REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
2002

3. REPORT TYPE AND DATES COVERED
Journal Article

4. TITLE AND SUBTITLE
The natural history and risk factors of musculoskeletal conditions resulting in disability among US Army personnel

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Research Institute of Environmental Medicine
Military Performance Division
Natick, MA 01760-5007

8. PERFORMING ORGANIZATION REPORT NUMBER
M01-42

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Medical Research and Materiel Command
Fort Detrick
Frederick, MD 21702-5012

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

20030128 142

13. ABSTRACT *(Maximum 200 words)*
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14. SUBJECT TERMS
Musculoskeletal conditions, natural history, disability, epidemiology, occupation, military personnel, injury

15. NUMBER OF PAGES
15

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Work 18 (2002) 99–113
IOS Press

The natural history and risk factors of musculoskeletal conditions resulting in disability among US Army personnel

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Abstract: We describe the natural history of 13 musculoskeletal conditions requiring hospitalization and identify demographic, behavioral, psychosocial, occupational, and clinical characteristics most strongly associated with disability discharge from the Army. Subjects included 15,268 active-duty personnel hospitalized for a common musculoskeletal condition between the years 1989–1996 who were retrospectively followed through 1997. Back conditions had the greatest 5-year cumulative risk of disability (21%, 19%, and 17% for intervertebral disc displacement, intervertebral disc degeneration, and nonspecific low back pain, respectively). Cox proportional hazards models identified the following risk factors for disability among males: lower pay grade, musculoskeletal diagnosis, shorter length of service, older age, occupational category, lower job satisfaction, recurrent musculoskeletal hospitalizations, more cigarette smoking, greater work stress, and heavier physical demands. Among females, fewer covariates reached statistical significance, although lower education level was significant in more than one model. Modifiable risk factors related to work (job satisfaction, work stress, physical demands, occupation) and health behaviors (smoking) suggest possible targets for intervention.

Keywords: Musculoskeletal conditions, natural history, disability, epidemiology, occupation, military personnel, injury

1. Introduction

Musculoskeletal conditions are associated with the majority (51%) of diagnoses resulting in disability discharge from the US Army [20]. However, the natural history of these conditions is largely unknown. Despite the tremendous cost of musculoskeletal-related disability payments to veterans (lifetime costs of $485 million to newly disabled Army personnel in 1993) [28], few studies have examined the course of these conditions and the risk factors that may be associated with the outcome of discharge from the service due to disability.

Several investigators have examined the roles of demographics [3,5,11,20,25,32,36,37,46,52], physical demands [11,34,36,38], psychosocial factors [3,16,17, 25,36–38,52], and employment-related factors [5,8, 18,23,30,54] in the development of musculoskeletal-related disability, or the alternative outcome of return to work. While psychosocial factors are now recognized to play a primary role in a successful rehabilitation, few studies have simultaneously included demographic, behavioral, occupational, and clinical features using an extended follow-up period. The aims

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The opinions and assertions contained herein are the private views of the authors, and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

AQM03-04-0658

of this study were to: 1) describe the natural history of common musculoskeletal conditions requiring hospitalization of Army personnel; and 2) given hospitalization for a musculoskeletal condition, identify those factors that are most strongly associated with disability discharge. By identifying factors that play significant roles in the development of physical disability, we may distinguish those which are modifiable and, therefore, amenable to intervention. Resulting information can be used in rehabilitation programs to eliminate or decrease the modifiable risk factors associated with disability discharge.

2. Methods

2.1. Study design

A retrospective cohort design was used to follow active-duty Army personnel from their initial musculoskeletal-related hospitalization, which occurred between the years 1989 and 1996, through the development of physical disability, up to 1997. This design incorporated many different data sources from the US Army to include 22 variables that are often considered to be potential confounders of associations between various exposures and health outcomes.

2.2. Cohort definition

To be included in the study, cohort subjects must have met several criteria: 1) been on active duty at the time of hospitalization; 2) been hospitalized for a specified musculoskeletal disorder or severe sprain/strain during the period 1989 to 1996; and 3) completed a health risk appraisal (HRA) at some point during the same time period. The goal of the study was to capture hospitalized subjects at their first admission for one or more of the diagnoses of interest. Therefore, subjects hospitalized for the same condition prior to 1989 ($N = 1053$) or having a disability board preceding the initial musculoskeletal hospitalization ($N = 27$) were disqualified and eliminated from the cohort (left censored). The total number of subjects remaining was 15,268.

2.3. Data sources

Data were obtained from the Total Army Injury and Health Outcomes Database (TAIHOD), a relational database linking information from seven Department of Defense agencies [1,2]. Information is linked by encrypted Social Security Numbers at the level of the individual soldier. The database provides excellent follow-up with minimal loss of cohort subjects. This study used the following components: personnel files from the Defense Manpower Data Center (including demographic variables and date of separation from service); hospitalization files (including dates of admission and diagnoses); health behavior data from the HRA (such as smoking status and work-related stress); and disability files (including functional outcomes such as disability ratings).

2.4. Diagnostic categories

Diagnostic categories were selected based on the likelihood of well-defined clinical symptoms (e.g., cruciate ligament injury) to permit an accurate diagnosis or large enough numbers (e.g., non-specific back pain) to provide adequate statistical power (Table 1). Diagnoses included both "acute" injuries within ICD-9-CM codes 836, 840, or 844 and "chronic" conditions (710–739, 354) that represent similar clinical presentations. These 40 diagnoses in 13 categories were further classified into 4 functional groups for more detailed analyses: knee, back, overuse, and other musculoskeletal conditions. Discussions with an injury researcher with experience in coding, a practicing orthopedist, and a practicing physiatrist led to development of diagnostic categories and functional groupings that involve similar mechanisms of injury or healing. We decided not to examine all musculoskeletal injuries; rather we sought to focus on a group of more precise diagnostic and clinical entities.

