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; 1997. Publication number 97-141. www.cdc.gov/niosh/97-141.pdf.html.
2. **Kasser JR.** Occupational orthopaedics and disability. In: Kasser JR, editor. *Orthopaedic knowledge update 5: home study syllabus.* Rosemont, IL: American Academy of Orthopaedic Surgeons; 1996. p 109-16.
3. **Wojtys E, editor.** *The ACL deficient knee.* Rosemont, IL: American Academy of Orthopaedic Surgeons; 1994.
4. **Frank CB, Jackson DW.** The science of reconstruction of the anterior cruciate ligament. *J Bone Joint Surg Am.* 1997;79:1556-76.
5. **Johnson DL, Harner CD, Maday MG.** Revision anterior cruciate ligament surgery. In: Fu FH, Harner CD, Vince KG, editors. *Knee surgery.* Baltimore: Williams and Wilkins; 1994. p 877-95.
6. **Badley EM, Ibanez D.** Socioeconomic risk factors and musculoskeletal disability. *J Rheumatol.* 1994;21:515-22.
7. **Katz JN, Harris TM, Larson MG, Krushell RJ, Brown CH, Fossel AH, Liang MH.** Predictors of functional outcomes after arthroscopic partial meniscectomy. *J Rheumatol.* 1992;19:1938-42.
8. **Katz JN, Keller RB, Fossel AH, Punnett L, Besette L, Simmons BP, Mooney N.** Predictors of return to work following carpal tunnel release. *Am J Ind Med.* 1997;31:85-91.
9. **Noyes FR, Barber-Westin SD.** A comparison of results of arthroscopic-assisted anterior cruciate ligament reconstruction between workers' compensation and noncompensation patients. *Arthroscopy.* 1997;13:474-84.
10. **Leino PI, Hanninen V.** Psychosocial factors at work in relation to back and limb disorders. *Scand J Work Environ Health.* 1995;21:134-42.
11. **Manninen P, Heliovaara M, Riihimaki H, Makela P.** Does psychological distress predict disability? *Int J Epidemiol.* 1997;26:1063-70.
12. **Sulsky SI, Mundt KA, Bigelow C, Amoroso PJ.** Case-control study of discharge from the U.S. Army for disabling occupational knee injury: the role of gender, race/ethnicity, and age. *Am J Prev Med.* 2000;18(3 Suppl):103-11.
13. **Lancourt J, Kettelhut M.** Predicting return to work for lower back pain patients receiving worker's compensation. *Spine.* 1992;17:629-40.
14. **Coste J, Delecoeuillerie G, Cohen de Lara A, Le Parc JM, Paolaggi JB.** Clinical course and prognostic factors in acute low back pain: an inception cohort study in primary care practice. *BMJ.* 1994;308:577-80.
15. **Nagle D, Harris G, Foley M.** Prospective review of 278 endoscopic carpal tunnel releases using the modified chow technique. *Arthroscopy.* 1994;10:259-65.
16. **Misamore GW, Ziegler DW, Rushton JL 2nd.** Repair of the rotator cuff. A comparison of results in two populations of patients. *J Bone Joint Surg Am.* 1995;77:1335-9.
17. **Noyes FR, Moar LA, Barber SD.** The assessment of work-related activities and limitations in knee disorders. *Am J Sports Med.* 1991;19:178-88.
18. **Wexler G, Bach BR Jr, Bush-Joseph CA, Smink D, Ferrari JD, Bojchuk J.** Outcomes of anterior cruciate ligament reconstruction in patients with Workers' Compensation claims. *Arthroscopy.* 2000;16:49-58.
19. **Noyes FR, Barber SD.** The effect of an extra-articular procedure on allograft reconstructions for chronic ruptures of the anterior cruciate ligament. *J Bone Joint Surg Am.* 1991;73:882-92.
20. **Shino K.** Reconstruction of the anterior cruciate ligament using allogeneic tissues: overview and current practice. *Bull Hosp Jt Dis Orthop Inst.* 1991;51:155-74.
