2011-10

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American College of Rheumatology

þÿ A R T H R I T I S & R H E U M A T I S M Vol. 63, No. 10, October 2011, pp 2974 2982

http://hdl.handle.net/10945/47586

ARTHRITIS & RHEUMATISM
Vol. 63, No. 10, October 2011, pp 2974–2982
DOI 10.1002/art.30498

Incidence of Physician-Diagnosed Osteoarthritis Among Active Duty United States Military Service Members

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Objective. **To examine the incidence of osteoarthritis and the influence of demographic and occupational factors associated with this condition among active duty US service members between 1999 and 2008.**

Methods. **To determine the total number of incident cases of osteoarthritis, the Defense Medical Surveillance System (DMSS) was queried by sex, race, age, branch of military service, and rank using code 715 of the International Classification of Diseases, Ninth Revision, Clinical Modification. Multivariable Poisson regression analysis was used to estimate incidence rates, rate ratios, and 95% confidence intervals (95% CIs) for osteoarthritis per 1,000 person-years.**

Results. **A total of 108,266 incident cases of osteoarthritis were documented in the DMSS within a population that experienced 13,768,885 person-years at risk of disease during the study period. The overall unadjusted incidence rate among all active duty US service members during the study period was 7.86 cases per 1,000 person-years. Significant demographic and occupational risk factors for osteoarthritis included sex, age, race, branch of service, and rank ($P < 0.001$). Women experienced an adjusted incidence rate for osteoarthritis that was nearly 20% higher than that for men (rate ratio 1.19 [95% CI 1.17–1.21]). Service members ages ≥40 years experienced an adjusted incidence rate for osteoarthritis that was ~19 times higher than that for those ages <20 years (rate ratio 18.61 [95% CI 17.57–19.57]). Black service members experienced significantly higher incidence rates of osteoarthritis than those in the white and "other" race categories.**

Conclusion. **Rates of osteoarthritis were significantly higher in military populations than in comparable age groups in the general population.**

Osteoarthritis is considered to be the most common form of arthritis, affecting an estimated 26.9 million adults ages ≥25 years in the US (1), and osteoarthritis accounts for >25% of all arthritis-related healthcare visits (2). The economic burden of direct and indirect costs associated with osteoarthritis is also significant, likely exceeding $60 billion annually (1,3–5). Although osteoarthritis has traditionally been considered a disease that affects older individuals, in whom the incidence increases with advancing age, recent studies suggest that the majority of adults with osteoarthritis are younger than age 65 years (6). Occupational physical demands (7,8) and traumatic joint injury (9,10) have been associated with the development of osteoarthritis. Studies also suggest that physical activity involving repetitive joint loading may be associated with the occurrence of osteoarthritis (11,12).

Despite the burden associated with osteoarthritis, population-based estimates of the incidence of this condition are limited (6,13). Studies that have estimated incidence rates for osteoarthritis have typically focused on a single joint, and their findings may not represent the overall incidence of the disease (6,8,14). The majority of population-based studies have estimated the prevalence, rather than the incidence, of osteoarthritis (1,15–18). Furthermore, surprisingly little is known about the incidence of osteoarthritis in younger and physically active populations. The active duty US military population provides an excellent opportunity to examine the incidence of osteoarthritis in a young and physically

The views and opinions expressed herein are those of the author(s) and do not reflect the official policy of the Department of the Army, the Department of Defense, or the US Government.

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Submitted for publication November 18, 2010; accepted in revised form June 7, 2011.

active population that is regularly exposed to repetitive joint loading physical activity and occupational tasks. This is particularly important because osteoarthritis is a leading cause of disability and medical discharge in this population (19,20). Therefore, the purpose of this study was to examine the incidence of physician-diagnosed osteoarthritis and the influence of demographic and occupational factors associated with this condition among active duty US service members between 1999 and 2008.