2.5. Endpoint

The outcome of interest, disability, was defined as having been assigned the following status at a medical evaluation board at some point between the initial hospitalization and the end of 1997: 1) permanent disability/retirement (disability rating of at least 30% or having at least 20 years of service); 2) severance without benefits (disability rating of less than 30% and having less than 20 years of services); or 3) temporary disability (similar to permanent disability, except for the possibility that the condition will change within the next five years and enable the subject to return fit for duty).

Time to disability (number of months) was determined from the point of the initial musculoskeletal hospitalization until the subject was medically discharged,

Table 1
Functional groups and diagnostic categories of ICD-9-CM codes for musculoskeletal disorders and sprain/strains ($N = 15,268$)

Functional group	Diagnostic category (no. of subjects)	ICD-9-CM code
1. Back conditions	A. Non-specific back pain (691)	724.2 Lumbago 724.5 Backache, unspecified
	B. Displacement of intervertebral disc (1608)	722.0 Displacement of cervical intervertebral disc without myelopathy 722.1 Displacement of thoracic or lumbar intervertebral disc without myelopathy (includes .1, .10, .11) 722.2 Displacement of intervertebral disc, site unspecified, without myelopathy
	C. Degeneration and other disc disorders (130)	722.4 Degeneration of cervical intervertebral disc 722.5 Degeneration of thoracic or lumbar intervertebral disc (includes .51, .52) 722.6 Degeneration of intervertebral disc, site unspecified 722.7 Intervertebral disc disorder with myelopathy (includes .70, .71, .72, .73) 722.8 Postlaminectomy syndrome (includes .80, .81, .83) 722.9 Other and unspecified disc disorder (includes .90, .91, .92, .93)
2. Knee conditions	D. Meniscal injury (3691)	717.0 Old bucket handle tear of medial meniscus 717.1 Derangement of anterior horn of medial meniscus 717.2 Derangement of posterior horn of medial meniscus 717.3 Other and unspecified derangement of medial meniscus 717.4 Derangement of lateral meniscus (includes .4, .40, .41, .42, .43, .49) 717.5 Derangement of meniscus, not elsewhere classified 836.0 Tear of medial cartilage or meniscus of knee, current 836.1 Tear of lateral cartilage or meniscus of knee, current 836.2 Other tear of cartilage or meniscus of knee, current
	E. Cruciate ligament injury (2266)	717.83 Old disruption of anterior cruciate ligament 717.84 Old disruption of posterior cruciate ligament 844.2 Sprain/strain of cruciate ligament of knee
	F. Collateral ligament injury (564)	717.81 Old disruption of lateral collateral ligament 717.82 Old disruption of medial collateral ligament 844.0 Sprain/strain of lateral collateral ligament 844.1 Sprain/strain of medial collateral ligament
	G. Chondromalacia (923)	717.7 Chondromalacia of patella
3. Overuse conditions	H. Synovitis and tenosynovitis (817)	727.0 Synovitis and tenosynovitis (includes .0, .00, .01, .02, .03, .04, .05, .06, .09)
	I. Carpal and cubital tunnel syndromes (547)	354.0 Carpal tunnel syndrome 354.2 Lesion of ulnar nerve (Cubital tunnel syndrome)
	J. Rotator cuff injury (330)	726.1 Rotator cuff syndrome of shoulder and allied disorders (includes .1, .10, .11, .12, .19) 840.3 Infraspinatus (muscle) (tendon) 840.4 Rotator cuff (capsule) 840.5 Subscapularis (muscle) 840.6 Supraspinatus (muscle) (tendon)
4. Other MS Conditions	K. Ganglion and cyst of synovium, tendon, and bursa (1356)	727.4 Ganglion and cyst of synovium, tendon, and bursa (includes .4, .40, .41, .42, .43, .49)
	L. Bunion and deformities of toe (1533)	727.1 Bunion 735.0 Hallux valgus (acquired)
	M. Malunion and nonunion of fracture (812)	733.8 Malunion and nonunion of fracture (includes .8, .81, .82)

discharged for other reason (e.g., honorable discharge), or censored because of the end of the follow-up period. Although an individual may have been evaluated for disability determination on more than one occasion (e.g., if they were placed on temporary disability), their first occurrence in the disability database was used to represent the outcome from the Physical Evaluation Board. Persons assigned a temporary disability for a condition that had not yet stabilized frequently went on to receive a permanent disability status. But even those who were later found fit for duty were included in the study as "disability" cases if they had been off work for a significant length of time.

2.6. *Military Occupational Specialty (MOS) and physical demands*

Physical demands for specific MOSs were classified as Light, Medium, Moderately Heavy, Heavy, and Very Heavy [14]. These categories represent maximum upper body strength requirements as required for "combat conditions" performance for enlisted personnel [14]. The Department of Defense occupational coding structure was used to classify enlisted personnel into one of 10 occupational categories [13].

2.7. *Analysis*

Kaplan-Meier estimates of cumulative survival of subjects receiving a medical disability discharge were calculated for each of the 13 diagnostic categories. Estimates of the cumulative proportion receiving a disability discharge were examined for each of the risk factors considered one at a time. The statistical significance of the association between each risk factor and the cumulative probability of disability discharge were assessed using log-rank tests for equality of factor levels and for linear trend [12]. Comparisons were made between age groups, gender, races, pay grades, occupational specialties, physical demand levels, smoking status, alcohol use, health practices, body mass, education levels, marital status, number of dependents, length of time in service, diagnostic categories, hospitalization recurrence, sick days, alcohol-related comorbidity, job satisfaction, and frequency of experiencing work stress.

The Cox proportional hazards model was used to estimate the combined effect of multiple risk factors and the contribution of each factor independently [12]. Variables were entered into the model as either categorical (gender, age group, race/ethnicity, education level, pay grade, gender-specific body mass index quintile, cigarette smoking status, alcohol use, marital status, occupational specialty, MOS physical demand, length of time in service, job satisfaction, work stress, diagnostic category, recurrent hospitalization) or continuous (health practice index, number of dependents) covariates. Gender-specific Cox proportional hazards models were fitted using a forward-conditional stepwise approach ($p_{entry} = 0.10$, $p_{removal} = 0.20$). Plots of log minus log (survival) functions against time were used to check assumptions of proportional hazards. All analyses were performed with SPSS for Windows 7.5.2 (Chicago, IL: SPSS, Inc.).

