

Incidence and Risk Factors for Chronic Anterior Knee Pain

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Abstract

Chronic anterior knee pain is a common clinical entity, more so in the active individual. The incidence and risk factors, however remain unexplored. We investigated the correlation of demographic and occupational risk factors as well as the incidence of chronic anterior knee pain in an active military population. We performed a retrospective review of all U. S. Military active duty service members with the diagnosis of chondromalacia patellae, representative of the clinical syndrome of chronic anterior knee pain, between 2006 and 2012 using the Defense Medical Epidemiology Database. The demographic and occupation risk factors were categorized and the subgroup and overall incidence rates were determined via multivariable analysis. A total of 42,040 cases of chondromalacia patellae were identified in an at-risk population of 9,723,449, corresponding to an incidence rate of 4.32 cases per 1,000 person-years. Increasing chronological age, female sex, Black race, junior enlisted rank, and primary ground forces (Marines and Army) significantly correlated with an increased risk for chronic anterior knee pain. This study is the first report of incidence and risk factors for chondromalacia patellae in a large athletic population. We determined that sex, age, race, branch of service, and rank all correlated with the incidence of chondromalacia patellae in an active population.

Keywords

- ▶ chondromalacia patellae
- ▶ chronic anterior knee pain
- ▶ anterior knee pain
- ▶ active
- ▶ incidence
- ▶ risk factor

Chronic anterior knee pain is a common clinical entity, particularly in physically active patients. Patellar chondromalacia is among the most common etiologies of chronic anterior knee pain. In previous studies, the articular surface of the patella was the most common site of knee involvement,^{1–4} frequently with grades III and IV defects.⁵ However, these patellar chondral lesions are often discovered incidentally during arthroscopy,⁶ and the incidence, severity, and degree of clinical symptomatology remains unknown.⁷

The patellofemoral joint experiences high shear and compressive forces, and these stresses may be exacerbated by a combination of both intrinsic (e.g., patellofemoral maltracking, trochlear hypoplasia) and extrinsic factors (e.g., trauma).⁸ Structural damage of the patellofemoral articulation may

arise from either acute traumatic events or chronic repetitive stresses, and articular cartilage is additionally limited by its poor inherent regenerative capacity.^{9–13} Furthermore, athletic cohorts are at an increased risk for developing chronic anterior knee pain related to patellar cartilage injury due to the nature of their at-risk movements (e.g., deep flexion, cutting), high activity level, and propensity for sport-related injury.^{10,13–15}

Few studies have rigorously evaluated risk factors for the clinical syndrome of patellar chondromalacia or articular cartilage defects. Some proposed risk factors have included older chronological age,^{16–18} female,¹⁶ increased body mass index,^{14,16,18} previous knee injury,¹⁴ heavy workload,¹⁴ and repetitive kneeling or squatting activities.¹⁴ Despite these

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proposed associations, no broad-based population study has evaluated the demographic and occupational factors leading to chronic anterior knee pain or patellar chondromalacia.

To this end, we sought to determine the incidence rate and role of age, sex, military rank, and branch of service on patellar chondromalacia, representative of the clinical syndrome of chronic anterior knee pain, using the Defense Medical Epidemiological Database (DMED) between 2006 and 2012. The DMED has been used reliably to quantify incidence and risk factors for various orthopedic conditions.^{19–23} The findings have also been shown to translate to a civilian population.^{19,20,24,25} We hypothesize that older females in a branch of service with greater physical demands would be predisposed to developing chronic anterior knee pain, in part due to the cumulative occupational demands on the patellofemoral joint.

Materials and Methods

Following the institutional review board approval, a systematic inquiry of the DMED was performed to identify all U. S. Military service members diagnosed with chondromalacia of the patella (International Classification of Disease 9th Edition [ICD-9] code 717.7) between 2006 and 2012. In military practice, the diagnosis of chondromalacia patellae is not solely based on supplementary histopathological or arthroscopic findings, but may be reflect a combination of clinical and radiographic findings. Chondromalacia patellae are therefore representative of the clinical syndrome of chronic anterior knee pain.