SUBJECTS AND METHODS

Design and setting. A retrospective cohort study was conducted to examine the incidence and risk factors associated with the occurrence of osteoarthritis among all active duty US service members between 1999 and 2008 inclusive. Data were extracted from the Defense Medical Surveillance System (DMSS), which serves as the central repository for all medical surveillance data and captures nearly all healthcare encounters between providers and beneficiaries for all 4 branches of military service (21,22). The structure, utility, and capabilities of the DMSS for public health surveillance and epidemiologic research have been described previously in the literature (21–24). An emerging line of research has begun to utilize the data contained within the DMSS to examine the incidence and risk factors for a number of upper (25–28) and lower (24,29,30) extremity musculoskeletal injuries and conditions (14,31,32). Data for hospitalizations and ambulatory visits are summarized in the DMSS by major diagnostic categories at the 3-digit level using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes to document every patient encounter occurring in military treatment facilities and through outpatient referrals covered by Tricare (21). An exemption for human subjects research was granted by the Institutional Review Board at our institution for this investigation.

Population characteristics. As noted previously, active duty US military personnel comprise a relatively young, healthy, and physically active population that regularly engage in physically demanding occupational tasks. According to information from the Defense Manpower Data Center, the median age of this population is 26 years. Males make up ~88% of this population with females making up the remaining 12%. The racial distribution among active duty US military personnel is 71% white and 19% black, and 10% are classified as other. All active duty US military personnel have free and open access to medical care through the Military Health System. In addition to receiving all of their medical treatment through a closed healthcare system once on active duty, all prospective service members are screened to ensure they meet military medical fitness standards during the accession process. Upon entry to military service all candidates undergo a comprehensive medical evaluation, and those with any significant history of musculoskeletal injury or disease are likely to be disqualified from military service. Specifically, the current presentation or a history of chronic or posttraumatic osteoarthritis would result in medical disqualification from military service (33). In addition, findings of preexisting physical abnormalities, including potential causes of secondary osteoarthritis, would also preclude individuals from entering military service (14,33).

Data acquisition and operational definitions. For the current study, the DMSS was queried to identify all incident cases of osteoarthritis among active duty US service members between 1999 and 2008 by sex, age, race, branch of military service, and grade or military rank. Specifically, the DMSS was queried for ICD-9-CM code 715 (osteoarthritis and allied disorders). This operational definition of osteoarthritis has been recommended by the Centers for Disease Control and Prevention's National Arthritis Data Workgroup (2,34) and has been used previously in similar studies (6,13). The age categories used were <20, 20–24, 25–29, 30–34, 35–39, and ≥ 40 years, which are standard within DMSS and correspond to the age groupings used in previous studies (6). The race categories were white, black, and other, which are standard categories used within DMSS (22). Those classified as other included Latinos, Asians, American Indians, and other racial groups. The service categories were US Army, US Marine Corps, US Navy, and US Air Force, representing each branch of military service. The categories for military rank included junior enlisted (E1–E4), senior enlisted (E5–E9), junior officer (O1–O4), and senior officer (O5–O9).

All active duty US service members who joined the military prior to January 1, 1999, as well as those who joined during the study period, were included in the cohort; however, subjects who were on active duty prior to the start of the study and had received a prior diagnosis of osteoarthritis (ICD-9-CM code 715) were excluded. Only data from ambulatory visits were used to determine the total number of incident cases of osteoarthritis documented as a primary diagnosis for the ICD-9-CM code listed above for each stratum. Events were limited to "first occurrences" to exclude repeat coding for the same initial case of osteoarthritis for all service members during the study period using a filtering procedure (22). Similar to previous studies (28,30), a "first occurrence" was operationally defined so that all incident cases during the study period represented the first case of osteoarthritis for each individual from the time they entered military service, and all subsequent healthcare visits for osteoarthritis for each individual patient were excluded.