To determine whether the study population was representative of both active-duty Army personnel and soldiers who experienced a musculoskeletal-related hospitalization, the sociodemographic characteristics of the study cohort and two comparison groups were assessed using chi-square tests. The comparison group of injured personnel included all active duty soldiers who were hospitalized for any of the principal diagnoses used to define the study cohort between 1989 and 1995. Only the first occurrence of an individual in the hospitalization file was used to be consistent with the establishment of the other groups ($N = 52,021$). The active duty sample was generated by random selection of the end-of-year personnel file for 5000 subjects for each of 9 years between 1989 and 1997 ($N = 44,045$).

3. Results

3.1. *Sample generalizability*

Relative to all personnel with a musculoskeletal hospitalization, there was no difference in the study cohort in terms of sex ($p = 0.40$), as both groups are predominantly male (85%). However, the study cohort appeared to be significantly older (mean age = 31.0 years, $SD = 7.5$ versus mean age = 29.5 years, $SD = 8.3$) ($p < 0.0001$) and had a correspondingly higher pay grade/rank (chi-square = 873.0, $df = 5$, $p < 0.0001$). The primary difference between these two groups was that the study cohort had definitely taken the HRA, whereas all personnel with a musculoskeletal hospitalization may or may not have taken it.

In comparison with a sample of all active duty personnel over the period of study, both the study and sample populations were found to be predominantly male (85% for study cohort versus 87% for active duty sample), white (63% versus 62%), and well-educated (99.7% had at least a high school diploma or equivalent versus 99.5%). As in the comparison with the hospitalized group, the study cohort was slightly older (mean age = 31.0 years vs. 28.2 years) than the active duty sample ($p < 0.0001$). Similarly, there were significant differences ($p < 0.0001$) in the distribution of pay grade (89% of the study cohort had an annual income of at least $30,000 (E4 or above) versus 78% of the active duty sample). It was expected that differences in age and pay grade/rank were meaningful to these analyses, while the significant differences for the other sociodemographic characteristics were less likely to be relevant.

Table 2
Demographics and bivariate analysis of study population

Category	Strata	Disability discharge ($N = 1454$),	(%)	Study cohort ($N = 15,268$),	(%)	Disability rate (per 100 admits)	Log-rank (equality)*	Log-rank (trend)**
Sex	Male	1236	85.0	13,013	85.2	9.50	$p = 0.78$	–
	Female	218	15.0	2246	14.7	9.71		
	Missing	0	0	9	0.1	0.00		
Age groups	< 21	31	2.1	1057	6.9	2.93	$p = 0.00$	$p = 0.00$
	21–25	435	29.9	3582	23.5	12.14		
	26–34	691	47.5	5550	36.4	12.45		
	35 +	297	20.4	5079	33.3	5.85		
Race/ethnicity	White	957	65.8	9603	62.9	9.97	$p = 0.02$	–
	Black	398	27.4	4375	28.7	9.10		
	Hispanic	50	3.4	603	3.9	8.29		
	American Indian/ Alaskan Native	10	0.7	87	0.6	11.49		
	Asian/Pacific Islander	13	0.9	219	1.4	5.94		
	Other	26	1.8	371	2.4	7.01		
	Unknown	–	–	10	0.1	0.00		
Education level	No H.S. diploma	4	0.3	47	0.3	8.51	$p = 0.00$	$p = 0.00$
	H.S. grad/GED	1274	87.6	11,258	73.7	11.32		
	Some college	62	4.3	1017	6.7	6.10		
	College degree	101	6.9	2721	17.8	3.71		
	Unknown	13	0.9	220	1.4	5.91		
	Missing	0	0	5	0.0	0.00		
Pay grade	E1–E3	289	19.9	1706	11.2	16.94	$p = 0.00$	$p = 0.00$
	E4–E6	1010	69.5	8702	57.0	11.61		
	E7–E9	72	5.0	2095	13.7	3.44		
	W1–W5	12	0.8	446	2.9	2.69		
	O1–O3	56	3.9	1266	8.3	4.42		
	O4–O10	15	1.0	974	6.4	1.54		
	Cadets	0	0	77	0.5	0.00		
	Missing	0	0	2	0.0	0.00		
Total		1454		15,268		9.52	–	

*Test of equality of survival distributions for different levels of a factor.
**Test for linear trend across levels of factor.

3.2. Disability discharge rates by population subgroups

Results of bivariate analyses are presented in Tables 2 and 3. Differences among strata, as determined by the log-rank test for equality ($p < 0.05$), included age groups, race/ethnicity, education level, pay grade, body mass index quintile, cigarette smoking status, marital status, number of dependents, occupational specialty, MOS physical demands, work stress, job satisfaction, length of service, health practices index, and within the diagnostic subgroups of knee and other conditions. (Note: Not all are shown.) Disability rates were highest among the following subgroups: 21–25 year olds (12.1/100) or 26–34 year olds (12.5); enlisted personnel in the lowest pay grades (E1–E3) (17.0); those in the service for æ 6 months (18.7) or 7–12 months (16.7); diagnosed with intervertebral disc displacement (16.7), intervertebral disc degeneration (14.6), nonspecific back pain (13.8), or chondromalacia (12.4); having multiple musculoskeletal hospitalizations (15.0); having a duty MOS of electronic equipment repair (13.3) or other technical jobs (13.6); being in a "very heavy" physically demanding occupation (12.8); often stressed at work (13.7); not satisfied with present job (13.2); heavy smokers (1+ pack/day) (12.3); heavy drinkers (> 24 drinks/week) (12.4); and single persons (11.7) or those having no dependents (11.3). Diagnoses of meniscal injury ($N = 300$), displacement of intervertebral disc ($N = 268$), and cruciate ligament injury ($N = 244$) were most frequently associated with disability discharge. Log-rank tests for linear trend identified older age group, lower education level, lower pay grade, more cigarette smoking, having fewer dependents, more physically demanding job, greater work stress, lower job satisfaction, shorter length of service, recurrent hospitalizations, and fewer health practices to be at increased risk for disability discharge ($p < 0.001$).

