Case Control Study of Disabling Knee Injuries in the United States Army: Classification of Injury for Etiological Research

A Master's Thesis Presented by

Padmaja Patnaik

Biostatistics and Epidemiology Department
University of Massachusetts, Amherst

May 1998

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figures

ACKNOWLEDGMENTS

Gratitude is extended to the following people for their time, patience and helpful feedback:

Mr. Kenneth A. Mundt, Ms. Carol Bigelow, and Mr. Harris Pastides, Thesis Committee, Department of Biostatistics and Epidemiology, University of Massachusetts Amherst.

Ms. Sandra I. Sulsky and Ms. Rachel E. Williams, Thesis Associates, Department of Biostatistics and Epidemiology, University of Massachusetts Amherst.

Mr. Paul J. Amorso, MD, Ms. Michelle Yore, and Dr. Charles Peck, Us Army Research Institute for Environmental Medicine, Natick, MA

Mr. Bryan Heiderscheit, Mr. Gregory Kline, Mr. Joseph Hamil, Wepartment of Exercise Science, University of Massachusetts Amherst.

CHAPTER I

INTRODUCTION

Injury is defined as "harm or hurt; a wound or maim; usually applied to damage inflicted to the body by an external force" (1). It is projected to become one of the leading causes of disability and premature death in the developing world (2) and is currently the fourth leading cause of death in Americans (3). Among Americans under age forty-four, injury is the number one cause of death (3). This increasing trend in morbidity and mortality due to injury makes it an important aspect of public health that deserves increased attention, including epidemiological study.

Musculoskeletal injuries, or injuries "pertaining to or comprising the skeleton and the muscles, as musculoskeletal system" (1), are one of the most prevalent injuries that occur as a result of rigorous physical activity (4). Rigorous physical activity is typical of training and occupations in the Army where the prevalence of injury, and musculoskeletal injury in particular, is concordantly high (3,4). Among musculoskeletal injuries in the Army, knee injury is predominant probably due to the mechanically stressful nature of many types of Army jobs (5) and is especially important because it often leads to disability (6).

Disability, on the other hand, is defined as the condition in which one is "deprived of mental or physical ability" (7). Disability in the Army, however, is simply the inability of an enlistee to perform his or her occupational duty (8). Although there have been modest reductions in the number of occupational injuries and illnesses, disability continues to be

one of the leading causes of lost work days (5). Besides lost work days for the disabled, disability also leads to lost time and efficiency for the employer and economic costs of treating disability (5). Thus disability, too, is an important public health issue that is worthy of study.

Injuries related to the knee that lead to disability commonly result from impairment of the femur, impairment of the tibia and fibula, and knee impairments. Problems with flexion and dislocation of the knee also lead to disability fairly often. Some injuries that would not necessarily lead to disability among civilians would do so by the definition of disability in the Army (the inability to perform one's duty). These include strains, sprains, tendinitis and shin splints. Arthritic knee injuries such as chondromalacia and osteoarthritis may or may not lead to disability. These tend to be chronic and debilitating where one may be ambulatory, as opposed to disabling, in which one is typically unable to walk without physical or mechanical assistance. In the Army, most of these would be classified as disabling depending on the job of the individual. Similarly, classification of non-disabling injuries that occur in the Army would also be dependent on job type of the individual .

As suggested by research, risk factors for knee injury include occupation type, demographic variables, history of injury, adherence to safety regulations, environmental factors and congenital factors. However, relatively little is known about how these risk factors may be linked to specific types of knee injury. The ability to identify the risk factors that are associated with specific subtypes of knee injury would provide the basis upon which preventive measures aimed at decreasing disability could be made. This would

be important since knee disability is associated with a range of costs: medical dollar costs, loss of training and occupational time, loss of occupation all together and socioeconomic burden to the disabled. The fiscal impact of physical disability estimated by the US Army for 1994 alone was $500 million (5). Finding risk factors associated with particular knee injury subtypes would provide points of intervention. Thus, preventive measures that address the risk factor in question could be implemented and thereby prevent disability in the first place.

Despite these known social and economic burdens associated with disabling knee injury in the Army, there have been few efforts to reduce disability due to knee injury in the US Army. Even the only existing classification scheme for disabling knee injury is based on a non-specific coding system created mainly for the purpose of determining compensation levels. Little information on the different types of knee injuries is available due to their complex nature and the use of non-specific coding systems. The ability to classify knee injuries by specific types and subtypes would help form discrete groupings that would serve to minimize misclassification for future etiologic research.

Several studies on occupational injury and disability have found a limited amount of non-specific information on knee injury and disability in general and in the US Army (3,4,5,6) . However, none of the studies attempted to identify a specific classification system for disabling knee injury that would be useful in etiologic research. Furthermore, the injury outcomes used in each of these studies was very non-specific.

The current study was initiated to identify a practical method of classifying knee injury to improve the detection of risk factor-outcome associations in etiologic research for disabling knee injury by illustrating the usefulness of using a classification system that provide a specific injury outcome. Specifically, the objectives for this study were as follows:

- to identify and compare the most prevalent categories of injury within different systems of classification for disabling knee injury in a subset of the US Army population
- to further compare these systems of classifying disabling knee injury at a more quantitative level with respect to their usefulness in etiologic research

CHAPTER II

REVIEW OF LITERATURE

A number of studies have been conducted on knee injuries in occupational settings, and in military or Army settings in particular (3,4,5,6,9,10,11).

A cohort study conducted at a military base in Alaska in 1993 investigated the incidence and types of injuries occurring in a sample of male infantry soldiers (3). The association of risk factors such as physical fitness and age with musculoskeletal injuries was also examined. Types of injuries most commonly reported were musculoskeletal pain, strains, sprains, and cold-related injuries. Injury was divided into musculoskeletal and all other types (including cold-related injuries, contusions, blisters and abrasions/lacerations) for analysis. A trend of higher proportion of injury among lower age categories (the middle age category being 20-24 years) was found, with higher injury occurring among those subjects who were less physically active (in terms of aerobic and muscle strength fitness). There was a discussion of how the age trend may be explained by more sedentary occupations among older men who tend to have higher ranks.

In another study conducted in the military, a retrospective case-control investigation of injury during basic military training was conducted at the Recruit Training Unit, Royal Australian Air Force Base Edinburgh, South Australia (9). This study found that some of the risk factors for injury during basic military training included being female, having body mass index greater than 26.9 kg per meter squared, undergoing winter

training, having a history of lower limb injury and having lower limb deformity. No significant associations were found with other potential risk factors such as age, height, weight and smoking. Categories of injury included stress fractures, "shin splints", achilles tendinitis, plantar fasciitis, blisters, retropatellar syndrome/ chrondromalacia patella and anterior compartment syndrome.

A study of the risk factors for injury during basic training in the Army was conducted at a US Army base, and showed that the most common injuries were muscle strains, sprains and overuse knee conditions (4). Risk factors identified included older age, smoking, previous injury, low levels of previous occupational or physical activity, low frequency of running prior to entry into the Army and low physical fitness on entry. Some of these findings conflict with the study by Ross and Woodward (9), but the differences may be attributed to differences in methodologies and definitions of risk factors as well as injury outcomes. For instance, in the Jones study (4), the risk factor, physical training, was measured in terms of physical fitness and physical training, the parameters being height, weight, girth of neck, girth of waist, body mass index, muscle strength and flexibility, 2-mile run times and daily calisthenics, drills, stretches and running. They defined cases of injury as subjects having received treatment for one or more lower extremity musculoskeletal injuries. On the other hand, in the previous study (9), risk factors were measured in terms of degree of activity, season of training (winter versus other), body mass index and history of lower limb deformity and injury cases were defined by subjects who had been held back in a training course due to a

musculoskeletal injury and had lost five days of training. Such differences in definition of the exposure and outcome may have contributed to the dissimilar results.

Jensen et al (10) conducted a review of the literature on the risk of knee disorders related to kneeling or squatting work and heavy physical work in an occupational setting. Subjects whose jobs required kneeling or squatting work had significantly higher prevalence of knee osteoarthritis and kneeling only was seen to have an association with bursitis. Other types of knee injury such as chondromalacia and meniscal lesions were not significantly associated to occupational exposure.

One study (5) specifically investigated disability due to musculoskeletal injuries in the US Army using the Army's Physical Disability Agency database. The investigators found that back-related disorders represented the most prevalent sources of disability, that risk of disability was related to job type, that women experienced higher risk of disability due to musculoskeletal injuries as well as injuries overall and that specific jobs were associated with this increased risk among women. A descriptive analysis of the codes from the Veterans' Administration Service Related Disability (VASRD) diagnostic system revealed that knee impairment was among the top five diagnoses, accounting for about 6% of the top twenty disabilities. The knees and ankles were the most common site of injury among working infantry soldiers.

Among other studies investigating disabling knee injury in the Army with emphasis on gender is the one currently underway at the University of Massachusetts (11).

It is an on-going study which will examine the risk factors for occupational disability resulting from knee injuries in the US Army with particular emphasis on differences in gender-specific risk factors for disabling knee injury. This is one of the first epidemiological studies to utilize the Total Army Injury and Health Outcomes Database (TAIHOD), a large, annually updated relational database developed at the US Army Research Institute of Environmental Medicine (Natick, Massachusetts) which links demographic, occupational, hospitalization, disability, fatality and other data sources on all active duty personnel between January 1, 1979 and December 31, 1994.

CHAPTER III

METHODS

A. Sample Selection

The current study was an extension of a large ongoing case-control study conducted by Sulsky at the University of Massachusetts Amherst (11). The study base was the population of men and women in the Total Army Injury and Health Outcomes Database (TAIHOD), a large, comprehensive database maintained by the Military Performance Division of the United States Research Institute of Environmental Medicine (Natick, Massachusetts). The TAIHOD includes about 2.5 million current and former active duty personnel , 11.8% of whom are women. This database consists of five units: the Individual Patient Data System, the Army Safety Management Information System, the Army Disability Data, the Army Casualty Information Processing System and a Health Risk Appraisal unit.

In the Sulsky study, cases were selected from the Army Disability Database and controls were identified from the Personnel Database. Cases were defined as individuals awarded disability between 1980 and 1994 and given one of eleven primary or secondary disability codes related to impairments of the knee. These eleven codes were selected in consultation with Dr. Paul J. Amoroso, Project Director, TAIHOD. Cases of disability were selected over cases of injury since the former were easily identifiable and would have occurred only once per case. Further, reduction of disability has become important to

military and civilian populations and more information is needed on the determinants of disability. There were 8728 knee-related disability cases that occurred in men and 860 in women. Sulsky used all 9588 subjects to create a study data library with one and a half controls each for men and six controls each for women. The controls were soldiers without knee-related disability as of the time the relevant case received disability determination and were selected from the personnel database and matched to the cases on gender. Their year of departure from the Army was matched to the case's year of disability diagnosis. Subjects with missing information on gender were not included in the study. From this data library, Sulsky selected a random sample of 1005 enlisted men and all 860 enlisted women with knee-related disability for a pilot study which investigated the relationship between demographic variables and risk factors for disabling knee injury. Three controls were randomly selected through simple random sampling by calendar year and gender in proportion to the number of cases per year. (Personal communication with Sandra Sulsky, October 20, 1997). Figure 3.1 is a schematic of the sample selection process.

The dataset from the pilot study was used for the current study, which was conducted in two parts. In part one of the study, four systems of classifying disabling knee injury were investigated and compared, first overall and then by strata of gender, race and age. In the second part of the study, these classification systems were further evaluated and compared with respect to their ability to improve the sensitivity with which risk factor variables could be linked to the top injury outcomes within each system of classification.