Outcome measures. The incidence rate for osteoarthritis per 1,000 person-years at risk during the study period was the primary outcome of interest in this investigation (35,36). Accurate population denominator data (person-time) for incidence rate calculations, which were validated against personnel data contained in the Defense Manpower Data Center database, were available through DMSS by strata (e.g., sex, age, race, etc.). Followup time accounted for time-varying characteristics such as age and military rank. During the study period, person-time at risk for osteoarthritis was calculated from the beginning of the study period starting January 1, 1999 until a subject 1) sustained an incident case of osteoarthritis, 2) was separated from military service, or 3) reached the administrative end of the study on December 31, 2008. As a result, incident cases of osteoarthritis were censored at the time of initial diagnosis and contributed no further exposure time during the study period. Time-varying characteristics were documented at the time of initial diagnosis based on information contained in the Defense Manpower Data Center data-

base on that date. For all subjects who joined the military after January 1, 1999, person-time at risk began accumulating on the date of entry into military service until one of the study end points described above was reached.

Statistical analysis. The overall incidence rate for osteoarthritis in the study population, along with the 95% confidence interval (95% CI), was calculated by dividing the total number of incident cases by the total person-years at risk and multiplying by 1,000. Multivariable Poisson regression was used to estimate the incidence rate of osteoarthritis per 1,000 person-years by strata (e.g., age), while controlling for the influence of the other variables in the model (e.g., sex, race, rank, and service). We also used Poisson regression to estimate the percentage increase in the incidence rate for osteoarthritis by age category, assuming a linear trend. We estimated incidence rates, rate ratios, and 95% CIs for each variable using the subset with the lowest incidence rate as the referent category. Incidence rate comparisons between strata for each variable (e.g., age) were made using model-adjusted incidence rates and rate ratios to evaluate the independent effect of each of the 5 variables on the incidence of osteoarthritis while holding the other variables in the model constant. We also compared the crude unadjusted incidence rates for osteoarthritis by age between the military population in the present study with the rates for the general population studied by Kopec et al (6), which is the only available study using similar methods (e.g., case definition, administrative data, age groups). Incidence rate ratios and 95% CIs were calculated for these comparisons using the general population incidence rates reported by Kopec et al (6) as the referent group for each age category. All data were analyzed using SAS software version 9.1.

RESULTS

A total of 108,266 individuals with incident cases of osteoarthritis and 13,768,885 person-years of followup were documented in DMSS during the 10-year study period. On average, 10,827 incident cases of osteoarthritis were diagnosed each year during the study period among 1,376,889 active duty US service members. The overall incidence rate for osteoarthritis during the study period within the military population was 7.86 (95% CI 7.82–7.91) cases per 1,000 person-years. The incidence rate for osteoarthritis varied significantly by sex, age, race, branch of military service, and rank, and all 5 demographic and occupational variables were associated with the incidence of osteoarthritis ($P < 0.001$). Unadjusted and adjusted incidence rates, rate ratios, and 95% CIs for all demographic and occupational variables are presented in Table 1.

Table 1. Unadjusted and adjusted incidence rates and rate ratios for osteoarthritis by demographic or occupational group among active duty US service members between 1999 and 2008*