Table 3
Occupational characteristics and bivariate analysis of study population

Category	Strata	Disability discharge ($N = 1454$),	(%)	Study cohort ($N = 15,268$),	(%)	Disability rate (per 100 admits)	Log-rank (equality)*	Log-rank (trend)**
Enlisted occupational specialty	Direct combat	14	1.0	238	1.6	5.88	$p = 0.00$	–
	Electronic equip repair	480	33.0	3599	23.6	13.34		
	Commun & intelligence	17	1.2	274	1.8	6.20		
	Health care	97	6.7	865	5.7	11.21		
	Other technical	28	1.9	206	1.3	13.59		
	Support & administration	56	3.9	636	4.2	8.81		
	Electrical/mech repair	186	12.8	1600	10.5	11.63		
	Craftsman	145	10.0	1840	12.1	7.88		
	Service & supply	55	3.8	485	3.2	11.34		
	Non-occupational	290	19.9	2752	18.0	10.54		
	Warrant Officers	12	0.8	444	2.9	2.70		
	Officers	71	5.0	2238	14.6	3.17		
Physical demand (Enlisted only)	Not determined	80	5.5	1131	7.4	7.07	$p = 0.00$	$p = 0.00$
	Light	23	1.6	233	1.5	9.87		
	Medium	60	4.1	802	5.3	7.48		
	Moderately heavy	196	13.5	1736	11.4	11.29		
	Heavy	12	0.8	138	0.9	8.70		
	Very heavy	791	54.4	6172	40.4	12.82		
	Missing	209	14.4	2372	15.5	8.81		
Frequency of experiencing work stress	Often	173	11.9	1263	8.3	13.70	$p = 0.00$	$p = 0.00$
	Sometimes	384	26.4	3637	23.8	10.56		
	Seldom	478	32.9	5820	38.1	8.21		
	Never	389	26.8	4089	26.8	9.51		
Job satisfaction	Not satisfied	233	16.0	1762	11.5	13.22	$p = 0.00$	$p = 0.00$
	Somewhat	327	22.5	3012	19.7	10.86		
	Mostly	382	26.3	4687	30.7	8.15		
	Totally	188	12.9	2793	18.3	6.73		
	N/A	288	19.8	2553	16.7	11.28		
Total		1454		15,268		9.52	–	

*Test of equality of survival distributions for different levels of a factor.
**Test for linear trend across levels of factor.

3.3. Natural history by diagnostic category

Survival curves for the 13 diagnostic categories provided estimates of the risk of disability discharge over an extended follow-up period. For many of the categories, Kaplan-Meier estimates were stable throughout 72 to 84 months of follow-up time, although some categories with relatively small numbers of subjects produced curves that are informative for only the initial 36 to 48 months. The maximum follow-up time obtainable was nine years (108 months).

A summary of the survival curves for all 13 diagnoses presents the cumulative risk of disability discharge at 6 months, 12 months, and 5 years after the initial musculoskeletal hospitalization (Fig. 1). These data indicate that intervertebral disc degeneration was the most severe condition, having the highest cumulative disability at 6 months (5.7%) and 12 months (9.1%). The five-year cumulative risk of disability was highest for the three back conditions: intervertebral disc displacement (20.8%), intervertebral disc degeneration (19.1%), and nonspecific back pain (16.7%).

Among back conditions, non-specific low-back pain provided the least risk of disability discharge, particularly in comparison with intervertebral disc displacement (Fig. 2). The log-rank test for equality of hazard function was marginally significant ($p = 0.08$). During the initial 15 months, the survival curve for degeneration and other disc disorders was most severe among the back conditions, but the small number of cases beyond that point made it difficult to interpret how the longer-term survival compared with other back conditions.

Knee conditions, representing the most commonly occurring musculoskeletal condition in the study cohort (49%), illustrated distinct progressions to disability among the diagnoses (log-rank test for equality p-value < 0.001). Chronic conditions, such as chondromalacia, were more likely to result in disability than acute knee injuries, such as meniscal injuries, given the

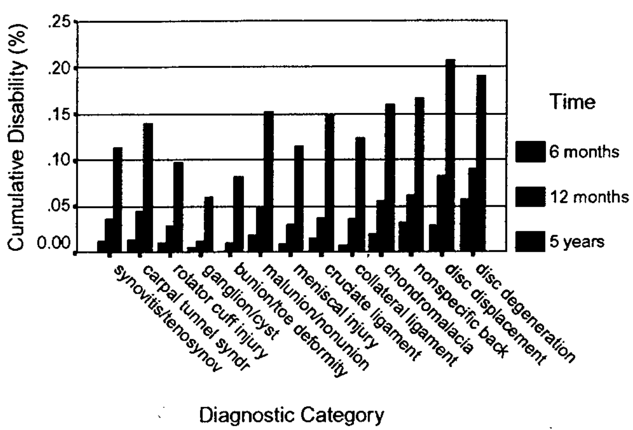

Fig. 1. Cumulative risk of disability discharge, US Army, 1989–1997.