The outpatient data in the DMED is a combination of the ambulatory data records located in the ambulatory data system, which is utilized throughout all military treatment facilities, as well as those records from nonmilitary outpatient health care facilities which provide care to active-duty service members. The DMED database additionally records the total number of service members on active-duty each year and catalogues their demographic and military-specific data. The DMED is frequently updated to account for active military personnel accessions as well as those that leave military service. Previous publications have thoroughly detailed methodology associated with the use of the DMED.^{19,20,23,25}

Unadjusted incidence rates (IR) were calculated for risk factors including age, sex, race, military rank, and branch of military service. Age categories were defined as follows: <20, 20 to 29, 30 to 39, and ≥40 years. Race was categorized as White, Black, or others (which includes Hispanic/Latino, native American/Alaskan/Pacific Islander, Asian, other race, mixed race, and no race reported). Branches of military service included Army, Marine Corps, Navy, and Air Force. Military rank was classified as junior enlisted (four lowest ranks in all branches), senior enlisted (the remainder of noncommissioned officers), junior officer (three lowest officer ranks in all branches, to include warrant officers), and senior officer (six highest officer ranks in all branches). To prevent analysis of duplicate diagnoses associated with a single patient, the DMED was only queried to reveal primary diagnosis of chondromalacia of the patella when identified as the “first occurrence” in the ambulatory setting.

Among the primary risk factors analyzed, age, race, and sex were recognized to have direct correlation to the civilian population. Military rank and branch of service were considered to serve as a surrogate for different levels of activity and occupational demands. Traditionally, the enlisted ranks and the Army and Marine Corps branches of service are associated with the highest level of activity. In addition, individual calendar years were evaluated in an effort to define any temporal trends associated with the diagnosis of chondromalacia of the patella.

U. S. Military service members are required to maintain a level of physical training, which typically exceeds that of the average civilian. In addition to required height and weight standards, all service members must successfully complete a service-specific, physical fitness test twice a year, which may include timed pushups, sit-ups, and an aerobic event. Service members are often involved in the following at-risk activities: daily aerobic fitness, weight training, tactical field exercises, and military movements with heavy fighting loads (e.g., 27 to >36 kg). Additionally, service members may also be required to maintain a level of physical training exceeding these baseline standards, depending upon their branch of service and military occupational specialty.

For incident patellofemoral chondromalacia, the outcome measure was the unadjusted incidence rate per 1,000 person-years. Multivariate Poisson regression analysis was performed on the various risk factors to determine their effect on incidence rate. Adjusted incidence rate ratios (IRR), as well as 95% confidence intervals (CI), were determined through comparison of risk factors in predetermined subcategories. SAS version 9.3 (SAS Institute Inc., Cary, NC) was utilized for all statistical analyses, and a *p*-value less than 0.05 was determined to be of statistical significance. Independent predictors of patellar chondromalacia were identified as risk factors which had an IR above the population mean, and demonstrated IRR and 95% CI exclusive of 1.0 when compared with their referent.

Results

A total of 42,040 cases of patellar chondromalacia were identified in a population at risk of 9,723,449 person-years between 2006 and 2012. This corresponds to an average of 6,006 incident cases of chondromalacia of the patella diagnosed per year, with an overall unadjusted incidence rate of 4.32 cases per 1,000 person-years. The adjusted annual incidence rate decreased from 5.27 cases per 1,000 person-years in 2006 to 3.84 cases per 1,000 person-years in 2009, and there was little change in adjusted annual incidence rate from 2009 to 2012 (–Table 1).

Multivariate analysis was used to determine the effect of independent risk factors including: age, sex, race, military rank, and branch of service on IRs for chondromalacia of the patella.

Patient Demographics

The adjusted IRR increased significantly (*p* < 0.0001) with each age group, with the exception of the <20-year-old group which demonstrated a marginally greater IRR than the 20 to

Table 1 Yearly incidence rates of patellar chondromalacia in the U. S. military (2006–2012)

Year	No. of cases	Person-years	Unadjusted		Adjusted	
			IR ^a (95% CI)	Percentage increase from previous year	IR ^{a,b} (95% CI)	Percentage increase from previous year
2006	7,259	1,365,991	5.31 (5.19–5.44)	–	5.27 (5.12–5.42)	–
2007	6,248	1,359,927	4.59 (4.48–4.71)	–13.54	4.53 (4.40–4.67)	–14.04
2008	5,632	1,374,570	4.10 (3.99–4.21)	–10.82	4.02 (3.89–4.15)	–11.26
2009	5,530	1,402,650	3.94 (3.84–4.05)	–3.78	3.84 (3.72–3.96)	–4.48
2010	5,874	1,417,105	4.15 (4.04–4.25)	5.14	4.00 (3.88–4.13)	4.17
2011	5,776	1,413,364	4.09 (3.98–4.19)	–1.41	3.93 (3.80–4.05)	–1.75
2012	5,721	1,389,842	4.12 (4.01–4.22)	0.72	3.94 (3.82–4.07)	0.25

Abbreviations: CI, confidence interval; IR, incidence rate.