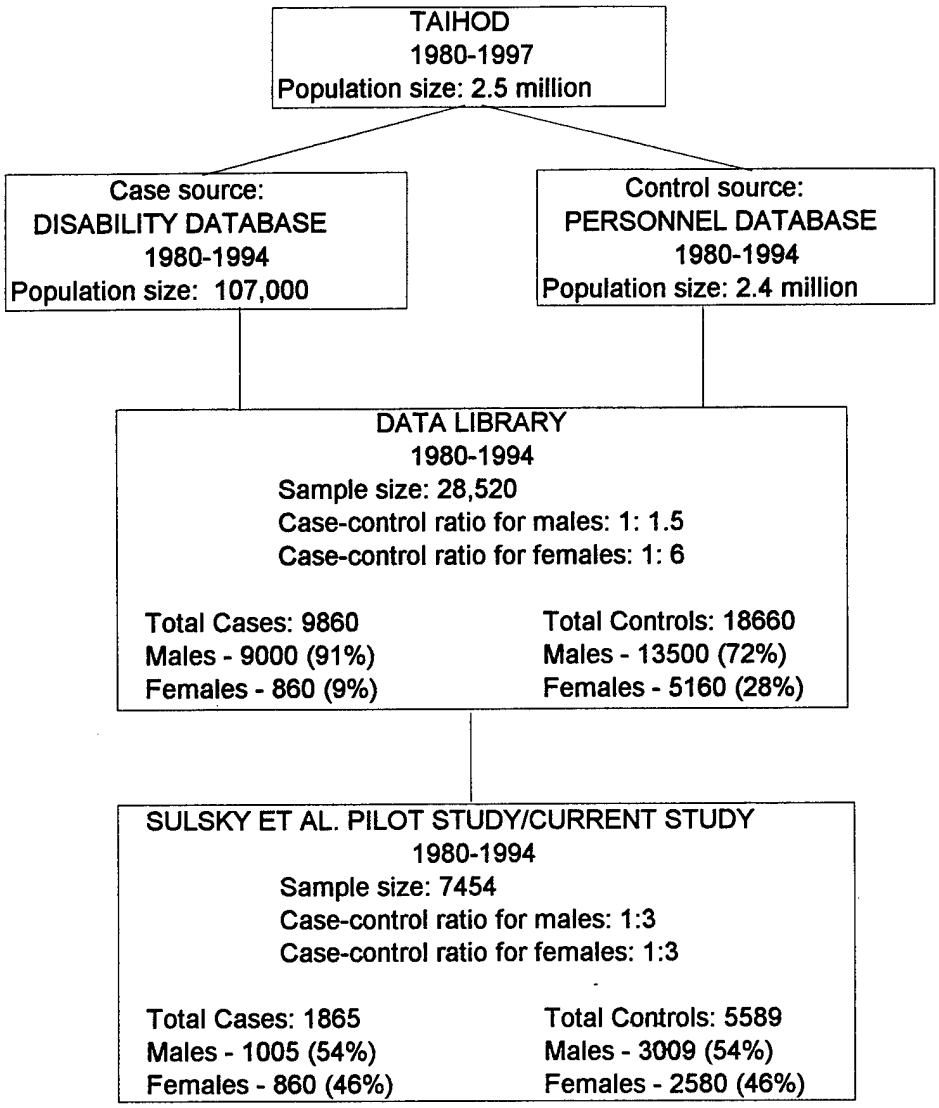


Figure 3.1. Data selection process and data profile

B. Study Variables

Ten principal variables were used in the study. The six outcome variables in this study were the Veteran's Administration Schedule for Rating Disability (VASRD) code, the International Classification of Disease-Ninth Revision (ICD-9) code, percent disability, nature of injury, requirement of surgery and affected tissue. The first three variables represented the first three systems of classification while the latter three constituted the fourth system of classification which was based on parameters used in the field of physical therapy. The exposure variable considered was the Primary Military Occupational Specialty (PMOS) which was the code assigned by the Army to designate each individual's primary occupation. The three variables that were considered as potential confounders or effect modifiers were gender, race and age. Data on VASRD and percent disability were extracted from the Disability database while data on ICD were extracted from the Hospital database and data on PMOS and demographics were extracted from the Personnel database. A description of these ten variables is presented in Table 3.1.

C. Part 1: Comparison of Classification Schemes Based on Frequency Distributions

The knee injury types were classified on the basis of four different systems, each based on one parameter with the exception of the fourth system which was based on three parameters. The parameters were VASRD, ICD-9, percentage of disability (percentage of function lost due to the injury) and the parameters used in physical therapy which consisted of nature of injury (traumatic versus repetitive), requirement of surgery

Table 3.1. Profile of study variables

Variable Name	Variable Type	Definition
VASRD	Outcome Variable	Congress established the department of the Veteran's Administration Schedule for Rating Disability (VASRD) for assignment of percentage rating of disability.A 4-digit diagnostic code, the VASRD code, was also assigned. For example, VASRD code 5257 designates "Other impairments of the knee".[1]
ICD	Outcome Variable	International Classification of Disease codes, revision 9, (ICD) were assigned to the subjects and entered in their Carded for Record Only (CRO) records. The CRO records are created by the medical evaluation board for those who are discharged for disability by the physical evaluation board. The CRO is then used by hospital for recording the resources expended and for tracking dispositions. Up to 8 ICD codes were assigned per injury, but only the first one, i.e. the primary diagnosis, was used in this study. [2]
Nature of Injury	Outcome Variable	Conventional parameter of disease classification in medicine/rehabilitation. Categories are based on type of assault:traumatic versus repetitive. Categories are not totally mutually exclusive since an injury may initially be traumatic, but become repetitive and vice versa. [3]
Require-ment of Surgery	Outcome Variable	Conventional parameter of disease classification in medicine/rehabilitation. Categories are based on requirement of surgery. Injuries classified as non-surgical may occasionally require surgery depending on severity. [3]
Affected Tissue	Outcome Variable	Conventional parameter of disease classification in medicine/rehabilitation. Categories are based on type of tissue affected. Combinations of bone,ligament, muscle, tendon or cartilage may exist. [3]
Percent Disability	Outcome Variable	A percentage rating of disability is assigned by the department of Veteran's Administration Schedule for Rating of Disability (VASRD) and represents average loss in earning capacity resulting from service acquired or service aggravated injury. Different criteria are applied to each injury type in determining the percent disability. For instance, for VASRD code 5257 ("Other knee impairments"): 30% - for use of knee brace for functional purpose 20% - for use of knee brace for protective purpose

Continued, next page

Table 3.1. continued

Variable Name	Variable Type	Definition
		10% - for lateral instability of knee that has failed to improve with physical therapy When injury that causes unfitness is lower than the minimum rating, a disability rating of 0% is assigned. Only overall percent rating was used in the study. [1]
MOS	Exposure Variable	Military Occupation Specialty (MOS) is the variable that describes the occupation of the subject. Each subject is assigned a primary MOS (PMOS) for which he or she is trained and a duty MOS(DMOS) which he or she actually performs.
Gender	Potential Confounder or Effect Modifier	Gender of subject was obtained from the personnel file and was one of the required variables during sample selection, ie., subjects with missing information for gender were not selected.
Race	Potential Confounder or Effect Modifier	Race of the subject was obtained from the personnel file. Race categories used were white, black, other/unknown. The other' portion of the latter includes Asians, Native Americans and Hispanics. The 'unknown' portion consists of only 5 subjects.
Age	Potential Confounder or Effect Modifier	Age was calculated by subtracting the date of birth, obtained from personnel files, from the date of discharge, obtained from the disability files. Ages ranged from 17 years to 54 years and were grouped according to quintiles of age distribution in the pilot study.

Sources:
[1] Army Regulation 635-40: Personnel Separations. Physical Evaluation for Retention, Retirement or Separation. Department of the Army. Washington DC. 1990
[2] Personal communication with Dr. Paul Amoroso, Project Director, TAIHOD, US Army Research Institute for Environmental Health.
[3] Personal communication with Bryan Heiderscheit (MSPT), Department of Exercise Science, University of Massachusettts Amherst.

(surgical versus non-surgical) and tissue type involved (bone versus ligament versus tendon versus muscle versus cartilage versus various combinations of the five tissue types).

Univariate and stratified analyses were performed for VASRD, ICD-9 and percent disability. For each parameter, the overall frequency distribution was first generated. Since the demographic variables had been identified as effect modifiers by Sulsky (11), the frequency of injury codes was generated separately for men and women, for each of the race categories, and for each of the age categories. A different approach was used in investigating the fourth system of classification which is elaborated upon in sub-section 4. All analyses in this section were done using SAS (13).

1. Classification by VASRD

VASRD codes, as described in Table 3.1, were four digit disability codes created by the Department of Veteran's Affairs and assigned to cases of disabling injury by the physical evaluation board of the Army. Subjects were assigned either a primary VASRD alone for the most serious injury or both a primary and a secondary VASRD in cases where there was a significant secondary condition (Electronic communication with Dr. Charles Peck, Retired Surgeon, US Army). Over 99% of the cases were assigned a VASRD code for the primary disability (VASRD1) and about 74% of these individuals were also assigned a VASRD code for secondary disability (VASRD2). Since the numbers of cases within categories of VASRD2 were too small for conducting meaningful analyses,

VASRD1 and VASRD2 were combined for analysis in the following manner. Cases having either VASRD1 or VASRD2 that was one of the eleven knee-related VASRD (as defined by Dr. Paul Amoroso during the sample selection process) were selected into a single dataset so that records for all 1865 cases and their first knee-related VASRD were present. This dataset was used for subsequent analyses.

2. Classification by ICD-9

The ICD-9 coding assigned to knee injuries that led to disability was considered as a second parameter for classifying disabling knee injuries. This was selected to serve as a more standard, internationally used method for classifying injury. Although each individual may have been assigned up to eight different ICD-9 codes for subsidiary diagnoses, only the primary ICD code was taken into consideration with the assumption that the primary diagnosis would be knee-related since the sample selection for the pilot study was done based on primary or secondary knee-related disability. Although one would not expect the primary diagnosis assigned to correspond to the VASRD code in every case, the primary ICD assigned to the ten most frequently occurring VASRD were found to be highly associated with knee-injury. For those cases whose knee-related injury was represented by the secondary VASRD, the primary ICD code would be less likely to be knee-related. However, this happened for only 21% of these cases and was, therefore, not a serious problem. The ICD codes were truncated from four or five digits to the first three digits to group highly-related types of injury and for ease of analysis. ICD categories selected for analyses were the top ten 3-digit primary ICD-9 codes assigned to the 1865 cases. Before

attempting to investigate classification of knee injury by ICD, however, a cross tabulation of the top ten ICD codes by the top five VASRD codes was constructed to investigate whether conceivable similarities between the two classification schemes existed. The percentage of overlap was found. Only the top five VASRD were used, rather than top ten, to maintain sample size.

3. Classification by Percent Disability

The parameter of percent disability attributed to each knee injury was considered a severity measure for disability and was, therefore, used as the third method of grouping disabling knee injuries. Percent disability, as described in Table 3.1, was also assigned by the Veteran's Administration System for Rating Disability and was based on different criteria for each type of disability. Here, too, a cross-tabulation of top ten ICD by percent disability was first performed to investigate any similarities between the methods of grouping by ICD and by percent disability. Deciles of percent disability that were greater than fifty were collapsed into one category due to sparse numbers among the categories of higher percent disability.