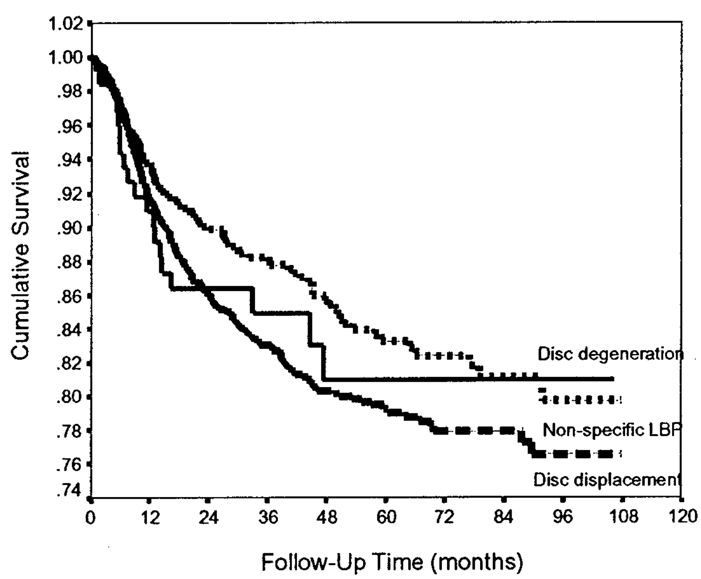

Fig. 2. Time to disability discharge among back conditions, US Army, 1989–1997.

physical demands associated with a military environment.

Among overuse conditions (e.g., synovitis and tenosynovitis, carpal and cubital tunnel syndrome, and rotator cuff injury), there was little difference in progression to disability (log-rank test for equality p-value = 0.90). Beyond 48 months, there was a greater hazard among those with carpal and cubital syndromes than for synovitis and tenosynovitis. Among other musculoskeletal conditions, those of fracture malunion/nonunion produced the greatest hazard ratio within this group, particularly within the initial 24 months.

3.4. Prognostic signs of disability discharge for men

Proportional hazards models for each diagnostic group provided estimates of relative hazard for disability discharge among men (Table 4). In multivariate models for back conditions, length of service ($p < 0.001$), diagnostic category ($p = 0.012$), age group ($p = 0.014$), physical demands ($p = 0.037$), and

Table 4
Cox proportional hazards models by diagnostic group (men)

Covariate	Back (N = 1160)			Knee (N = 3155)			Overuse (N = 742)			Other (N = 2627)		
	Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval	
Age group												
< 21 years	1.00	–		1.00	–		1.00	–		1.00	–	
21–25 years	11.10	1.53	80.54	2.71	1.56	4.68	8.64	1.16	64.45	15.98	2.20	116.30
26–34 years	13.09	1.81	94.68	3.95	2.24	6.95	8.43	1.12	63.57	24.41	3.31	180.21
35+ years	9.19	1.25	67.87	3.66	1.88	7.11	21.43	2.71	169.53	29.34	3.74	229.87
Pay grade												
E1–E3	1.44	0.69	3.03	6.27	2.78	14.11	not	significant		2.16	0.44	10.60
E4–E6	1.88	1.09	3.22	3.48	1.64	7.36				1.23	0.27	5.65
E7–E9	1.00	–		1.00	–					0.79	0.16	4.01
W1–W5										Unstable	–	
O1–O3										0.36	0.06	2.31
O4–O10										1.00	–	
Length of service												
⩽ 6 months	1.04	0.23	4.68	1.95	0.86	4.45	5.02	0.57	44.36	Unstable	–	
7–12 months	0.79	0.10	5.92	3.63	1.85	7.11	Unstable	–		1.75	0.51	5.99
1–4 years	2.79	1.81	4.29	2.32	1.51	3.55	10.08	4.40	23.09	3.67	1.87	7.23
5–10 years	1.74	1.20	2.51	1.77	1.21	2.61	5.75	2.68	12.33	3.08	1.66	5.70
> 10 years	1.00	–		1.00	–		1.00	–		1.00	–	
Job satisfaction												
Not satisfied	not	significant		1.71	1.15	2.56	not	significant		not	significant	
Somewhat satisfied				1.59	1.10	2.29						
Mostly satisfied				1.26	0.88	1.79						
Totally satisfied				1.00	–							
Frequency of experiencing work stress												
Often	not	significant		1.02	0.70	1.49	2.76	1.22	6.24	not	significant	
Sometimes				0.96	0.72	1.28	1.15	0.58	2.30			
Seldom				0.69	0.52	0.91	1.19	0.64	2.20			
Never				1.00	–		1.00	–				
Recurrent hospitalizations												
No	not	significant		1.00	–		not	significant		1.00	–	
Yes				1.36	1.08	1.72				1.42	0.98	2.06
Occupational category												
Direct combat	not	significant		not	significant		not	significant		0.64	0.06	7.49
Electrical equipment repair										1.52	0.31	7.42
Communication & intell										Unstable	–	
Health care										0.51	0.09	2.91
Other technical										1.22	0.19	7.87
Support & administration										0.99	0.18	5.56
Electrical/mechanical repair										0.75	0.15	3.86
Craftsman										0.75	0.14	3.86
Service & supply										0.85	0.14	5.19
Non-occupational										0.79	0.16	4.01
Warrant Officers & Officers										1.00	–	
Diagnostic category												
Ganglion/cyst							not	significant		1.00	–	
Bunion/toe deformities										1.10	0.71	1.71
Malunion/nonunion										2.53	1.71	3.73
Meniscal injury				1.00	–							
Cruciate ligament injury				1.13	0.88	1.44						
Collateral ligament injury				1.23	0.82	1.83						
Chondromalacia				1.52	1.11	2.08						
Non-specific back pain	1.00	–										
Disc displacement	1.52	1.13	2.06									
Disc degeneration	1.94	1.05	3.58									

Table 4, continued

Covariate	Back ($N = 1160$)			Knee ($N = 3155$)			Overuse ($N = 742$)			Other ($N = 2627$)		
	Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval	
Smoking												
Nonsmoker	not	significant		1.00	–		not	significant		not	significant	
Former smoker				0.85	0.60	1.23						
Light (< 1 pack/day)				1.29	0.98	1.69						
Heavy (1+ pack/day)				1.67	1.26	2.22						
Physical demands												
Light	1.00	–		1.00	–		1.00	–		not	significant	
Medium	0.23	0.07	0.72	0.86	0.33	2.23	0.56	0.11	2.83			
Moderately heavy	1.01	0.46	2.23	0.87	0.37	2.04	0.24	0.06	0.99			
Heavy	0.95	0.24	3.70	3.50	0.86	14.21	2.43	0.37	15.84			
Very heavy	0.93	0.44	1.99	1.25	0.55	2.81	0.69	0.21	2.28			