Demographic/ occupational factor	Observed		Unadjusted		Adjusted‡	
	Cases, no. (%)†	Person-years	Rate	Rate ratio (95% CI)	Rate	Rate ratio (95% CI)
Sex						
Male	91,305 (84.3)	11,757,094	7.77	1.00	5.26	1.00
Female	16,961 (15.7)	2,011,791	8.43	1.09 (1.07–1.10)	6.25	1.19 (1.17–1.21)
Age, years						
<20	2,030 (1.9)	1,105,294	1.84	1.00	1.43	1.00
20–24	12,859 (11.9)	4,562,576	2.82	1.53 (1.46–1.61)	2.27	1.59 (1.51–1.66)
25–29	14,260 (13.2)	2,869,395	4.97	2.71 (2.58–2.83)	4.36	3.05 (2.90–3.20)
30–34	15,446 (14.3)	2,010,759	7.68	4.18 (3.99–4.38)	7.08	4.95 (4.70–5.20)
35–39	25,721 (23.8)	1,810,458	14.21	7.74 (7.39–8.09)	13.31	9.30 (8.85–9.78)
≥40	37,950 (35.1)	1,410,403	26.91	14.65 (14.01–15.32)	26.62	18.61 (17.57–19.57)
Race						
Black	26,653 (24.6)	2,606,758	10.22	1.51 (1.48–1.55)	6.49	1.26 (1.24–1.29)
White	70,003 (64.7)	9,443,633	7.41	1.10 (1.08–1.12)	5.65	1.10 (1.08–1.12)
Other	11,610 (10.7)	1,718,494	6.76	1.00	5.13	1.00
Service						
Army	47,509 (43.9)	4,896,729	9.70	1.42 (1.40–1.45)	7.47	1.49 (1.47–1.52)
Air Force	28,320 (26.2)	3,514,148	8.06	1.19 (1.16–1.22)	5.40	1.08 (1.06–1.10)
Marines	8,331 (7.7)	1,770,483	4.71	0.70 (0.68–0.72)	5.36	1.07 (1.05–1.10)
Navy	24,106 (22.3)	3,587,525	6.72	1.00	5.00	1.00
Rank						
Junior enlisted	21,688 (20)	6,068,170	3.57	0.62 (0.61–0.64)	7.42	1.67 (1.63–1.72)
Senior enlisted	63,625 (58.8)	5,480,215	11.61	2.02 (1.97–2.07)	6.61	1.49 (1.46–1.53)
Junior officers	7,746 (7.2)	1,348,994	5.74	1.00	4.43	1.00
Senior officers	15,207 (14)	871,506	17.45	3.04 (2.96–3.12)	4.96	1.12 (1.09–1.15)

* 95% CI = 95% confidence interval.
† Proportions may not sum to 100% due to rounding.
‡ Rate per 1,000 person-years; adjusted for sex, age, race, branch of military service, and military rank.

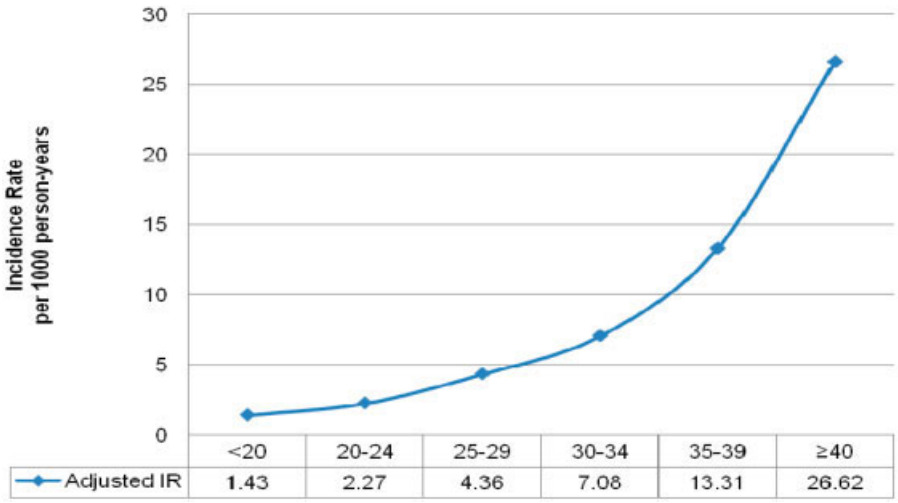

Figure 1. Increase in the adjusted incidence rate (IR) of osteoarthritis with increasing age among active duty US service members. Incidence rates were adjusted for sex, race, military rank, and branch of military service. Color figure can be viewed in the online issue, which is available at http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1529-0131.

Females experienced a slightly higher incidence rate for osteoarthritis when compared to males in the current study. The adjusted incidence rate for osteoarthritis was ~20% higher in women when compared to men after controlling for the influence of age, race, branch of military service, and military rank (Table 1).