4. Classification by Physical Therapy Parameters

The fourth and final method of grouping disabling knee injuries was by parameters of evaluation used in the field of physical therapy. The three diagnostic parameters included nature of injury, requirement of surgery and type of tissue affected (13). These

were chosen in consultation with Bryan Heiderscheit (MSPT), Dr. Joseph Hamil (PhD Biomechanics) and Dr. Gregory Kline (PhD Exercise Physiology) from the Department of Exercise Science at the School of Public Health and Health Sciences, University of Massachusetts Amherst. Physical therapists categorize injury as 'traumatic' or 'repetitive' based on the mode of assault. In traumatic injuries, the "hit" occurs at one point in time, whereas multiple "hits" are responsible for repetitive injuries. Some injuries, however, may have been initiated by a traumatic event and worsened over time due to repeated stress. At the time of diagnosis, such an injury would then be classified as 'repetitive'. Therefore, this parameter of classification may not necessarily produce discrete, mutually exclusive categories. Once divided into traumatic or repetitive categories, injuries are further classified into those requiring surgery and those that do not. Again, there are some types of injury that typically do not require surgery, but do so under extreme circumstances. The third and final level of classifying knee injury would be by the type of tissue affected. The five types of tissue typically considered are bone, muscle, ligament (which connects muscle to bone), tendon (which connects muscle to muscle) and cartilage, or varying combinations of the five tissue types.

The primary ICD-9 codes were used for classifying disabling knee injuries by physical therapy parameters. Injuries classified by VASRD or percent disability could not be used since these were too broadly defined. In attempting to group the ten most frequently occurring ICD codes by these three physical therapy parameters, the truncated three-digit ICD codes were too broad to classify by nature of injury, requirement of surgery and type of tissue affected. Therefore, full length ICD codes were used. The

subset of the top ten most frequently occurring 3-digit ICD codes was first obtained. Expanding the ten 3-digit codes in this subset to their full length resulted in a much larger subset of codes. Only those codes that occurred with a frequency of five or more were selected and grouped by the three physical therapy parameters. This resulted in the use of thirty-nine different full-length, i.e., four or five digit, ICD codes that represented a little over half the cases.

D. Part 2: Comparison of Classification Schemes Based on Risk Factor Associations

After comparisons were made based on frequency distributions, the four systems of classifying disabling knee injury were further compared on the basis of the strength of their association with four sets of predictor variables described below. The index of comparison used was odds ratios produced by multivariable logistic regression models. The odds ratios produced by models representing each system of classification were compared to those produced by a "crude" model that considered 'any injury' as the outcome. 'Any injury' included all categories of injury. The absolute difference between the two odds ratios was assessed as a measure of the potential improvement in sensitivity with which an etiologic association could be established by using the outcome specified by the classification system concerned as opposed to using the outcome 'any injury'.

There were four different sets of predictor variables.

The first set consisted of the demographic variables alone: gender, race and quintiles of age. This served to investigate differences in odds ratios when considering only the demographic variables as predictors. Race was dichotomized as white and non-white. Blacks and person of other races were combined into one group based on the fact that their risks of discharge for disability were similar based on univarite logistic regression models (11). The referent group was white males in the 23-26 years age category since the strata of men, whites, and subjects aged 23-26 years were the most stable in terms of sample size.

The second and third sets of independent variables consisted of the demographic variables as well as terms for the interaction of gender with race and gender with age, respectively. These models were run to account for the interaction of gender with race and age seen in the study by Sulsky (11).

The fourth set of independent variables consisted of a primary military occupational specialty (PMOS) variable in addition to the demographic variables and was constructed to assess potential improvement in the ability to identify military occupation as a risk factor for disabling knee injury. The distribution of the top five PMOS codes that were represented by both men and women was first produced (Table 3.2). The PMOS Military Police (95B) was chosen based on having a stable population of both men and women. The same rationale was used in selecting Administrative Specialist (71L) as the referent group for PMOS.

Table 3.2. Distribution of the top five most frequently occurring primary military occupation specialties (PMOS) that occur among both men and women.

	PMOS	Definition	n	% Men	% Women
1	71L	Administative specialist	434	17.65	89.95
2	95B	Military police	263	49.43	50.57
3	94B	Food service specialist	248	41.53	58.47
4	88M	Motor transport operator	101	44.55	55.45
5	63B	Light-wheel vehicle mechanic	221	64.25	35.75

There were thirteen dependent variables. All thirteen dependent variables defined outcome and were dichotomized as case or control. The first included all cases and all controls and served as the 'any injury' outcome. The other twelve dependent variables were case-control status, where cases met a specific outcome definition and all controls were included. The twelve different conditions specified for cases were the top three VASRD categories of 5257, 5255 and 5262, the top four ICD-9 categories of 717, 718, 719 and 733, the top three percent disability categories of 10%, 20% and 30% and, lastly, the first two physical therapy parameters, traumatic and repetitive. These categories were chosen to represent each classification system based on the fact that they were highly representative of each system respectively.

Each of the six sets of independent variables was modelled against each of the thirteen outcome variables resulting in a total of 52 different models.

CHAPTER IV

RESULTS

A. Part 1: Comparison of Classification Schemes Based on Frequency Distributions

A frequency distribution of the 1865 cases by demographic variables (gender, race and age) revealed that a large majority of the cases were white and between ages 23 and 26 years (Table 4.1).

The top three categories of the VASRD, each representing at least 10% of the cases, together constituted 93% of all cases (Table 4.2). Clearly, more than half of the cases were afflicted with 'Impairments of knee other than ankylosis' (5257), a broad, inclusive category that revealed little information regarding the impairment. The second and third highest VASRD codes, 'Impairment of femur' (5255) and 'Impairment of tibia and fibula' (5262) were also somewhat inclusive revealing little information other than their relation to the bones of the lower limbs.

Stratified analysis by gender showed minor differences between men and women. The top three VASRD codes, 'Impairments of knee other than ankylosis' (5257), 'Impairment of femur' (5255) and 'Impairment of tibia and fibula' (5262), were found in both men and women, had similar distributions, and were each represented by at least 10% of the cases in both strata (Figure 4.1). The proportion of men and women with any VASRD varied by no more than 6% .

Table 4.1 . Overall demographic distribution of cases

Variable		n	%
Gender			
1	Male	1005	53.9
2	Female	860	46.1
3	Missing	0	0
	TOTAL	1865	100
Race			
1	White	1283	68.79
2	Black	450	24.13
3	Other	129	6.92
4	Missing	3	0.16
	TOTAL	1865	100.00
Age group			
1	17 to 20	290	15.55
2	21 to 22	311	16.68
3	23 to 26	491	26.33
4	27 to 30.35	283	15.17
5	30.36 to 54	337	18.07
6	Missing	153	8.20
	TOTAL	1865	100.00

Table 4.2 . Overall distribution of knee-related VASRD (VASRD1 and 2 combined)

	VASRD	Definition	n	% of total (N=1865)
1	5257	Impairments of knee other than ankylosis	1187	63.65
2	5255	Impairment of femur	318	17.05
3	5262	Impairment of tibia and fibula	238	12.76
4	5259	Removal of semilunar cartilage	96	5.15
5	5258	Dislocation of semi lunar cartilage	12	0.64
6	5263	Genu recurvatum	6	0.32
7	5256	Ankylosis of knee	4	0.21
8	5161	Amputation of upper third of thigh	2	0.11
9	5160	Disarticulation of thigh	1	0.05
10	5055	Knee replacment	1	0.05
TOTAL			**1865**	**100.00**

For instance, the proportion of men with 'Impairment of knee other than ankylosis' (5257) was 66.17% whereas this number was 60.7% for women, a between-stratum difference of about 5.5%. The rest of the knee injury categories represented by men were also represented by women in similar proportions. However, an additional four categories of knee injury that were not present among men occurred among women. The total proportion of women represented by these four categories, however, was very small (1.87%). At a bivariate level of analysis, gender did not appear to be a substantial determinant of knee injury outcome defined by VASRD codes. (Table A 4.1).

Similarly, the distribution of VASRD by race and age did not seem to substantially contribute to the knee injury outcome of a case as defined by VASRD codes. The top three VASRD codes were, once again, 'Impairments of knee other than ankylosis' (5257), 'Impairment of femur' (5255) and 'Impairment of tibia and fibula' (5262) (Figures 4.2 and 4.3). As with gender, the rest of the VASRD codes were similar between the strata, but for a few codes that were not represented by the three race-groups and the five age-groups. Once again, these codes constituted very few subjects within each stratum (less than 1%). (Tables A4.2 and A4.3).

The cross tabulation between the top five VASRD and the top ten ICD showed that although there were one or two ICD codes that corresponded with each VASRD relatively closely, the percentage of overlap was fairly low, ranging from 0% to 55%. One exception was the overlap between 'Impairment of femur' (VASRD 5255) and 'Other

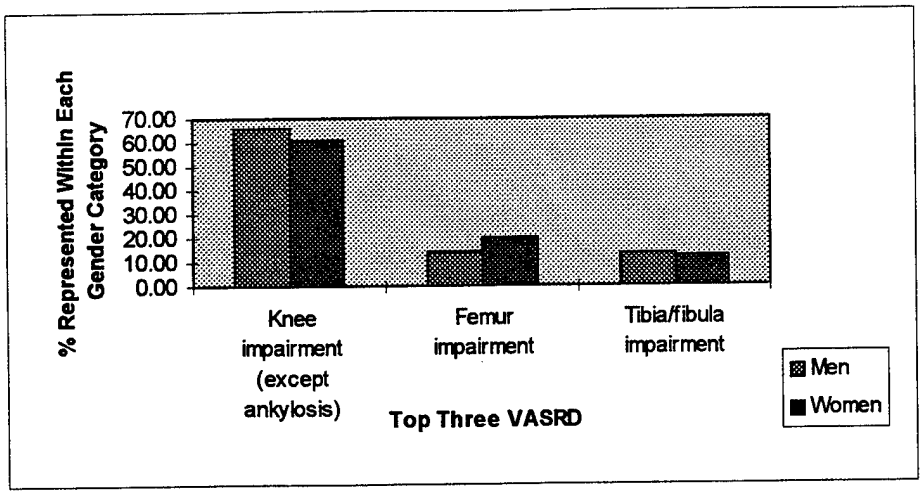


Figure 4.1. Distribution of VASRD codes by gender.

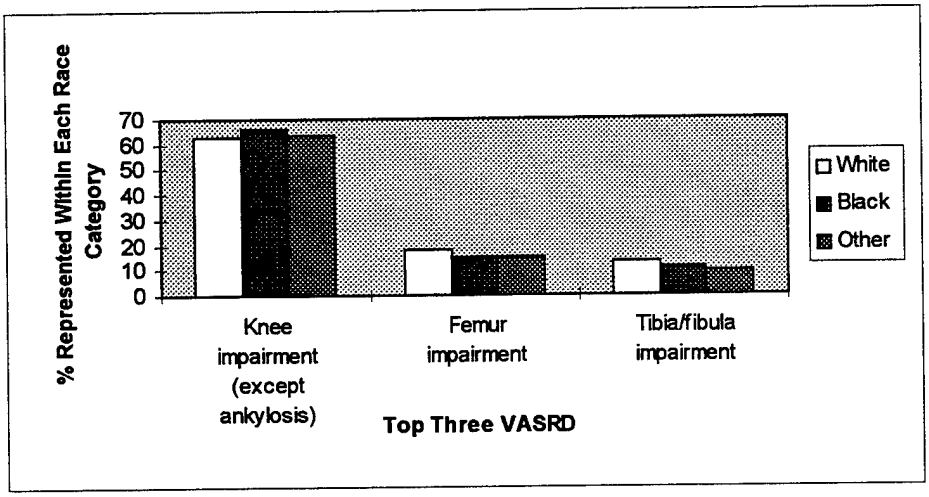


Figure 4.2. Distribution of VASRD codes by race.