Not significant – not included in final model.
Unstable – too few subjects in strata.

pay grade ($p = 0.044$) were significantly associated with disability discharge. Personnel at highest risk included: those in the service for 1–4 years relative to those with greater than 10 years of service; 26–34 years old relative to those < 21 years old; diagnosed with intervertebral disc degeneration relative to nonspecific back pain; and those of lower rank (E4–E6) relative to E7–E9. Those with "medium" physical demands were at decreased risk relative to those with "light" demands, while those with "heavy" or "very heavy" demands did not exhibit increased risk.

Significant predictors among males with knee conditions included age group ($p < 0.001$), pay grade ($p < 0.001$), cigarette smoking ($p < 0.001$), length of service ($p = 0.001$), recurrent hospitalizations ($p = 0.009$), frequency of experiencing work stress ($p = 0.024$), job satisfaction ($p = 0.025$), physical demands ($p = 0.031$), and diagnostic category ($p = 0.066$). Personnel at highest risk were: 26–34 years old; lowest ranking enlisted personnel (E1–E3); heavy smokers (1+ pack/day); those with 7–12 months of service; those with one or more recurrent musculoskeletal hospitalizations; those not satisfied with their job; those in MOSs with heavy physical demands; and those diagnosed with chondromalacia. Those who seldom experienced work stress were at decreased risk relative to those who never experienced work stress, while often experiencing work stress was not associated with increased risk.

Among overuse conditions, length of service ($p < 0.001$), age group ($p = 0.004$), physical demands ($p = 0.044$), and frequency of experiencing work stress ($p = 0.083$) were significantly associated with disability discharge. Personnel at highest risk included those who were: 35+ years old; in the service for 1–4 years; often experienced work stress; and in MOSs with heavy physical demands, although the wide confidence interval reflects the small number in the heavy classification ($N = 16$).

For the other musculoskeletal conditions, diagnostic category ($p < 0.001$), length of service ($p = 0.002$), age group ($p = 0.004$), occupational category ($p = 0.018$), recurrent hospitalization ($p = 0.061$), and pay grade ($p = 0.084$) were predictive of disability discharge. At greatest risk were those with: a diagnosis of fracture malunion or nonunion; 1–4 years of service; 35+ years old; jobs in electrical equipment repair; lowest ranking enlisted personnel (E1–E3); and having at least one recurrent musculoskeletal hospitalization.

3.5. *Prognostic signs of disability discharge for women*

Fewer covariates reached statistical significance in proportional hazards models for females (Table 5). Predictors of disability discharge for back conditions included only diagnostic category ($p = 0.018$) and length of service ($p = 0.065$). Greatest risk existed for those diagnosed with intervertebral disc displacement relative to nonspecific back pain and those who had served 1–4 years relative to those with more than 10 years of service.

For females with knee conditions, education level ($p < 0.001$), length of service ($p = 0.023$), and job satisfaction ($p = 0.024$) were identified as significant predictors of disability discharge. Those at highest risk were high school graduates relative to college graduates, those who have served 6 or fewer months relative to those with more than 10 years of service, and those

Table 5
Cox proportional hazards models by diagnostic group (women)

Covariate	Back ($N = 252$)			Knee ($N = 210$)			Overuse ($N = 334$)			Other ($N = 952$)		
	Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval		Relative hazard	95% Confidence interval	
Education												
High school grad/GED	not	significant		8.76	2.67	28.70	3.62	1.10	11.92	not	significant	
Some college				1.73	0.18	16.82	1.21	0.20	7.24			
College degree				1.00	–		1.00	–				
Length of service												
⩽ 6 months	1.41	0.30	6.63	6.26	1.87	20.92	not	significant		not	significant	
7–12 months	Unstable	–		2.62	0.51	13.57						
1–4 years	2.65	1.33	5.31	2.43	0.94	6.33						
5–10 years	1.37	0.63	2.99	1.54	0.55	4.30						
> 10 years	1.00	–		1.00	–							
Job satisfaction												
Not satisfied	not	significant		1.73	0.73	4.13	not	significant		not	significant	
Somewhat satisfied				0.56	0.24	1.33						
Mostly satisfied				0.73	0.33	1.61						
Totally satisfied				1.00	–							
Frequency of experiencing work stress												
Often	not	significant		not	significant		not	significant		0.68	0.27	1.69
Sometimes										0.87	0.47	1.62
Seldom										0.25	0.12	0.54
Never										1.00	–	
Diagnostic category												
Non-specific back pain	1.00	–		not	significant		not	significant				
Disc displacement	2.37	1.28	4.37									
Disc degeneration	0.91	0.12	7.13									
Ganglion/cyst										1.00	–	
Bunion/toe deformities										1.10	0.60	2.03
Malunion/nonunion										5.15	2.22	11.91

Not significant – not included in final model.
Unstable – too few subjects in strata.

not satisfied with their jobs relative to those totally satisfied.

Among females with overuse conditions, only education level was found to be a significant predictor of disability ($p = 0.044$), with high school graduates at elevated risk relative to college graduates. For other musculoskeletal conditions, those with a diagnosis of fracture malunion or nonunion were at elevated risk relative to those diagnosed with ganglion/cyst ($p < 0.001$). Also, those who seldom experienced work stress were at less risk than those who never experienced work stress.