^aPer 1,000 person-years.

^bAdjusted for age, sex, race, rank, and branch of service.

29-year-old group. The 20 to 29-year-old group demonstrated the lowest IRR, followed by the <20-year-old group, the 30 to 39-year-old group, and finally the >40-year-old group. Members over the age of 40 were found to have the highest IRR (7.58; 95% CI 7.34, 7.83; $p < 0.0001$) (►Table 2).

A complete listing of the patellar chondromalacia incidence rates with the associated risk factors of sex, race, military rank, and branch of service is shown in ►Table 3. A total of 34,002 males were diagnosed with chondromalacia of the patella within the study period, for an IR of 3.42 per 1,000 person-years while 8,032 females were diagnosed with chondromalacia of the patella for an IR of 5.14 per 1,000 person-years. Female service members had a significantly higher IRR compared with male service members (IRR 1.50; 95% CI 1.47, 1.54; $p < 0.0001$).

In examining race, Black service members had a significantly higher IRR than White service members (IRR 1.10; 95% CI 1.08, 1.13), while individuals of other races demonstrated significantly lower IRR than White service members (IRR 0.83; 95% CI 0.80, 0.85; $p < 0.0001$).

Rank and Branch of Service

Considering the military rank, junior enlisted personnel had the highest IRR for chondromalacia of the patella (IRR 3.75, 95% CI 3.57, 3.93, $p < 0.0001$), with the senior officer group as the lowest IR. When compared with officers, enlisted service

members demonstrated significantly higher IRs irrespective of seniority.

Finally, Marine Corps service members displayed the highest rates of chondromalacia of the patella (IRR 2.08, 95% CI 2.01, 2.16, $p < 0.0001$), followed by the Army (IRR 1.79, 95% CI 1.74, 1.84, $p < 0.0001$), Air Force, and Navy, respectively.

Discussion

We present the first known, population-based investigation evaluating the incidence and epidemiology of chronic anterior knee pain in an active duty military population of the United States. With 42,040 cases among active duty service members, we found the incidence of chondromalacia patellae to be 4.32 per 1,000 person-years. The rate of diagnosis initially declined, but relatively stabilized over the latter course of the study. In the only other study describing chondral lesions of the knee in a military population, Kuikka et al, found the incidence of 0.2 per 1,000 person-years among a population of over 100,000 Finnish male military conscripts.¹⁸ By comparison, our incidence of patellar chondromalacia was roughly 20-fold greater than that described by Kuikka et al which may be attributable to the fact that only inpatient hospitalizations data were considered in the aforementioned study. Additionally, there are considerable differences in the operational tempo between the peacetime

Table 2 Incidence rate ratios of patellar chondromalacia by age group, in the U. S. military (2006–2012)

Age	No. of cases	Person-years	Unadjusted IR ^a	Adjusted IR (95% CI) ^b	Adjusted IRR (95% CI) ^b	p-Value
< 20	3,068	624,955	4.91	2.61 (2.50–2.73)	1.43 (1.38–1.49)	< 0.001
20–29	14,977	5,492,895	2.73	1.82 (1.78–1.87)	1	N/A
30–39	12,311	2,580,926	4.77	4.71 (4.60–4.83)	2.59 (2.51–2.66)	< 0.001
≥ 40	11,684	1,024,673	11.4	13.82 (13.48–14.15)	7.58 (7.34–7.83)	< 0.001

Abbreviations: CI, confidence interval; IR, incidence rate; IRR, incidence rate ratio; N/A, not applicable (because this category was used as the referent).

^aPer 1,000 person-years.

^bAdjusted for age, sex, race, rank, and branch of service.