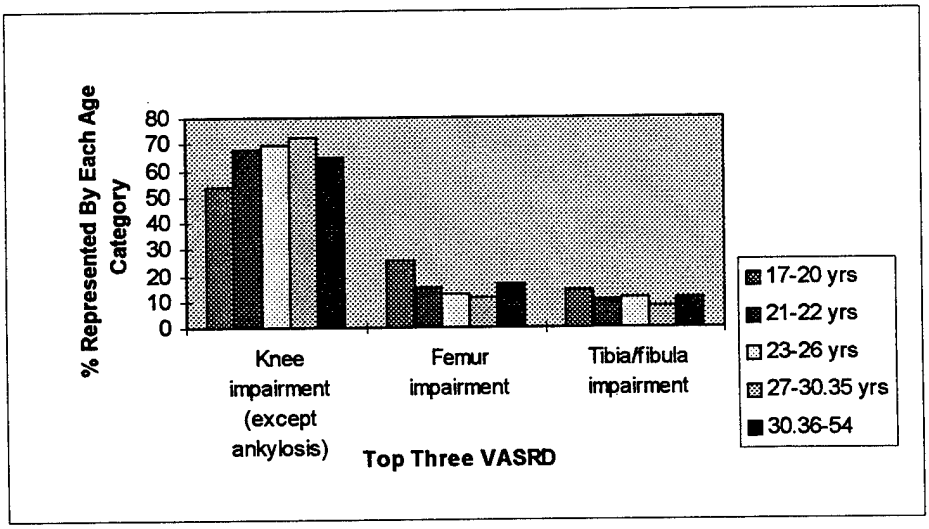


Figure 4.3. Distribution of VASRD codes by age.

bone/cartilage disorders: osteoporosis, pathological fracture' (ICD 733), which was 67% (Table 4.3). These results indicate that, although most VASRD codes have a few ICD codes that together constitute almost all of that VASRD, the two types of classification are considerably different and cannot be used interchangeably. This motivated the generation of the next set of results.

The cases that corresponded with the top ten most frequently occurring ICD codes represented 78.36% of all cases that had information on ICD and therefore served as a fairly representative sample. About 80% of the cases had information on ICD. As shown in Table 4.4, the overall distribution of the top ten ICD codes is concentrated in the top two, 'Ankylosis and joint derangement of knee' (718) and 'Internal derangement of knee' (717), which together represent nearly 50% of the cases. As in the case of top VASRD codes, these ICD codes are both inclusive and not very specific.

Results of the stratified analysis of ICD by gender, race and age showed marginally higher differences than those produced by stratified analysis of VASRD. This indicated that classification of knee injury by ICD was slightly more susceptible to demographic differences.

Regarding gender, the proportion of cases represented among the top ten ICD was 63% for both men and women. The top four ICD codes were the same ('Ankylosis and joint derangement of knee' (718) and 'Internal derangement of knee' (717), 'Other

Table 4.3. Percent overlap of top ten groupings by ICD codes and top five groupings by VASRD codes

VASRD	Definition	ICD	n	%overlap
5257 (N=794)	Impairments of knee other than ankylosis			
		718	262	33.0
		717	257	32.4
		719	127	16.0
		715	40	5.0
		844	36	4.5
		716	25	3.1
		728	18	2.3
		733	17	2.1
		823	5	0.6
		821	7	0.9
			794	100.0
5255 (N=167)	Impairment of femur			
		733	112	67.1
		719	17	10.2
		718	10	6.0
		715	4	2.4
		716	2	1.2
		728	2	1.2
		823	2	1.2
		844	1	0.6
		717	0	0.0
		821	17	10.2
			167	100.0
5262 (N=134)	Impairment of tibia and fibula			
		733	75	56.0
		823	23	17.2
		821	5	3.7
		718	10	7.5
		719	10	7.5
		716	4	3.0
		728	4	3.0
		717	2	1.5
		844	1	0.7
		715	0	0.0
			134	100.0

Continued, next page

Table 4.3. continued

5259 (N=96)	Removal of semilunar cartilage			
		717	2	40.0
		719	2	40.0
		718	1	20.0
		715	0	0.0
		716	0	0.0
		728	0	0.0
		733	0	0.0
		823	0	0.0
		824	0	0.0
		844	0	0.0
			5	100.0
5258 (N=12)	Dislocation of semilunar cartilage			
		717	13	35.1
		718	8	21.6
		719	8	21.6
		715	4	10.8
		733	2	5.4
		716	1	2.7
		728	1	2.7
		823	0	0.0
		824	0	0.0
		844	0	0.0
			37	100.0

Table 4.4. Overall distribution of the ten most frequently occurring ICD-9 codes

	ICD-9	Definition	n	% of top ten (N=1166)	% of total with ICD (N=1488)	% of total (N=1865)
1	718	Ankylosis and joint derangement of knee	290	24.87	19.49	15.55
2	717	Internal derangement of knee: degeneration, rupture, old tear, old cartilage, old meniscus	284	24.36	19.09	15.23
3	733	Other bone/cartilage disorders: osteoporosis, pathological fracture.	204	17.50	13.71	10.94
4	719	Other unspecified joint disorders	182	15.61	12.23	9.76
5	715	Osteoarthritis, polyarthritis,	52	4.46	3.49	2.79
6	844	Sprains/strains of knee/leg	37	3.17	2.49	1.98
7	716	Other unspecified arthropathies	33	2.83	2.22	1.77
8	823	Fracture of tibia and fibula	29	2.49	1.95	1.55
9	824	Fracture of ankle	29	2.49	1.95	1.55
10	728	Disorders of muscle, ligament, fascia	26	2.23	1.75	1.39
TOTAL			**1166**	**100.00**	**78.36**	**62.52**

unspecified joint disorders' (719) and 'Other bone/cartilage disorders'(733)) for both groups, but were ranked differently (Figure 4.4). Each ICD was represented by similar proportions of men and women (Tables A 4.4 and A4.5).

The differences seen in the result of stratified analysis of ICD by race were marginally higher than those seen with VASRD. For instance, the top three ICD were different between the three strata (Figure 4.5). While 'Other unspecified joint disorders' (719) ranked third among whites, 'Other bone/cartilage disorders' (733) was third among blacks and other races. The proportion of blacks with 'Other bone/cartilage disorders' (733) was also relatively higher among blacks compared to whites as was 'Osteoarthritis or polyarthritis' (715), both by 6%. Overall there were only slight differences in the ICD codes and their ranks between strata (Tables A 4.6-8).

Stratified analysis of ICD by age, once again, showed small differences (Figure 4. 6). The top five ICD codes were similar for all strata of age except for 'Sprain/strains of knee/leg' (844) which occurred only among those aged 17-20 years and those aged 21-22 years, and 'Disorders of muscle, ligament, fascia' (728) which occurred only among the age group of 23-26 years. The proportion of cases having 'Other bone/cartilage disorders' (733) was clearly highest in the 17-20 years age group and 'Internal derangement of knee' (717) was similarly highest in the 23-26 age group. (Table A 4.9). As with gender and race, age was not found to be a significant factor in knee injury outcomes as defined by ICD coding.

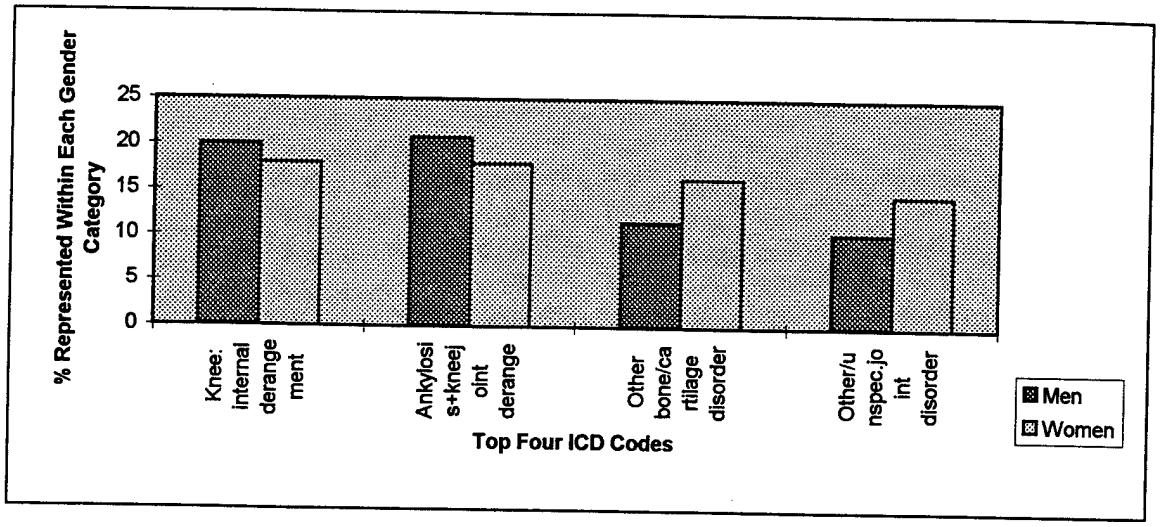


Figure 4.4. Distribution of ICD codes among cases by gender.

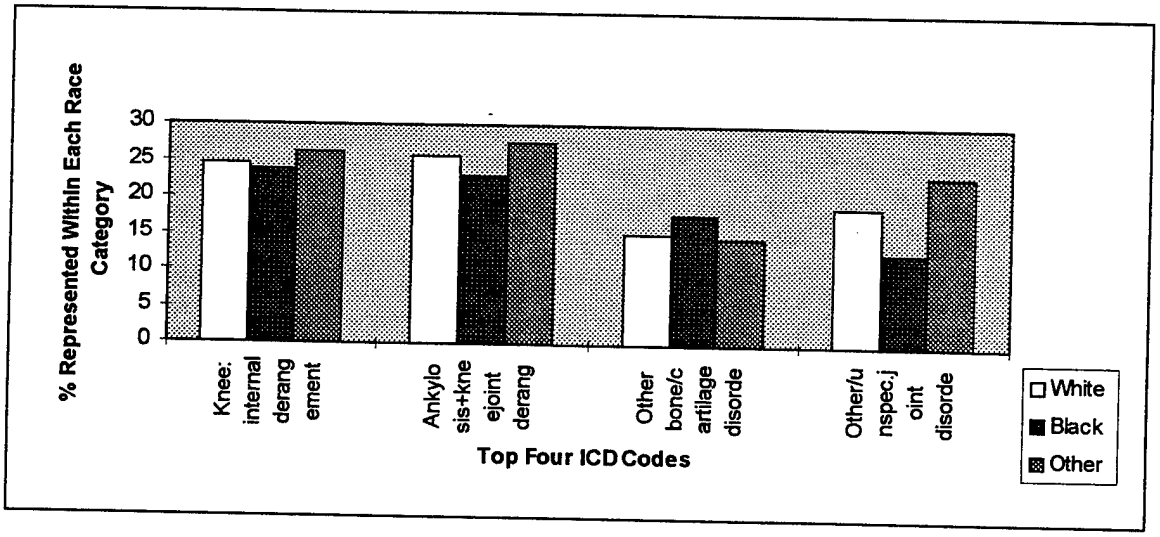


Figure 4.5. Distribution of ICD codes among cases by race.