21. **Harter RA, Osternig LR, Singer KM, James SL, Larson RL, Jones DC.** Long-term evaluation of knee stability and function following surgical reconstruction for anterior cruciate ligament insufficiency. *Am J Sports Med.* 1988;16:434-43.
22. **Kaplan N, Wickiewicz TL, Warren RF.** Primary surgical treatment of anterior

- cruciate ligament ruptures. A long-term follow-up study. *Am J Sports Med.* 1990;18:354-8.
23. **Andersson C, Odensten M, Good L, Gillquist J.** Surgical or non-surgical treatment of acute rupture of the anterior cruciate ligament. A randomized study with long-term follow-up. *J Bone Joint Surg Am.* 1989;71:965-74.
 24. **Cullison TR, O'Brien TJ, Getka K, Jonson S.** Anterior cruciate ligament reconstruction in the military patient. *Mil Med.* 1998;163:17-9.
 25. **Belmont PJ Jr, Shawen SB, Mason KT, Sladicka SJ.** Incidence and outcomes of anterior cruciate ligament reconstruction among U.S. Army aviators. *Aviat Space Environ Med.* 1999;70:316-20.
 26. **Amoroso PJ, Yore MM, Weyandt B, Jones BH.** Chapter 8. Total Army injury and health outcomes database: a model comprehensive research database. *Mil Med.* 1999;164(8 Suppl):1-36.
 27. **Robbins AS, Fonseca VP, Chao SY, Coil GA, Bell NS, Amoroso PJ.** Short term effects of cigarette smoking on hospitalisation and associated lost workdays in a young healthy population. *Tob Control.* 2000;9:389-96.
 28. **Bell NS, Amoroso PJ, Williams JO, Yore MM, Engel CC Jr, Senior L, DeMatos AC, Wegman DH.** Demographic, physical, and mental health factors associated with deployment of U.S. Army soldiers to the Persian Gulf. *Mil Med.* 2000;165:762-72.
 29. **Yore MM, Bell NS, Senior L, Amoroso PJ.** Progress toward attainment of the Healthy People 2000 objectives in the U.S. Army: measured by health risk appraisal results. *Am J Prev Med.* 2000;19:87-93.
 30. **Miller M, Hemenway D, Bell NS, Yore MM, Amoroso PJ.** Cigarette smoking and suicide: a prospective study of 300,000 male active-duty Army soldiers. *Am J Epidemiol.* 2000;151:1060-3.
 31. **Bell NS, Amoroso PJ, Yore MM, Smith GS, Jones BH.** Self-reported risk-taking behaviors and hospitalization for motor vehicle injury among active duty army personnel. *Am J Prev Med.* 2000;18(3 Suppl):85-95.
 32. **Frazier EL, Okoro CA, Smith C, McQueen DV.** State- and sex-specific prevalence of selected characteristics—Behavioral Risk Factor Surveillance System, 1992 and 1993. *MMWR CDC Surveill Summ.* 1996;45:1-36.
 33. **Siegel PZ, Frazier EL, Mariolis P, Brackbill RM, Smith C.** Behavioral Risk Factor Surveillance 1991: monitoring progress toward the nation's year 2000 health objectives. *MMWR CDC Surveill Summ.* 1993;42:1-21.
 34. **Lincoln AE.** The influence of smoking on disability following hospitalization for musculoskeletal disorders. Defense Technical Information Center (DTIC); 1998. AD number ADA375020.
 35. **Medicode.** *ICD-9-CM: International classification of diseases, 9th revision, clinical modification.* 5th ed. Salt Lake City, UT: Medicode; 1998.
 36. **Yelin EH.** Musculoskeletal conditions and employment. *Arthritis Care Res.* 1995;8:311-7.
 37. **Department of the Army.** Regulation 635-40: physical evaluation for retention, retirement, or separation. Washington, DC: Department of the Army; 1990. www.usapa.army.mil/pdffiles/r635_40.pdf.