An exponential increase in the incidence of osteoarthritis was observed with advancing age in the present study (Figure 1). The adjusted incidence rate for osteoarthritis was highest among service members in the ≥40-year age group (Table 1). Those in the oldest age group experienced incidence rates for osteoarthritis that were nearly 19 times higher than those of service members in the youngest age group (<20 years). Poisson regression results demonstrated an average 58.32% (95% CI 56.57–60.07) increase in the incidence rate of osteoarthritis per increase in age category ($P < 0.001$), while adjusting for the other demographic and occupational variables in the model. When crude unadjusted incidence rates for osteoarthritis by age were compared between the military population in the present study and the general population studied by Kopec et al (6), the rates were significantly higher among military service members for each age group (Table 2). Furthermore, the magnitude of the difference in incidence rates for osteoarthritis between those in the military and those in the general population increased with advancing age (Figure 2).

The incidence rate for osteoarthritis was significantly higher among black service members when compared with white service members and those in the "other" category for race (Table 1). Black service mem-

Table 2. Comparison of unadjusted incidence rates and rate ratios for osteoarthritis between military and general populations by age*

Age group, years	Military population, present study			General population, Kopec et al (13)			
	Incident cases	Person-years	Rate per 1,000 (95% CI)	Incident cases	Person-years	Rate per 1,000 (95% CI)	Incidence rate ratio (95% CI)
<20	2,030	1,105,294	1.84 (1.76–1.92)	–	990,112	–	–
20–24	12,859	4,562,576	2.82 (2.77–2.87)	576	257,861	2.23 (2.06–2.42)	1.26 (1.16–1.37)
25–29	14,260	2,869,395	4.97 (4.89–5.05)	833	265,419	3.14 (2.93–3.36)	1.58 (1.48–1.70)
30–34	15,446	2,010,759	7.68 (7.56–7.80)	1,336	290,244	4.60 (4.36–4.86)	1.67 (1.58–1.77)
35–39	25,721	1,810,458	14.21 (14.03–14.38)	2,319	327,474	7.08 (6.80–7.38)	2.01 (1.92–2.09)
≥40†	37,950	1,410,403	26.91 (26.64–27.18)	7,486	603,543	12.40 (12.12–12.69)	2.17 (2.12–2.22)

* 95% CI = 95% confidence interval.
† Incidence rate data for the 40–44-year and 45–49-year age groups from Kopec et al (6) were combined for this category.

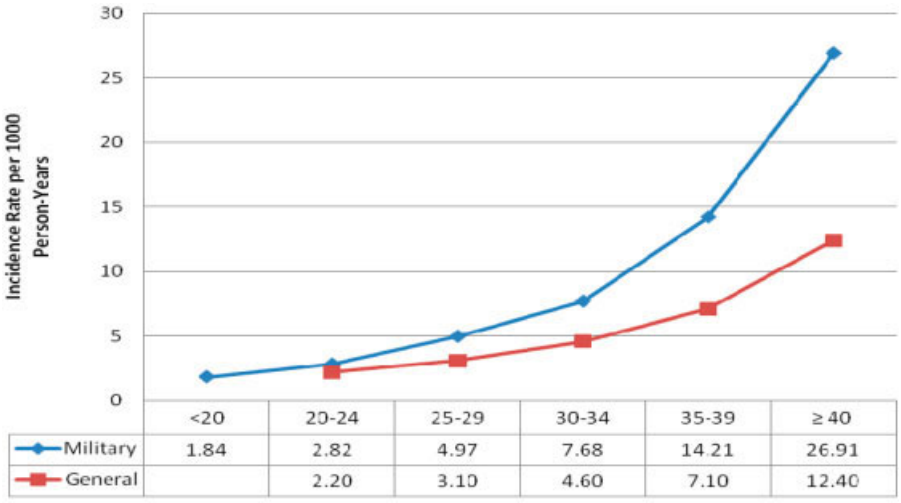

Figure 2. Comparison of unadjusted incidence rates for osteoarthritis between military and general populations by age. Incidence rate data for the 40–44-year and 45–49-year age groups in the general population studied by Kopec et al (6) were combined for the ≥40-year age group.

bers were 15% and 26% more likely to be diagnosed as having osteoarthritis than were service members in the white and "other" racial categories, respectively. White service members experienced a significantly higher rate of osteoarthritis (10%) when compared with those in the "other" category for race.