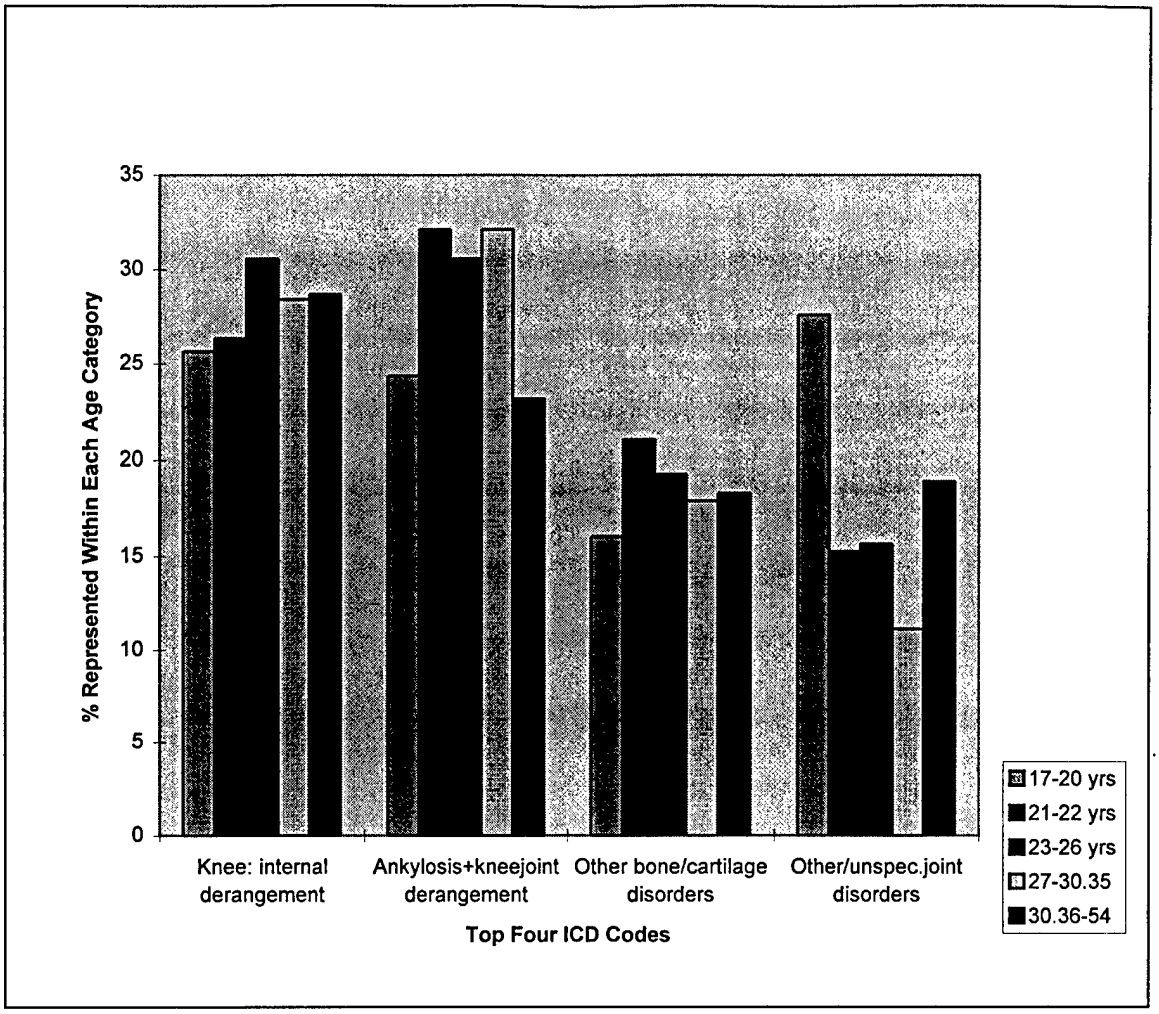


Figure 4.6. Distribution of ICD codes among cases by age.

The cross tabulation between ICD and percent disability did not show patterns that were clear enough to conclude that the two methods of classifying injury were similar (Table 4.5). This finding motivated the generation of the following results.

Percent disability information was available for about 68% of the cases (Table 4.6). The overall frequency distribution of percent disability indicated that a majority of the cases were either 30% disabled or 20% disabled. The next two highest categories of percent disability were 10% and 40%.

Stratified analysis of percent disability by gender showed that the highest category of percent disability remained 30% among both men and women and that the proportions of men and women within each stratum of percent disability did not show substantial variation (Figure 4.7). Higher percent disability (i.e., > 50%) seemed to occur more commonly among men than among women. Other differences due to gender were, once again, marginal. Stratified analysis by race also revealed little other than that the most commonly occurring level of percent disability varied from 20% to 30% (Figure 4.8). Unlike the overall distribution and distribution stratified by gender and race, stratified analysis by age showed that the most commonly occurring level of percent disability within strata of age was clearly 10% (Figure 4.9). This was explained by further stratification of the cases within the age categories by gender and race.

About 50% of the cases were classified by the physical therapy parameters of nature of injury, requirement of surgery and type of tissue affected. The results showed

Table 4.5. Percent overlap of top ten ICD codes and percent disability

% Disability	ICD	n	%overlap
0%	719	8	66.7
(N=12)	717	2	16.7
	718	2	16.7
	715	0	0.0
	844	0	0.0
	716	0	0.0
	728	0	0.0
	733	0	0.0
	823	0	0.0
	824	0	0.0
		12	100.0
10%	719	70	36.1
(N=194)	717	64	33.0
	718	30	15.5
	733	12	6.2
	715	8	4.1
	716	5	2.6
	728	3	1.5
	821	1	0.5
	824	1	0.5
	823	0	0.0
		194	100.0
20%	718	27	29.0
(N=93)	717	26	28.0
	719	16	17.2
	733	11	11.8
	715	7	7.5
	728	5	5.4
	823	1	1.1
	716	0	0.0
	821	0	0.0
	824	0	0.0
		93	100.0
30%	718	14	29.2
(N=48)	717	11	22.9
	733	9	18.8
	715	3	6.3
	719	3	6.3
	824	3	6.3
	728	2	4.2
	716	1	2.1
	821	1	2.1
	823	1	2.1
		48	100.0

Continued, next page

Table 4.5. continued

% Disability	ICD	n	%overlap
40%			
(N=16)	733	8	50.0
	718	2	12.5
	719	2	12.5
	823	2	12.5
	715	1	6.3
	717	1	6.3
	716	0	0.0
	728	0	0.0
	821	0	0.0
	824	0	0.0
		16	100.0
50%			
(N=1)	718	1	100.0
	715	0	0.0
	716	0	0.0
	717	0	0.0
	719	0	0.0
	728	0	0.0
	733	0	0.0
	821	0	0.0
	823	0	0.0
	824	0	0.0
		1	100.0
>50%			
(N=11)	733	6	54.5
	719	2	18.2
	821	2	18.2
	718	1	9.1
	715	0	0.0
	716	0	0.0
	717	0	0.0
	718	0	0.0
	728	0	0.0
	823	0	0.0
	824	0	0.0
		11	100.0

Table 4.6. Overall distribution of the percent disablity values attributed to all cases

	%disability	n	%	% of total
			(N=1272)	(N=1865)
1	0	78	6.13	4.18
2	10	223	17.53	11.96
3	20	322	25.31	17.27
4	30	355	27.91	19.03
5	40	132	10.38	7.08
6	50	33	2.59	1.77
7	60	79	6.21	4.24
8	70	14	1.10	0.75
9	80	18	1.42	0.97
10	90	7	0.55	0.38
11	100	11	0.86	0.59
TOTAL		1272	100.00	68.20

Note: Missing cases= 593 i.e. actual population=1865.

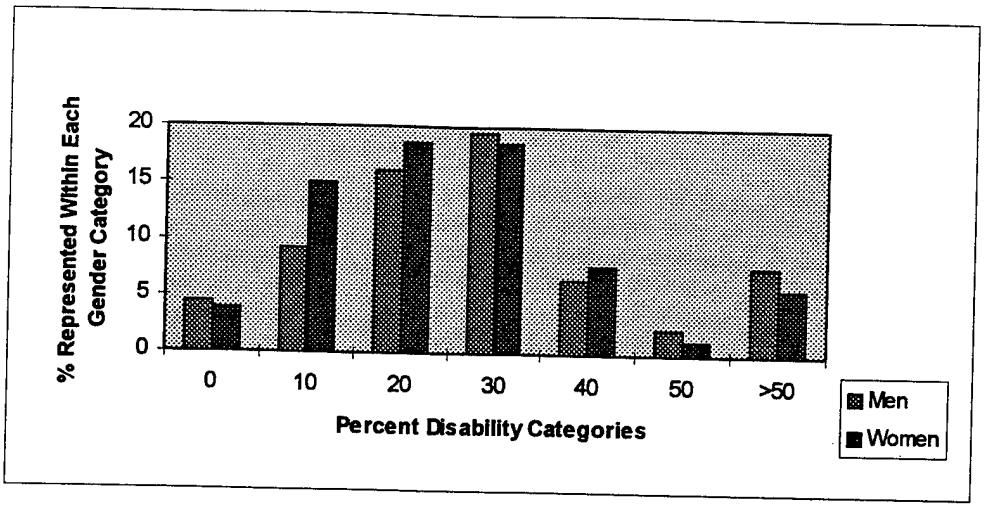


Figure 4.7. Distribution of percent disability by gender.

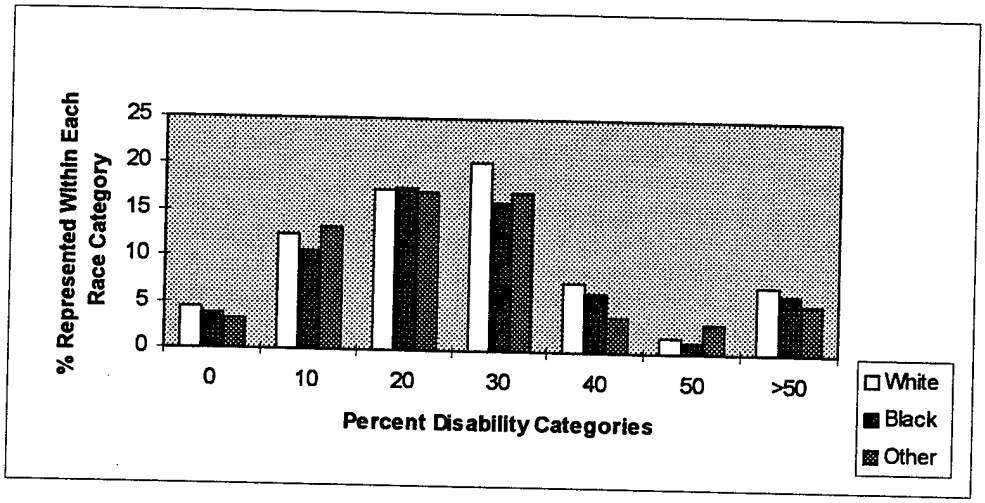


Figure 4.8. Distribution of percent disability by race.