4. Discussion

4.1. Findings

Results of this study provide a broad picture of musculoskeletal conditions and a wide range of covariates that may affect the progression towards disability. Overall, these common musculoskeletal conditions represent a substantial risk of disability discharge with a rate of 9.5 per 100 initial hospitalizations and a 5-year cumulative risk of 13.2% (95% confidence interval: 12.5%, 13.9%). Back conditions were associated with the highest 5-year cumulative risk of disability discharge. This is consistent with high back-related disability rates in civilian studies [11] and exposures to heavy physical demands [34] associated with many military occupations. Survival curves for specific diagnoses suggest that intervertebral disc degeneration and displacement are the most severe conditions, as indicated by their steep slopes within the initial 12 months of follow-up.

Multivariate survival analysis techniques identified the adjusted risk of disability discharge for covariates subsequent to an initial musculoskeletal hospitalization. For males, significant predictors included older age group, lower pay grade, intermediate length of service, lower job satisfaction, greater work stress, recurrent musculoskeletal hospitalizations, diagnosis, occupational category, heavy physical demands, and heavy cigarette smoking. Fewer consistent predictors (five) were identified for females than males (ten), including lower education level, shorter length of service, lower job satisfaction, and diagnosis. As suggested by the IOM [26] and Feuerstein et al. [20], perhaps women in the military are affected by unique physical and psychosocial factors beyond the 22 covariates included in this investigation. Pinsky et al. also found far fewer significant predictors among women than among men [44], suggesting that these findings are consistent and valid.

4.1.1. *Effect of age*

Of particular interest is the finding of very large relative hazards for males 35+ years old for overuse (RH = 21.4, 95% CI: 2.7, 169.5) and other (RH = 29.3, 95% CI: 3.7, 229.9) conditions. This is consistent with several other studies of musculoskeletal-related disability [3,5,11,25,33,34,36,52]. The NIOSH review of musculoskeletal disorders and workplace factors suggests, "loss of tissue strength with age may increase the probability or severity of soft tissue damage from a given insult [6]." The effect of older age has a slightly different interpretation in this study than in the studies cited above; the outcome for those studies is the incidence of musculoskeletal-related injury or disability, whereas the outcome of this study is the development of disability following the incidence of a condition.

Based on the findings of greater disability risk with increasing age, we might also expect an increasing risk with length of service, which is highly correlated with age. However, we found males with 1–4 years of service to have the highest risk of disability for back, overuse, and other conditions, while males with 7–12 months of service had the highest risk for knee conditions. Among females, those with the shortest length of service ($\leqslant$ 6 months) were at highest risk for knee conditions while those with 1–4 years of service were at greatest risk for back conditions. This presents the unusual scenario whereby increased risk is associated with an increase in age but a decrease in both pay grade and length of service. While older persons may not heal as readily as younger persons, those in higher pay grades may not have as stringent physical demands associated with their jobs. Also, older persons may not need to return to as high a level of physical capacity as those in lower pay grades and with less time in service. Younger Army personnel, who tend to perform more physically demanding jobs, have also been found to have a higher risk of repeat injury [48], possibly associated with higher levels of physical capacity required to perform their jobs. Surprisingly, heavy physical demands were not associated with elevated risk of disability among subjects with back diagnoses, as others have identified [11,38]. Perhaps the broad categorization scheme for physical demands resulted in some misclassification bias, thereby diluting the effect of this factor.

4.1.2. *Effect of work stress*

Among males with overuse conditions, frequently experiencing work stress was associated with increased risk of disability (RH = 2.8, 95% CI: 1.2, 6.2). This finding is consistent with the magnitude of risk found by Berkowitz et al. [5] for higher work stress in relation to low back disability in Army soldiers (OR = 2.7). Also, those not satisfied with their job were at elevated risk (RH = 1.7) among both males and females with knee conditions. These findings support the hypothesis that work stress and job satisfaction may play a fundamental role in the development of musculoskeletal conditions [9] and their resulting physical disability [54]. However, inconsistencies in the magnitude and direction of effect associated with work stress across diagnoses and gender suggests the need to better understand this complex relationship.

4.1.3. *Effect of recurrent hospitalization*

Recurrent hospitalization, a surrogate measure of injury severity in some cases and of healing in others, was associated with increased risk for males with knee conditions (RH = 1.4, 95% CI: 1.1, 1.7) or other conditions (RH = 1.4, 95% CI: 1.0, 2.1), but not back or overuse conditions. One may have expected recurrent hospitalization to have a greater relative hazard for knee and overuse conditions and to be highly significant among back conditions as well. However, the requirement that the principal diagnosis in later hospitalizations exactly match the fourth or fifth digit ICD code may have resulted in a lack of sensitivity for this measure. Other research has suggested that the level of agreement for external cause of injury (E) coding is greater at the level of the third digit than at the fourth or fifth [31]. It is likely that an increased level of agreement would have been obtained by using the third digit level of the nature of injury (N) coding as well.

4.1.4. Effect of education

Although a lower level of education was found to be an independent predictor of disability discharge among women for knee (RH = 8.8) and overuse (RH = 3.6) conditions, it was not found to be predictive among males for any diagnostic group. Similarly, other studies have found education to be the lone predictor among women, other than age, of good function [44]. Many studies have identified education level as one of the strongest predictors of disability resulting from musculoskeletal conditions such as low back pain, lower extremity fracture, and rheumatoid arthritis [3,16,17, 25,36,38,43,44]. Pincus and Callahan proposed education level to be "a composite or surrogate variable, reflecting intrinsic abilities, income, access to and use of medical facilities, levels of personal responsibilities for health care, problem-solving experience" and others [43]. However, perhaps the military environment, unique in its command-oriented structure and universal access to medical care, minimizes the effect of formal education on the development of physical disability. Also, the fact that even those with the least education had attained a high school diploma limits the variation in education level and may have muted its effect.