Branch of military service and military rank were important occupational factors associated with the incidence of osteoarthritis in the current study (Table 1). Those serving in the Army experienced the highest incidence rate for osteoarthritis, followed by those serving in the Air Force, Marine Corps, and Navy after controlling for sex, age, race, and military rank. Junior enlisted service members experienced the highest incidence rate for osteoarthritis after adjustment, followed by senior enlisted service members, senior officers, and junior officers.

DISCUSSION

In the current study, we examined the incidence of osteoarthritis among active duty US service members between 1999 and 2008 using data extracted from the DMSS and established operational definitions for osteoarthritis (6,13,34). The overall incidence rate for osteoarthritis in the present study was 7.86 cases per 1,000 person-years. Kopec et al (6) reported an incidence rate of 11.7 per 1,000 person-years for osteoarthritis over a 1-year period within the general population in British Columbia, Canada. Similar results were reported in a subsequent study by the same group; however, an increasing trend in the incidence of osteoarthritis over time was also observed (13). It should be noted that both of these studies included much older populations when compared to the current study. When the incidence rate for osteoarthritis within a comparable age range (20–49 years) is calculated from the data presented by Kopec et al (6), the incidence for osteoarthritis was 7.19 per 1,000 person-years, which is similar to the rate calculated for the present study.

Increasing age was associated with the incidence of osteoarthritis in the current study, and the observed increase was exponential in nature. Kopec et al (6) reported similar findings for the relationship between age and the incidence of osteoarthritis. They also observed an exponential increase in the incidence rate for osteoarthritis between the ages of 20 and 50 years; however, after age 50 years, this relationship was more linear in nature (6). Despite the similar findings between these 2 studies, the crude unadjusted incidence rate for osteoarthritis was significantly higher among active duty military personnel in the present study for each age category when compared to the data presented by Kopec et al (6) (Table 2). Furthermore, the incidence of osteoarthritis among military personnel increased at a greater rate with increasing age (Figure 2) when compared to the incidence in the study by Kopec et al (6). For example, the incidence rate for osteoarthritis was 26% higher in military service members within the

20–24-year age group; however, in the ≥40-year age group the incidence of osteoarthritis was over twice as high within the military population. The number of incident cases in those ages <40 years in the current study is noteworthy, particularly considering the disability-adjusted life years associated with osteoarthritis that will impact members of this relatively young group during their lifetime.

The difference in the incidence of osteoarthritis by age between the current study and the previous study by Kopec et al (6) may be attributable to differences in the 2 populations. Specifically, the increased physical activity and occupational demands among active duty military service members are worth mentioning, as these factors have been associated with the occurrence of osteoarthritis (7,11). Several other studies have identified a relationship between age and osteoarthritis; however, most of those studies have examined disease prevalence, and an increase in disease prevalence does not necessarily suggest an increase in incidence (13).

The adjusted incidence rate for osteoarthritis among women was nearly 20% higher than that in men in the present study. Scher et al (14) reported a similar finding for the relationship between sex and the incidence of primary hip osteoarthritis in an active duty military population. Previous studies have clearly demonstrated that women have higher prevalence and incidence rates for osteoarthritis (2,6,13). Kopec et al (6) reported overall incidence rates for osteoarthritis that were 34% higher for women when compared to men. While the incidence of osteoarthritis was higher in women in every age category studied, the difference in the incidence between men and women increased around the time of menopause (6). When the crude incidence rates for osteoarthritis between men and women were calculated from the data presented by Kopec et al (6) for a comparable age range (20–49 years), the incidence rate for osteoarthritis among women was 17% higher, which is similar to the results observed in the present study.