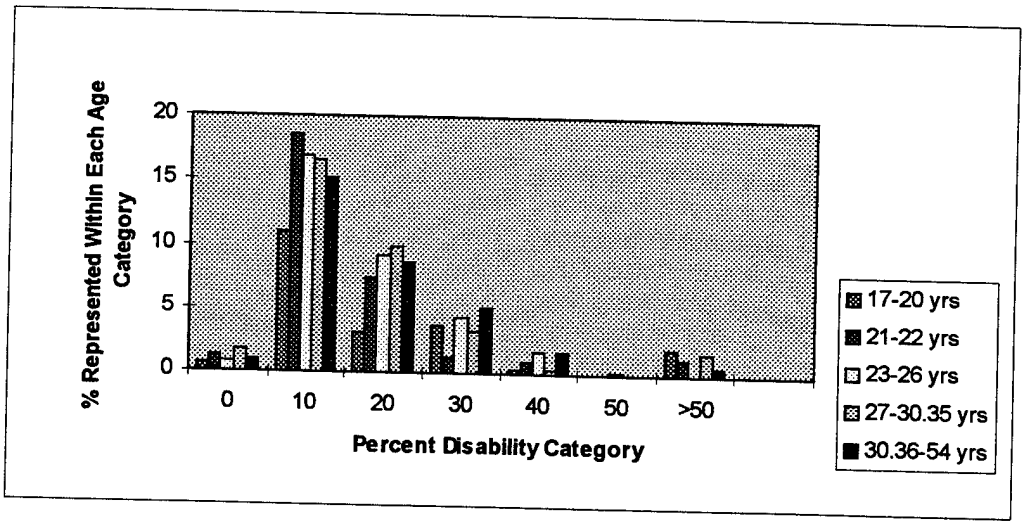
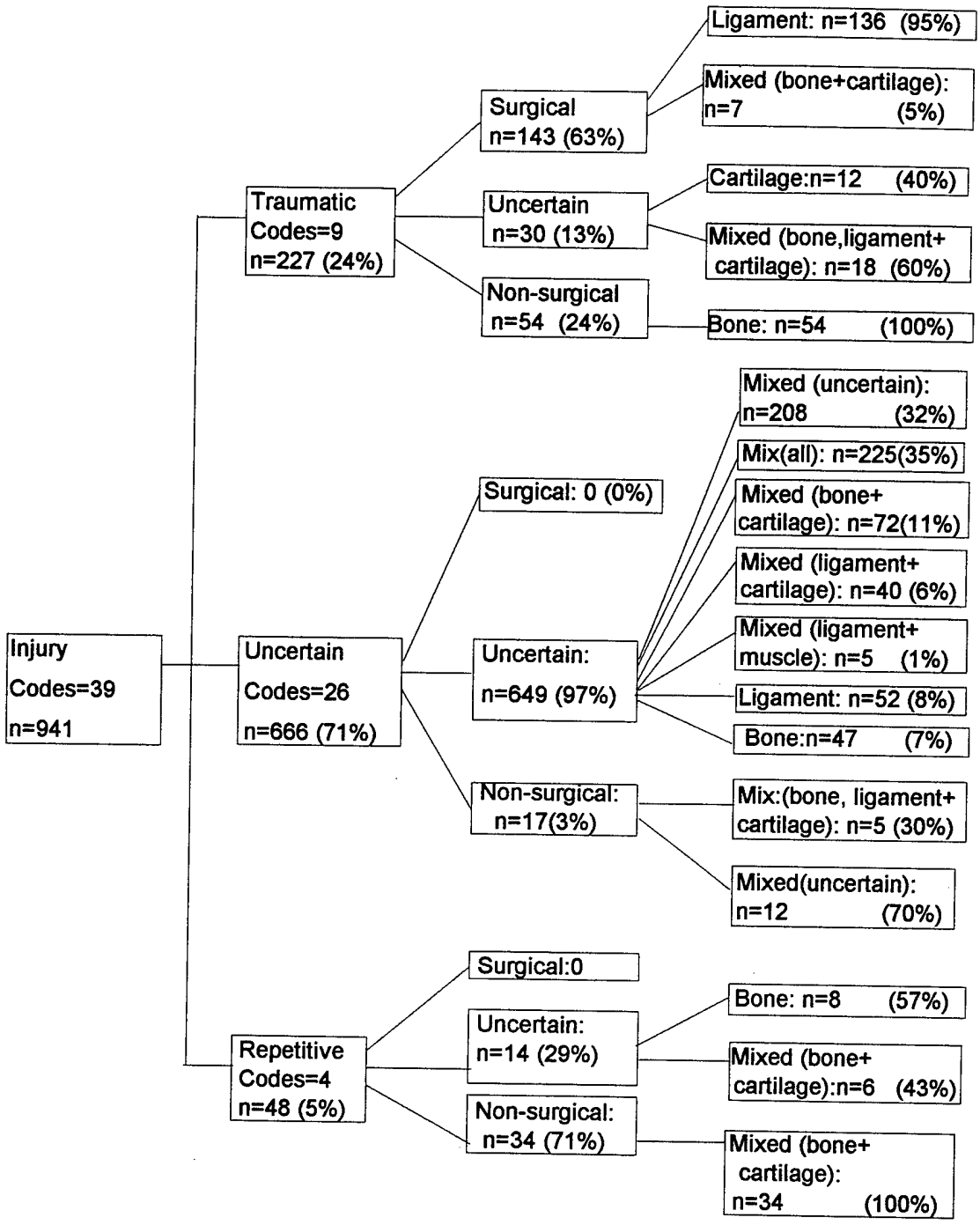


Figure 4.9. Distribution of percent disability by age.

that although such a system would carry considerable information about each injury, it may not be useful to pursue for using the current data set since a large majority of the cases were categorized as 'Uncertain'. As shown in Figure 4.10, 71% of the cases fell into the 'Uncertain' category at the 'Traumatic' versus 'Repetitive' level. Of these 'Uncertain' cases, 97% fell into the 'Uncertain' category with regard to requirement of surgery. In the 'Traumatic' and 'Repetitive' groups however, most cases were 'Surgical' and 'Non surgical' respectively as expected. At the third level, type of tissue affected, a considerable portion of the cases fell into 'Mixed' categories.

D. Part 2: Comparison of Classification Schemes Based on Risk Factor Associations

The first set of logistic regression models that contained the demographic variables as risk factors showed that classifying knee injury outcomes by specific parameters did affect the strength of association between these predictor variables and the injury outcomes (Table 4.7). This served as evidence for potential reduction in misclassification. Specifically, the odds ratios produced for the link between each predictor variable and each of the specific outcome variables changed considerably from the 'any injury' model in which the injury outcome was not classified by any specific parameter. Although the amount of heterogeneity in the odds ratio ranged from as little as a reduction by 6 % as seen in the association of being female and the risk of being disabled due to a 'repetitive' knee injury to as much as an increase by 69 % as seen in the association of being 21-22 years of age and the risk of being 30% disabled, nearly all odds ratios changed from their corresponding values in the "crude" model.



Note: Codes=Number of ICD groups within each category
n=Total number of cases within each category
Source: Bryan Heiderscheit (MSPT) and Saunders 1985

Figure 4.10. Distribution of top thirty-nine ICD codes and the corresponding cases by physical therapy parameters.

Table 4.7. Absolute changes in odds ratio estimators of associations between predictor variables and 'any injury' outcome versus specific injury outcomes: model using demographic variables as predictors.

		Female	Non White	17-20 years	21-22 years	23-26 years	27-30.35 years	30.36-54 years
Any injury		**0.96**	**1.73**	**1.3**	**1.23**	**1.00**	**0.96**	**1.11**
VASRD								
5257	Knee impairments other than ankylosis	1.01	1.69	1.68	1.26	1.00	0.92	1.196
5255	Impairment of femur	0.64	2.01	0.66	1.07	1.00	1.11	0.83
5262	Impairment of tibia and fibula	1.22	2.18	1.03	1.27	1.00	1.24	1.11
ICD								
717	Internal derangment of knee	1.06	1.81	1.62	1.32	1.00	1.01	1.38
718	Ankylosis and joint derangement of knee	1.17	1.88	1.7	1.08	1.00	0.89	1.72
719	Other unspecified joint disorders	0.7	1.66	1.61	1.03	1.00	1.02	1.29
733	Other bone/cartilage disorders	0.67	2.05	0.77	1.17	1.00	1.33	1.01
% disability								
	10	1.09	1.6	1.98	1.11	1.00	0.98	1.26
	20	1.02	1.49	3.79	1.51	1.00	0.9	1.19
	30	1.28	1.12	1.42	3.97	1.00	1.33	0.98
Physical therapy parameters								
	Traumatic	1.06	2.11	1.41	1.22	1.00	1.08	1.47
	Repetitive	0.95	0.91	2.65	1.62	1.00	0.46	0.77

Within each system of classification, the risk of one category of injury changed in one direction while that of other injury events changed in the opposite direction. For instance, using the VASRD system of classification showed that the risk of having 'Impairments of the knee other than ankylosis' (5257) and 'Impairments of tibia and fibula' (5262) increased for women as compared to men (change in OR from 0.96 to 1.01 and 1.22 respectively) while the risk of having 'Impairments of the femur' (5255) was reduced for females (change in OR from 0.96 to 0.64). Similarly, while being of a non-white race was protective, relative to the crude, with regard to 'Impairments of the knee other than ankylosis' (5257) compared to being white (change in OR from 1.73 to 1.69), non-whites appeared to be at higher risk of having 'Impairments of tibia and fibula' (5262) and 'Impairments of the femur' (5255) (change in OR from 1.73 to 2.01 and 2.18 respectively). Regarding age category as a risk factor, using the VASRD system indicated that being in the age range of 17-20 years was protective for the injuries coded by 5255 and 5262, but was associated with higher risk of 'Impairments of knee other than ankylosis' (5257).

Similar patterns of heterogeneity were also seen within the other three systems of classifying knee injury. Use of the ICD system of classification indicated increases in risk of being disabled due to 'Ankylosis and joint derangement of knee' (718) and 'Internal derangement of knee' (717) (change in OR from 0.96 to 1.17 and 1.06 respectively) and a marked decrease for 'Other unspecified joint disorders' (719) and 'Other bone/cartilage disorders'(733) (change in OR from 0.96 to 0.70 and 0.67 respectively) for women

compared to men. Specifying the injury outcomes using percent disability indicated an increased risk of being 20 or 30% disabled, but a decreased risk of being 10% disabled among non-whites compared to whites. Classification of disabling knee injuries by physical therapy parameters showed that while the risk associated with all demographic variables was increased for 'traumatic' injuries, it was decreased for 'repetitive' ones and vice versa (Table 4.7).

The results from the second set of models, i.e., those with the demographic variables that also accounted for interaction of gender with race and age, illustrated the usefulness of using specific rather than broad outcomes of disabling knee injury in revealing that interactions between the independent variables which could not be detected in the model using 'any injury' as the outcome.

In the set of models that accounted for interaction of gender with race (Table 4.8), using the VASRD system for specifying knee injury outcome revealed changes in odds ratios which indicated that using a specific injury outcome was explaining some of the interaction that was not explained when using the "crude" model. For instance, using white men as the referent group, the risk of 'any injury' for white women was 52% that of white men whereas that of 'Impairment of tibia/fibula' (5262) for white women was 99% that of white men. Classification of injury outcomes by ICD showed similar results in that effect modification of gender on race was influenced when considering specific outcomes of 'Other unspecified joint disorders' (719) and 'Other bone/cartilage disorders' (733). The usefulness of employing specific injury outcomes in etiologic research was, once

Table 4.8. Absolute changes in odds ratio estimators of associations between predictor variables and 'any injury' outcome versus specific injury outcomes: model using demographic variables and gender-race interaction terms as predictors.

	White Women	Non-white Men	Women
Any injury	**0.52**	**0.51**	**0.88**
VASRD			
5257 Knee impairments other than ankylosis	0.84	1.33	1.87
5255 Impairment of femur	0.54	1.46	1.4
5262 Impairment of tibia/fibula	0.99	1.60	3.38
ICD			
717 Internal derangement of knee	0.91	1.46	2.10
718 Ankylosis and joint derangement of knee	1.02	1.56	2.43
719 Other unspecified joint disorders	0.59	1.24	1.24
733 Other bone/cartilage disorders	0.54	1.36	1.55
% disability			
10	1.05	1.52	1.79
20	0.75	1.01	1.76
30	0.86	0.78	1.70
Physical therapy parameter			
Traumatic	0.97	1.83	2.41
Repetitive	0.52	0.51	0.88

again, illustrated by the heterogeneity in odds ratios produced by using percent disability and physical therapy parameters as outcomes compared to 'any injury' as the outcome (Table 4.8).

The results from the set of models that accounted for interaction between gender and age served to reinforce the findings stated above. Interaction that was apparent in the "crude" model was affected by the use of specific knee injury outcomes (Table 4.9). For instance, using 23-26 year old males as the referent group, the "crude" model showed that 17-20 year old males had a 60% higher risk of 'any injury' compared to 23-26 year old males. However, when 'Impairment of femur' (VASRD 5255) was used as the injury outcome, the risk increased by more than 200% compared to the referent group. Using other categories of VASRD or the outcomes coded as ICD 717, 718 and 719 produced similar heterogeneous odds ratios. Additionally, almost all of the results from the models using percent disability and physical therapy parameters as injury outcomes revealed changes in odds ratios compared to the "crude" model indicating that using a specific outcome in the model explained some of the interactions that existed between gender and age.