4.1.5. Effect of smoking

Smoking is a significant predictor of disability among males for knee injuries (RH=1.7), but not back injuries. There is a significant literature that relates smoking to the incidence of back conditions [4,7,10,15, 21,22,24,29,40,41,45,47,49,51]. A recent review suggests that cigarette smoking may be associated with the progression of musculoskeletal conditions to disability [35]. However, there is relatively little to suggest that knee conditions (as a specific lower extremity injury) would be affected by cigarette smoking [27,45, 53].

4.1.6. Effect of diagnosis

The finding that chondromalacia has the highest risk for disability among knee conditions may also be considered surprising. Perhaps the physical demands of military life combined with limited treatment options combine to increase the risk of disability discharge relative to meniscal and ligamentous injuries.

4.2. Limitations

There are several concerns with using HRA data in these analyses. Although many variations of the HRA have been shown to be valid, reliable, and internally consistent [19], this specific instrument has not been tested for these parameters. Another concern regards the stability and accuracy of behavioral practices in Army personnel and whether the measures, as recorded by the HRA prior to their hospitalization, are likely to be the same at the time of initial musculoskeletal hospitalization. In order to assess the likelihood that smoking behavior may have changed over time, a subanalysis was performed using the kappa measure of agreement for smoking history among those subjects who completed the HRA prior to and following the initial musculoskeletal hospitalization ($N = 1482$). Results indicate very good agreement (kappa = 0.74, 95% CI (0.71, 0.77)) between first and last HRAs in regard to smoking status (e.g., nonsmoker, former, current). This suggests smoking practice remained stable over several years (mean = 37 months, $SD = 42$ months) for this cohort. Among subjects who were current smokers at both HRAs ($N = 360$), the mean difference in number of cigarettes smoked per day was an increase of 0.89 (2-sided p-value = 0.035). Although these results were encouraging, we were still concerned about the opportunity for simultaneous equation bias, whereby the dependent variable (disability) and covariate (smoking) may have a two-way causal relationship (i.e., smoking may increase the risk of disability, or disability may encourage one to smoke) [33]. In an effort to minimize this, the last semiannual personnel file update immediately prior to the initial hospitalization was used to capture covariates as accurately as possible. This is an important point as the subject may have changed their job after their hospitalization. Similarly, if the HRA was taken on multiple occasions, the survey occurring closest to the hospitalization was used in data collection.

Another potential limitation is the validity of self-reported behavior associated with responding to the HRA. A previous meta-analysis has indicated that self-reported tobacco use is accurate in most studies, particularly if students are not included in the study population [42]. In addition, the study cohort appears to be slightly older and has a higher pay grade/rank than both Army personnel who experienced a musculoskeletal-related hospitalization and active duty personnel in general as well. This may stem from a length of service bias resulting from the requirement that the cohort subjects must take the HRA. Because age was associated with the development of disability (at least among men), this additional 2 to 3 years of age on average among the study cohort should be recognized.

A potential limitation involves the use of a hospitalization, for case ascertainment, because it does not necessarily represent the initial injury or event. In studies by Tomlinson et al. [50] and Reynolds et al. [45], only 3 and 2.4 percent, respectively, of musculoskeletal injuries/conditions that were reported to sick call resulted in hospitalization. Therefore, following subjects from initial hospitalization only provides a partial view of the natural history and most likely underestimates the length of the condition's history.

This study is intended to be generalizable to an adult population with activity levels that approach those of active duty Army personnel. However, attempts to generalize the findings to civilians should be made with caution. Despite some differences in civilian and military work environments, this study population represented a wide variety of occupational groups, most of whom had directly comparable tasks to those found in civilian jobs.

4.3. Strengths

The primary strength of this study is the ability to collect a wide array of exposure data and follow subjects over time to determine the likelihood of disability discharge. The key to the success of this study is the linkage of several high quality data sources to assess demographic, behavioral, psychosocial, occupational, and clinical factors. Such a linkage of relevant data systems is one of the identified research needs identified by the NIOSH National Occupational Research Agenda Traumatic Injury Team as necessary for effective research [39].

The study includes a range of potential confounders in a study of disability development, and provides significant insight into the natural history of many prevalent health conditions. In addition, the tremendous size of the target population offers the ability to follow a cohort with power to detect associations between covariates and the outcome of interest. The study benefits from a reduction of the antagonistic employee-employer relationship that is often evident with civilian worker compensation cases. Also, the determination of disability is fairly objective relative to the experience of private sector disability policy.

5. Conclusion

Musculoskeletal conditions requiring hospitalization represent a substantial risk of disability resulting in discharge from the US Army. Back conditions are shown to be the most severe and have the highest 5-year cumulative risk of disability. Demographic, behavioral, psychosocial, occupational, and clinical characteristics are associated with disability discharge, demonstrating the multivariate nature of disability. Modifiable risk factors related to work (job satisfaction, work stress, physical demands, occupation) and health behaviors (smoking) suggest possible targets for intervention to achieve a successful rehabilitation.

Acknowledgments

Portions of this research were supported by funding from the Defense Women's Health Research Program (Army Medical Research and Materiel Command; #W4168044). Dr. Lincoln was supported by the NIOSH Educational Resource Center at The Johns Hopkins School of Hygiene and Public Health (# T42CCT310419), the William Haddon, Jr. Fellowship in Injury Prevention, and NIOSH grant 1R01 OH03703-01A1. Dr. Bell was supported by a grant from the National Institute on Alcohol Abuse and Alcoholism (grant # 1 R29 AA11407-01A1). The investigators have adhered to the policies for protection of human subjects as prescribed in Army Regulation 70–25, and the research was conducted in adherence with the provisions of 45 CFR. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, the US Government, the National Institute for Occupational Safety and Health, or the National Institute on Alcohol Abuse and Alcoholism.

The authors would like to acknowledge Michelle Yore for her tremendous assistance in the creation of this database; Drs. Richard Hinton and Tamara Lauder for their clinical guidance; Drs. Susan Baker, Jacqueline Agnew, Mei-Cheng Wang, Ellen MacKenzie, and Clifford Mitchell for their editorial suggestions; and Laura Senier for her assistance in manuscript preparation.

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