Table 3 Incidence rate ratios of patellar chondromalacia in the U. S. military (2006–2012)

Category	No. of cases	Person-years	Unadjusted IR ^a	Adjusted IR (95% CI) ^b	Adjusted IRR (95% CI) ^b	p-Value
Sex						
Male	34,002	8,323,069	4.09	3.42 (3.35–3.49)	1	N/A
Female	8,038	1,400,380	5.74	5.14 (5.00–5.28)	1.50 (1.47–1.54)	< 0.0001
Race						
Other	4,584	1,297,251	3.53	3.58 (3.46–3.70)	0.83 (0.80–0.85)	< 0.0001
White	28,166	6,770,040	4.16	4.32 (4.24–4.41)	1	< 0.0001
Black	9,290	1,656,158	5.61	4.76 (4.64–4.89)	1.10 (1.08–1.13)	N/A
Rank						
Sr. officer	2,920	628,021	4.65	2.14 (2.05–2.24)	1	N/A
Jr. officer	3,009	976,249	3.08	3.65 (3.51–3.80)	1.70 (1.61–1.80)	< 0.0001
Sr. enlisted	19,531	3,865,721	5.05	4.91 (4.81–5.02)	2.29 (2.20–2.39)	< 0.0001
Jr. enlisted	16,580	4,253,458	3.9	8.04 (7.86–8.22)	3.75 (3.57–3.93)	< 0.0001
Service						
Navy	6,301	2,294,555	2.75	2.72 (2.64–2.80)	1	N/A
Air Force	10,129	2,317,564	4.37	4.13 (4.03–4.24)	1.52 (1.47–1.57)	< 0.0001
Army	19,281	3,753,567	5.14	4.86 (4.75–4.97)	1.79 (1.74–1.84)	< 0.0001
Marines	6,329	1,357,763	4.66	5.66 (5.49–5.84)	2.08 (2.01–2.16)	< 0.0001

Abbreviations: CI, confidence interval; IR, incidence rate; IRR, incidence rate ratio; N/A, not applicable (because this category was used as the referent for respective categories).

^aPer 1,000 person-years.

^bAdjusted for age, sex, race, rank, and branch of service.

Finnish forces compared with the U.S. military forces which have been at war since 2001. These patella chondromalacia incidence rates in military service members are an order of magnitude greater than that expected in a more sedentary, general population and may more adequately approximate that of athletic civilian patients.²⁶

Patellar chondromalacia is a common and underrecognized source of disability in physically active cohorts, often due to its nonspecific presentation and frequent coexistence with other knee pathology.^{4,27,28} The present literature exploring risk factors for the development of patellar chondral lesions is limited, primarily as a result of undersized patient cohorts and a lack of statistical power. In a recent systematic review of articular cartilage injury in athletes,²⁶ Flanigan et al found a prevalence rate of 0.89 chondral lesions per knee, 36% of which were full-thickness focal defects. Furthermore, the patellofemoral joint (37%) was involved most frequently, with patellar cartilage accounting for the majority (64%). The authors concluded that while chondral lesions were significantly more common in the athletic versus the general population, the geographic distribution of lesions were similar.

The prevalence of patellar chondral lesions has largely been defined in the general population through incidental arthroscopic findings, which may be prone to significant selection bias. Data from over 58,000 diagnostic knee arthroscopies found a 34 to 66% prevalence of articular cartilage lesions,^{1,4,27,29,30} and the patella was involved as many as

37.5% of cases.^{1–4,30} An acute traumatic onset of symptoms and a relation to sporting activity were reported in 46 to 59% and 46 to 49% of cases, respectively.^{4,29,30} The largest review of 31,516 knee arthroscopies by Curl et al revealed that the patella was the most common location of chondral involvement, and it tended toward more advanced grades of chondromalacia (Outerbridge grades III and IV).¹ The advanced nature of these patellar chondral lesions at the time of diagnosis result from the indolent nature of this disease and its nonspecific symptomatology, features which also complicate the ability to isolate population-based risk factors for the development of patellar chondromalacia.¹¹