The set of models that considered military occupation as a risk factor for disabling knee injury was not robust enough to produce odds ratios that were justifiably interpretable. This happened due to the reduction in sample size that resulted from using a subset of the cases and controls (n=697) that had the PMOS Military Police (95B)

(n=263) which was selected as an occupational risk factor and the PMOS Administrative Specialist (71L) (n=434) which was selected as the referent category for occupation .

Table 4.9. Absolute changes in odds ratio estimators of associations between predictor variables and 'any injury' outcome versus specific injury outcomes: model using demographic variables and gender-age interaction terms as predictors.

	17-20		21-22		27-30.35		30.36-54	
	Men	Women	Men	Women	Men	Women	Men	Women
Any injury	**1.6**	**1.3**	**1.35**	**1.42**	**1.04**	**1.12**	**1.54**	**0.93**
VASRD								
5257 Knee impairments other than ankylosis	2.16	1.62	1.31	1.55	0.95	1.12	1.58	1.02
5255 Impairment of femur	0.71	0.44	1.06	0.77	1.03	0.84	1.01	0.48
5262 Impairment of tibia and fibula	1.24	1.85	1.86	1.69	1.57	2.00	2.14	0.98
ICD								
717 Internal derange-ment of knee	3.01	1.43	1.5	1.86	1.03	1.66	2.29	1.15
718 Ankylosis and joint derangement of knee	2.14	2.08	1.18	1.62	1.2	1.04	2.39	1.71
719 Other unspecified joint disorders	1.75	1.09	1.01	0.77	0.86	0.88	1.62	0.74
733 Other bone/cartilage disorders	0.82	0.73	1.55	0.89	2.05	0.94	1.66	0.62
% disability								
10	2.66	1.87	1.33	1.2	0.81	1.84	1.63	1.14
20	3.45	5.56	1.87	1.46	1.09	0.91	1.29	1.32
30	2.73	1.3	3.61	9.59	1.29	2.59	1.22	1.25
Physical therapy parameter								
Traumatic	1.87	1.37	1.22	1.71	1.15	1.36	2.03	1.25
Repetitive	high	1.97	2.28	3.13	1.68	0.48	1.09	1.67

CHAPTER V

DISCUSSION

The objectives of the study were to compare systems of classifying disabling knee injury and attempt to identify the one that would be most suitable for etiologic research.

From the findings of the first part of the study, it is evident that the use of VASRD, ICD-9, percent disability and physical therapy parameters represent distinct systems for classifying disabling knee injury. While categories created by VASRD coding appear to be rather non-specific and inclusive, those created by ICD-9 coding are only marginally more discriminating in terms of incorporating information on the details of the knee injury. The use of percent disability, too, involves the same problem of a lack of descriptive information. Additionally, although percent disability is indeed a viable method of subsetting disabling knee injury, in the current study, each value of percent disability is linked to a particular knee injury outcome designated by a VASRD code. Therefore, the use of percent disability as a parameter for classifying knee injury would be more useful if it was assigned without being intrinsically linked to other factors so that an overall comparison of percent disability would be reasonable. It was, perhaps, due to the simplistic nature of the bivariate analysis that none of the gender, race and age effects that were found in the Sulsky study (11) were detected at this level of the study.

The system of classification based on parameters used in physical therapy proved to be the most specific in terms of incorporating the most descriptive information

regarding the characteristics of the injury. Unfortunately the data in the current study was not specific enough to fully illustrate the usefulness of such a classification system and, instead, led to far too many 'Uncertain' and 'Mixed' categories. Had the disability data been more amenable to classification by such specific criteria, it is plausible that this system of classification may have been identified as the most useful for etiologic research on the basis of the amount of information it carries. An injury outcome with this degree of descriptive detail would, conceivably, lend itself to improved etiologic research by considerably affecting the measure of association due to increased precision of event definition.

After having gained familiarity with each of the systems of classification in terms of the degree of distinction with which they were able to categorize knee injury and how much this was able to influence the ability to illustrate the effects of demographic determinants on knee injury outcome, a reasonable second step was to attempt to contrast the classification systems by means of their ability to affect measures of association in etiologic research.

Multivariate analyses of all four systems of classifying knee injury indicated that the use of specific injury outcomes from these systems led to heterogeneity in the odds ratios produced for etiologic research regardless of the whether the independent variables taken into consideration were simply the demographic variables or the demographic variables along with a variable accounting for interactions between them. This indicated that a specific set of predictors exists for being disabled due to a specific injury whether

the latter is identified by a VASRD code, an ICD code, a percentage of disability or a parameter used in the field of physical therapy. Clearly, an added advantage of using specific injury outcomes is that it confers the ability to further explain effect modification that would otherwise remain only somewhat understood and therefore produce limited research results.

To select one system as being most useful, however, was difficult for several reasons. Firstly, the amount of change in the odds ratios was variable and no set trends were found between systems of classification. There was no consistent pattern in the differences in odds ratios in all four systems. Secondly, a gold standard for classifying disabling knee injury was not established prior to the current study, nor does one exist in the literature. This prevented the ability to rank these systems of classification by their performance in the multivariate analyses. Lastly, it may be questionable to compare one system to the other if the population base captured in the categories of VASRD 5257, 5255 and 5262 was not the same as that of ICD 717, 718, 719 and 733 and so on for the other two classification systems.

A strength of this study is that, thus far, it demonstrates the usefulness of classifying knee injury for etiologic research. As an extension of this study, one could perhaps utilize the findings of the study by Williams (14) to further investigate the effect of military occupation as an indicator for disabling knee injury with the goal of exploring the usefulness of classifying disabling knee injury in etiologic research targeting occupation as a predictor for disabling knee injury. For the specific purposes of etiologic research in the

Army, a reasonable recommendation, given the findings of the current study, would be to create a more multidimensional coding system for classifying knee injury that would incorporate the parameters used in physical therapy and could perhaps be a combination of the all six parameters investigated in the study. Such an outcome would presumably be highly distinct and informative and would thereby potentially reduce misclassification by increasing the precision of the event definition. The use of alternate parameters for classifying disabling knee injuries could be examined. Cost of disability could be one such parameter though the use of this alternative may not be appropriate if the ultimate goal is to refine the etiologic research methodology.

Nevertheless, the findings of this study and the recommendations made based on the findings, are subject to a number of limitations. Firstly, this was one of the first studies of this type which made it difficult to compare these findings to those that exist in the literature. On the same lines, the absence of a gold standard in terms of classification systems for knee injury made it difficult to rank the systems that were investigated in this study. Several aspects of the study that were hampered due to use of small sample sizes that led to instability. Larger samples sizes would have lent more statistical power.

There may have been alternate explanations for the heterogeneity in odds ratios such as random error. There may have been differences between the cases considered in each of the models that would have led to differences in odds ratios. Each model used a different subset of cases that would have led to some variability.

Another limitation to this study may have been that it was based on a fairly young and healthy population. Though a strength to the study itself, it may potentially serve to compromise the generalizability of the study. For instance, the results of the study could not be generalized to a population that is older than 54 years. However, this would not be a serious limitation at such an early stage of research in this area.

Despite these limitations, this study carries considerable public health importance. The clarity with which the importance of utilizing discrete categories of disabling knee injury in etiologic research is illustrated serves as the first step in a continuum of research in this area. Although the findings of this study may appear to be simplistic and rudimentary, they are an essential and informative prologue to further research into the determinants of disability due to knee injuries and other type of injuries in general. With a clearer understanding of the latter, preventive measures could be implemented to reduce disability, both in the Army and among civilian populations. This, in turn, would reduce not only the pain and suffering associated with disability, but also disability-related costs in terms of treatment expenses, occupational loss and disability payments. This would contribute to the overall effort of increasing injury prevention through training, creating a more ergonomic occupational environment and increasing employee awareness of occupational injury both in the US Army and among civilian populations. It is important for Epidemiology as a field to be able to make this contribution through sound research methodology.

APPENDIX: CHAPTER IV.

Table A 4.1. Distribution of VASRD codes stratified by gender

Gender		VASRD	Definition	n	% of cases within stratum	% of all cases (N=1865)
Male					**(N=1005)**	
	1	5257	Impairments of knee other than ankylosis	665	66.17	35.66
	2	5255	Impairment of femur	143	14.23	7.67
	3	5262	Impairment of tibia and fibula	134	13.33	7.18
	4	5259	Removal of semilunar cartilage	54	5.37	2.90
	5	5258	Dislocated semilunar cartilage	6	0.60	0.32
	6	5256	Ankylosis of knee	3	0.30	0.16
		TOTAL		1005	100.00	53.89
Female					**(N=860)**	
	1	5257	Impairments of knee other than ankylosis	522	60.70	27.99
	2	5255	Impairment of femur	175	20.35	9.38
	3	5262	Impairment of tibia and fibula	104	12.09	5.58
	4	5259	Removal of semilunar cartilage	42	4.88	2.25
	5	5258	Dislocation of semi lunar cartilage	6	0.70	0.32
	6	5263	Genu recurvatum	6	0.70	0.32
	7	5161	Amputation of upper third of thigh	2	0.23	0.11
	8	5055	Knee replacment	1	0.12	0.05
	9	5160	Disarticulation of thigh	1	0.12	0.05
	10	5256	Ankylosis of knee	1	0.12	0.05
		TOTAL		**860**	**100.00**	**46.01**

Table A 4.2. Distribution of VASRD codes stratified by race

Race		VASRD	Definition	n	% of cases within stratum	of all cases (N=1865)
White (N=1283)						
	1	5257	Impairments of knee other than ankylosis	805	62.74	43.16
	2	5255	Impairment of femur	233	18.16	12.49
	3	5262	Impairment of tibia and fibula	176	13.72	9.44
	4	5259	Removal of semilunar cartilage	54	4.21	2.90
	5	5258	Dislocated semilunar cartilage	6	0.47	0.32
	6	5263	Genu recurvatum	6	0.47	0.32
	7	5256	Ankylosis of knee	3	0.23	0.16
	TOTAL			**1283**	**100.00**	**68.79**
Black (N=450)						
	1	5257	Impairments of knee other than ankylosis	299	66.44	16.03
	2	5255	Impairment of femur	66	14.67	3.54
	3	5262	Impairment of tibia and fibula	48	10.67	2.57
	4	5259	Removal of semilunar cartilage	30	6.67	1.61
	5	5258	Dislocated semilunar cartilage	4	0.89	0.21
	6	5160	Disarticulation of thigh	1	0.22	0.05
	7	5161	Amputation of upper third of thigh	1	0.22	0.05
	8	5256	Ankylosis of knee	1	0.22	0.05
	TOTAL			**450**	**100.00**	**24.13**

Continued, next page

Table A 4.2 continued

Other (N=129)					
1	5257	Impairments of knee other than ankylosis	82	63.57	4.40
2	5255	Impairment of femur	19	14.73	1.02
3	5262	Impairment of tibia and fibula	12	9.30	0.64
4	5259	Removal of semilunar cartilage	12	9.30	0.64
5	5258	Dislocated semilunar cartilage	2	1.55	0.11
6	5055	Knee replacment	1	0.78	0.05
7	5161	Amputation of upper third of thigh	1	0.78	0.05
TOTAL			**129**	**100.00**	**6.92**

Table A 4.3 . Distribution of VASRD codes stratified by age

Age (years)		VASRD	Definition	n	% of cases within stratum	% of all cases (N=1865)
17 to 20 (N=290)						
	1	5257	Impairments of knee	155	53.45	8.31
	2	5255	Impairment of femur	75	25.86	4.02
	3	5262	Impairment of tibia and fibula	41	14.14	2.20
	4	5259	Removal of semilunar cartilage	15	5.17	0.80
	5	5258	Dislocated semilunar cartilage	2	0.69	0.11
	6	5161	Amputation of upper third of thigh	1	0.34	0.05
	7	5256	Ankylosis of knee	1	0.34	0.05
	Total			**290**	**100.00**	**15.55**
21-22 (N=311)						
	1	5257	Impairments of knee	211	67.85	11.31
	2	5255	Impairment of femur	47	15.11	2.52
	3	5262	Impairment of tibia and fibula	34	10.93	1.82
	4	5259	Removal of semilunar cartilage	15	4.82	0.80
	5	5263	Genu recurvatum	2	0.64	0.11
	6	5160	Disarticulation of thigh	1	0.32	0.05
	7	5256	Ankylosis of knee	1	0.32	0.05
	Total			**311**	**100.00**	**16.68**
23-26 (N=491)						
	1	5257	Impairments of knee	342	69.65	18.34
	2	5255	Impairment of femur	64	13.03	3.43
	3	5262	Impairment of tibia and fibula	54	11.00	2.90
	4	5259	Removal of semilunar cartilage	25	5.09	1.34