 38. **United States Army Physical Disability Agency: the Adjutant General Directorate.** Information paper: Physical Disability Evaluation System (PDES). June 22, 2001. www.perscom.army.mil/tagd/pda/infopaper.htm.
 39. **Tibshirani R.** A plain man's guide to the proportional hazards model. *Clin Invest Med.* 1982;5:63-8.
 40. **Katz MH, Hauck WW.** Proportional hazards (Cox) regression. *J Gen Intern Med.* 1993;8:702-11.
 41. **Kroutil LA, Bray RM, Marsden ME.** Cigarette smoking in the U.S. military: findings from the 1992 Worldwide Survey. *Prev Med.* 1994;23:521-8.
 42. **Bray RM, Kroutil LA, Luckey JM, Wheelless SC, Iannacchione VG, Anderson DW, Marsden ME, Dunteman GH.** Worldwide survey of substance abuse and health behaviors among military personnel. RTI document 5154/06-16FR. Research Triangle Park, NC: Research Triangle Institute; 1992.
 43. **Department of the Army.** Regulation 611-201: Enlisted career management fields and military occupational specialties. Washington, DC: Department of the Army; 1994.
 44. **Barrack RL, Bruckner JD, Kneisl J, Inman WS, Alexander AH.** The outcome of nonoperatively treated complete tears of the anterior cruciate ligament in active young adults. *Clin Orthop.* 1990;259:192-9.
 45. **Lincoln AE, Smith GS, Amoroso PJ, Bell NS.** The natural history and risk factors of musculoskeletal conditions resulting in disability among US Army personnel. *Work.* 2002;18:99-113.
 46. **Daniel DM, Stone ML, Dobson BE, Fithian DC, Rossman DJ, Kaufman KR.** Fate of the ACL-injured patient. A prospective outcome study. *Am J Sports Med.* 1994;22:632-44.
 47. **Berkowitz SM, Feuerstein M, Lopez MS, Peck CA Jr.** Occupational back disability in U.S. Army personnel. *Mil Med.* 1999;164:412-8.
 48. **Leino P.** Symptoms of stress predict musculoskeletal disorders. *J Epidemiol Community Health.* 1989;43:293-300.
 49. **Eastlack ME, Axe MJ, Snyder-Mackler L.** Laxity, instability, and functional outcome after ACL injury: copers versus noncopers. *Med Sci Sports Exerc.* 1999;31:210-5.
 50. **Sernert N, Kartus J, Kohler K, Stener S, Larsson J, Eriksson BI, Karlsson J.** Analysis of subjective, objective and functional examination tests after anterior cruciate ligament reconstruction. A follow-up of 527 patients. *Knee Surg Sports Traumatol Arthrosc.* 1999;7:160-5.
 51. **Johnson WG, Ondrich J.** The duration of post-injury absences from work. *Rev Econ Stat.* 1990;72:578-86.
 52. **Jefferson MT.** An investigation of medical discharges from the British Army 1979-1986. *JR Army Med Corps.* 1989;135:115-23.
 53. **Barber FA, Elrod BF, McGuire DA, Paulos LE.** Is an anterior cruciate ligament reconstruction outcome age dependent? *Arthroscopy.* 1996;12:720-5.
 54. **Cox JS, Lenz HW.** Women midshipmen in sports. *Am J Sports Med.* 1984;12:241-3.
 55. **Feuerstein M, Berkowitz SM, Peck CA Jr.** Musculoskeletal-related disability in US Army personnel: prevalence, gender, and military occupational specialties. *J Occup Environ Med.* 1997;39:68-78.
 56. **Cheadle A, Franklin G, Wolfhagen C, Savarino J, Liu PY, Salley C, Weaver M.** Factors influencing the duration of work-related disability: a population-based study of Washington State workers' compensation. *Am J Public Health.* 1994;84:190-6.
 57. **Institute of Medicine.** *Reliability of hospital discharge abstracts: report of a study, February 1977.* Washington, DC: National Academy of Sciences; 1977.