In the current study, we found that females were 50% more likely than males to develop patella chondromalacia. Our findings are concordant with previous studies, which have also shown an increased risk of sport-related injury in athletic females.^{22,23,31} A study of professional basketball injuries found that women were 1.6 times more likely than men to sustain a knee injury.³¹ In an analysis of 1,784 knee arthroscopies, Lindberg et al found females to have a greater incidence of chondromalacia with concomitant patellar subluxation, while males have a greater incidence of isolated chondral damage with normal patellofemoral kinematics.²⁸ This may represent an inherent gender-based difference in the predisposition toward chondral injury. In other words, females may have a higher likelihood of intrinsic abnormalities in patellofemoral joint dynamics, whereas males more likely to sustain chondral injury through external trauma due

to exposure to at-risk activity.²⁸ In a longitudinal magnetic resonance imaging (MRI)-based study of 395 older adults, Carnes et al found that female sex also correlated with increased overall severity of knee articular cartilage defects.¹⁶ These findings are likely due to a myriad of factors, including differences in dynamic muscle activation, rotational malalignment, patellofemoral maltracking, and increased ligamentous laxity predisposing females to greater abnormal stresses on the patellofemoral joint.³²

Our findings indicate that individuals over the age of 40 were most likely to be diagnosed with patellar chondromalacia, and this corroborates the results presented in previous studies.^{16–18} Generally, the IRR increased significantly with increased chronological age group. The elevated incidence of patellar chondromalacia with advancing age reflects the cumulative exposure of high activity level superimposed on age-related decline in the mechanical properties of cartilage. These age-dependent changes in the articular cartilage include fibrillation, decrease in size and number of proteoglycans, decrease in chondrocyte cellularity and viability, and loss of tensile strength and stiffness, all of which culminate in a greater predisposition toward cartilage injury.³³ In an MRI-based cross-sectional study of 372 patients, the authors found that age was significantly associated with decreased knee cartilage thickness as well as prevalence and severity of knee cartilage defects.¹⁷ Hjelle et al found a significant increase in the prevalence of high-grade chondromalacia with increasing age, from 5.3% in patients 40 and younger to over 7% in patients 50 and younger.²⁷ In a similar military cohort, Kuikka et al also found age to also be the most significant risk factor for knee injury among Finnish conscripts.¹⁸

As a result of the significant physical demands of the military, active duty service members are at an increased risk of developing chondromalacia of the patella with incidence varying by military rank and branch of service. Junior enlisted had the highest IRR and enlisted service members had a significantly higher IRR than that of officers. This trend parallels the physical demands associated with military rank, with junior enlisted subject to more vigorous physical demands versus their more senior, and often more increasingly administrative, counterparts. Enlisted ranks are furthermore less able to insulate themselves or self-modify their activity as compared with officer ranks. The increased IRR of the Army and Marines reflect their greater land-based activity than the Air Force or Navy. The Army and Marines are ground-based forces, requiring a significantly greater degree of impact activity, increased fighting loads, and more frequent land movements. The association of branch of service with different epidemiological profiles is supported by previous studies of active-duty military personnel.^{22,23,34}

There are several limitations to this study. First and foremost, as a database study, we were limited to the variables available in the existing databases. Therefore, we could not evaluate other possible confounding variables, such as body mass index. The validity of the data also relies on the accuracy of its input, and we are unable to control for provider miscoding. As the diagnosis often relies

on corresponding musculoskeletal imaging and intra-operative evaluation for optimal sensitivity, we are uncertain to what extent the diagnoses were determined by radiographic or MRI alone, clinical evidence of symptomatic patellar chondromalacia, or a combination of the two. Since the DMED data are derived from patient-driven visits, it is reasonable to expect that it is based upon symptomatic complaints within the framework of musculoskeletal imaging findings. There is a general propensity for underdiagnosis due to the subtle clinical symptomatology and frequent coexistence with concomitant intra-articular pathology. Symptomatic patellar chondromalacia is the clinical entity that causes pain, impairment, and utilization of health care resources and thus is the focus of the current investigation. However, despite these limitations, our study possesses several strengths, including the large sample size of athletic individuals, consecutive patient enrollment, and a closed patient population that may more accurately represent an athletic cohort.

Conclusion

We present the first report of incidence and risk factors for patellar chondromalacia in a large athletic population within the United States. The average annual incidence was found to be 4.32 per 1,000 person-years amongst active duty service members across all branches of service from 2006 to 2012. Multivariate analysis found that female sex, increased age, service members identified as Black, junior enlisted rank, and Marine and Army branches of service were associated with significantly increased rates of patellar chondromalacia. Further research is warranted to determine the impact of these variables on clinical outcomes.

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