Continued, next page

Table A 4.3 continued

5	5258	Dislocated semilunar cartilage	4	0.81	0.21
6	5161	Amputation of upper third of thigh	1	0.20	0.05
7	5263	Genu recurvatum	1	0.20	0.05
Total			**6**	**1.22**	**0.32**
27-30.35 (N=283)					
1	5257	Impairments of knee	206	72.79	11.05
2	5255	Impairment of femur	32	11.31	1.72
3	5262	Impairment of tibia and fibula	24	8.48	1.29
4	5259	Removal of semilunar cartilage	14	4.95	0.75
5	5258	Dislocated semilunar cartilage	3	1.06	0.16
6	5263	Genu recurvatum	3	1.06	0.16
7	5256	Ankylosis of knee	1	0.35	0.05
Total			**283**	**100.00**	**15.17**
30.36-54 (N=337)					
1	5257	Impairments of knee	220	65.28	11.80
2	5255	Impairment of femur	56	16.62	3.00
3	5262	Impairment of tibia and fibula	38	11.28	2.04
4	5259	Removal of semilunar cartilage	19	5.64	1.02
5	5258	Dislocated semilunar cartilage	2	0.59	0.11
6	5055	Knee replacment	1	0.30	0.05
7	5256	Ankylosis of knee	1	0.30	0.05
Total			**337**	**100.00**	**18.07**

Table A 4.4. Distribution of the ten most frequently occurring ICD-9 - men only

	ICD-9	Definition	n	% of top ten (N=633)	% of men having ICD (N=820)	% of male total (N=1005)
1	718	Ankylosis and joint derangement of knee	170	26.86	20.73	16.92
2	717	Internal derangement of knee: degeneration, rupture, old tear, old cartilage, old meniscus	164	25.91	20.00	16.32
3	733	Other bone/cartilage disorders: osteoporosis, pathological fracture.	95	15.01	11.59	9.45
4	719	Other unspecified joint disorders	85	13.43	10.37	8.46
5	715	Osteoarthritis, polyarthritis,	29	4.58	3.54	2.89
6	844	Sprains/strains of knee/leg	26	4.11	3.17	2.59
7	716	Other unspecified arthropathies	19	3.00	2.32	1.89
8	823	Fracture of tibia and fibula	16	2.53	1.95	1.59
9	821	Other unspecified fractures of femur	15	2.37	1.83	1.49
10	728	Disorders of muscle, ligament, fascia	14	2.21	1.71	1.39
TOTAL			**633**	**100.00**	**77.20**	**62.99**

Note: Male cases missing primary ICD = 185

Table A 4.5. Distribution of the ten most frequently occurring ICD-9 codes - women only

	ICD-9	Definition	n	% of top ten (N=537)	% of women having ICD (N=668)	% of female total (N=860)
1	717	Internal derangement of knee: degeneration, rupture, old tear, old cartilage, old meniscus	120	22.35	17.96	13.95
2	718	Ankylosis and joint derangement of knee	120	22.35	17.96	13.95
3	733	Other bone/cartilage disorders: osteoporosis, pathological fracture.	109	20.30	16.32	12.67
4	719	Other unspecified joint disorders	97	18.06	14.52	11.28
5	715	Osteoarthritis, polyarthritis,	23	4.28	3.44	2.67
6	824	Fracture of ankle	18	3.35	2.69	2.09
7	716	Other unspecified arthropathies	14	2.61	2.10	1.63
8	823	Fracture of tibia and fibula	13	2.42	1.95	1.51
9	728	Disorders of muscle, ligament, fascia	12	2.23	1.80	1.40
10	844	Sprains/strains of knee or leg	11	2.05	1.65	1.28
TOTAL			**537**	**100.00**	**80.39**	**62.44**

Note: Female cases missing primary ICD = 192

Table A 4.6. Distribution of the top ten most frequently occurring ICD-9 codes - whites only

	ICD code	Definition	n	% of white cases (N=802)	% of total (N=1865)
1	718	Ankylosis and joint derangement	205	25.56	10.99
2	717	Internal derangement of knee:degeneration, rupture, old tear, old cartilage,old meniscus	198	24.69	10.62
3	733	Other bone/cartilage disorders: osteoporosis, pathological fractures.	151	18.83	8.10
4	719	Other unspecified joint disorders	121	15.09	6.49
5	715	Osteoarthritis or polyarthritis	25	3.12	1.34
6	716	Other unspecified arthropathies	24	2.99	1.29
7	823	Fracture of tibia and fibula	23	2.87	1.23
8	844	Sprains/strains of knee or leg	21	2.62	1.13
9	824	Fracture of ankle	19	2.37	1.02
10	728	Disorders of muscle, ligaments, fascia.	15	1.87	0.80
TOTAL			**802**	**100.00**	**43.00**

Table A 4.7. Distribution of ten most frequently occurring ICD-9 codes - blacks only

	ICD code	Definition	n	% of black cases (N=286)	% of total (N=1865)
1	717	Internal derangement of knee:degeneration, rupture, old tear, old cartilage,old meniscus	68	23.78	3.65
2	718	Ankylosis and joint derangement	66	23.08	3.54
3	719	Other unspecified joint disorders	51	17.83	2.73
4	733	Other bone/cartilage disorders: osteoporosis, pathological fracture	36	12.59	1.93
5	715	Osteoarthritis or polyarthritis	25	8.74	1.34
6	844	Sprains/strains of knee or leg	10	3.50	0.54
7	821	Fractures of other unspecified parts of femur	9	3.15	0.48
8	728	Disorders of muscle, ligament, fascia	8	2.80	0.43
9	824	Fracture of ankle	7	2.45	0.38
10	716	Other unspecified arthropathies	6	2.10	0.32
TOTAL			**286**	**100.00**	**15.34**

Table. A 4.8. Distribution of ten most frequently occurring ICD-9 codes - races other than black and white

	ICD code	Definition	n	% of other races (N=81)	% of total (N=1865)
1	718	Ankylosis and joint derangement	19	23.46	1.02
2	717	Internal derangement of knee:degeneration, rupture, old tear, old cartilage,old meniscus	18	22.22	0.97
3	733	Other bone/cartilage disorders: osteoporosis, pathological fracture	16	19.75	0.86
4	719	Other unspecified joint disorders	10	12.35	0.54
5	844	Sprains/strains of knee or leg	6	7.41	0.32
6	716	Other unspecified arthropathies	3	3.70	0.16
7	824	Fracture of ankle	3	3.70	0.16
8	715	Osteoarthritis polyarthritis	2	2.47	0.11
9	820	Fracture of neck of femur	2	2.47	0.11
10	821	Other unspecified fracture o femur	2	2.47	0.11
TOTAL			**81**	**100.00**	**4.34**

Table A 4.9. Distribution of five most frequently occurring ICD-9 codes by age groups

	Age group (years)	Top 5 ICD	Definitions	n	% within group	% overall
1	17-20	733	Other bone/cartilage disorders: osteoporosis pathological fracture	43	27.56	2.31
		717	Internal derangement of knee	40	25.64	2.14
		718	Ankylosis and joint derangement	38	24.36	2.04
		719	Other unspecified joint disorders	25	16.03	1.34
		844	Sprains/strains of knee/leg	10	6.41	0.54
	Total			**156**	**100.00**	**8.36**
2	21-22	718	Ankylosis and joint derangement	61	32.11	3.27
		717	Internal derangement of knee	50	26.32	2.68
		719	Other unspecified joint disorders	40	21.05	2.14
		733	Other bone/cartilage disorders: osteoporosis pathological fracture	29	15.26	1.55
		844	Sprains/strains of knee/leg	10	5.26	0.54
	Total			**190**	**100.00**	**10.19**
3	23-26	717	Internal derangement of knee	84	30.55	4.50
		718	Ankylosis and joint derangement	84	30.55	4.50
		719	Other unspecified joint disorders	53	19.27	2.84
		733	Other bone/cartilage disorders: osteoporosis pathological fracture	43	15.64	2.31
		728	Disorders of muscle ligament, fascia	11	4.00	0.59
	Total			**275**	**100.00**	**14.75**

Continued, next page

Table A 4.9. continued

	Age group (years)	Top 5 ICD	Definitions	n	% within group	% overall
4	27-30.35	718	Ankylosis and joint derangement	52	32.10	2.79
		717	Internal derangement of knee	46	28.40	2.47
		719	Other unspecified joint disorders	29	17.90	1.55
		733	Other bone/cartilage disorders: osteoporosis pathological fracture	18	11.11	0.97
		715	Osteoarthritis polyarthritis	17	10.49	0.91
	Total			**162**	**100.00**	**8.69**
5	30.36-54	717	Internal derangement of knee	47	28.66	2.52
		718	Ankylosis and joint derangement	38	23.17	2.04
		733	Other bone/cartilage disorders: osteoporosis pathological fracture	31	18.90	1.66
		719	Other unspecified joint disorders	30	18.29	1.61
		715	Osteoarthritis polyarthritis	18	10.98	0.97
	Total			**164**	**100.00**	**8.79**

BIBLIOGRAPHY

1. The Random House Dictionary. Random House. New York. 1980.

2. Murray CJL and Lopez AD. 1996. Summary: The Global Burden of Disease. Global Burden of Disease and Injury Series. World Health Organization.

3. Knapik J, Ang P, Reynolds K and Jones B. 1993. Physical Fitness, Age, and Injury Incidence in Infantry Soldiers. Journal of Medicine. 35(6): 598-603.

4. Jones BH, Cowan DN, Tomlinson JP et al. 1993. Epidemiology of injuries associated with physical training among young men in the army. Medicine and Science in Sports and Exercise. 25(2): 197-203.

5. Feuerstein M, Berkowitz SM and Peck CA. 1997. Musculoskeletal-Related Disability in the US Army Personnel: Prevalence, Gender, and Military Occupational Specialties. Journal of Occupational and Environmental Medicine. 39(1): 68-78.

6. Tomlinson, JP, Lednar WM, and Jackson JD. 1987. Risk of Injury in Soldiers. Military Medicine. 152. 2:60.

7. Dorland's Illustrated Medical Dictionary. 25th Ed. W.B. Saunders. Philadelphia. 1974.

8. Personnel Separations. 1990. Army Regulation 635-40: Physical Evaluation for Retention, Retirement, or Separation. Department of the Army. Washington DC.

9. Ross J and Woodward A. 1994. Risk Factors for Injury During Basic Military Training: Is there a social element to injury pathogenesis? Journal of Occupational Medicine. 36(10): 1120-1126.

10. Jensen KL and Eenberg W. 1996. Occupation as a risk factor for knee disorders. Scand J Work Environ Health 22: 165-75.

11. Sulsky SI. 1998. Case-control study of disabling occupational knee injury in the US Army: The role of gender, race and age. Current manuscript submitted for publication to Am J Prev Med.

12. Saunders HD. Evaluation, Treatment and Prevention of Muskuloskeletal Disorders. Viking Press Inc. Minneapolis 1985. Chapter 3: Evaluation of Muskuloskeletal Disorders. pp.13-75.

13. Statistical Analysis Systems. SAS Institute Inc. SAS Campus Drive. Cary NC.