Race was associated with the incidence rate for osteoarthritis in the current study. Active duty US service members in the black racial category experienced a higher incidence rate of osteoarthritis than those in the white or "other" racial groups. To our knowledge, no previous studies have examined the relationship between race and the incidence of osteoarthritis in general. Scher et al (14) recently reported similar findings when examining the relationship between race and the incidence of primary hip osteoarthritis in a similar population, with the highest incidence rates among blacks, followed by whites and those in the "other" racial group. Recently reported results from the Johnston County Osteoarthritis Project suggest that estimates of the lifetime prevalence of symptomatic knee (37) and hip (38) osteoarthritis are similar for black and white racial groups; however, it is difficult to compare those findings with those of the current study because those investigators examined prevalence rather than incidence, and the population studied was ages ≥45 years at baseline (38). The Johnston County study has reported significantly more specific radiographic features associated with osteoarthritis among those in the black racial group in both the knee (39) and hip (40). Similar findings in the knee were reported by Mazzuca et al (41), who noted a 3-fold increase in osteophytosis and joint space narrowing among black subjects.

It has been suggested that basic anatomic, neuromuscular, and biomechanical differences by race, with higher bone mineral density (40,41) and greater muscle mass (41) within the black racial group, may contribute to altered weight bearing and loading associated with the joints in the lower extremity, which may account for these observed radiographic differences. Increased bone mineral density has been associated with increased risk of osteoarthritis in the lower extremity in previous studies (42). While these biomechanical and neuromuscular differences associated with race may not affect the lifetime prevalence of osteoarthritis, they may contribute to a higher rate of new disease onset in black service members as observed in the present study and in the study by Scher et al (14), particularly considering the young and physically active populations studied.

Occupational risk factors including military rank and branch of military service were associated with the incidence of osteoarthritis in the current study. Junior and senior enlisted service members and those serving in the Army experienced the highest incidence rates for osteoarthritis. Scher et al (14) reported similar findings for the incidence rate of primary hip osteoarthritis in a military population. It is likely that service members in these occupational groups engage in regular knee and hip bending and medium, heavy, or very heavy physical demands on a regular basis. They also engage in physical activities involving significant joint loading, particularly in the lower extremity. Previous studies have noted that high-level occupation-related physical demands, particularly those that involve bending, kneeling, climbing, and lifting, may be associated with knee (7,43–47) and hip (46–49) osteoarthritis. Although repetitive joint use has been described as a possible mechanism for this relationship, the causal biomechanical pathway is still

poorly understood (47). Military rank and branch of military service may be surrogate measures for engaging in these types of activities (14); however, further analysis by specific Department of Defense occupational groups is warranted to determine which occupational codes are associated with the highest incidence of osteoarthritis.

Military service members are also at increased risk for traumatic joint injuries (24,28–30), and joint trauma has been identified as a risk factor for osteoarthritis (9,10,37,38,50,51). It is unclear how many of the incident cases of osteoarthritis in the current study are the result of trauma, which is an inherent limitation of our data. However, joint trauma in military populations is associated with high rates of disability and medical discharge from military service (19,20,52–54). Further research is warranted into the relationship between traumatic joint injury and the incidence of posttraumatic osteoarthritis, particularly in high-risk populations such as athletes and active duty US military service members. The latter high-risk population may be well suited for studying the progression of posttraumatic osteoarthritis from the preinjury state due to the closed Military Health System and the available surveillance resources (21).

Administrative databases can be a useful source of information for osteoarthritis surveillance (6,13,14). When utilizing administrative data to estimate incidence rates for osteoarthritis, it is important to ensure that prevalent cases are excluded, as inclusion of these cases can inflate estimates of incidence (6). Furthermore, inclusion of prevalent cases can limit the ability to compare incidence rates between studies using similar methods. Kopec et al (6) utilized a 10-year run-in period to exclude prevalent cases from their study. In the present study, all active duty US service members in the study population completed a comprehensive medical evaluation upon entry to military service that would have likely identified prevalent cases of osteoarthritis during the accession process, and subsequently, all care was provided through the Military Health System. As a result, individuals with chronic or posttraumatic osteoarthritis or with physical abnormalities predisposing to osteoarthritis would have likely been disqualified from military service during accession and excluded from the study population (14,33).

There are some limitations associated with the present study that should be considered when interpreting the results, and many of these limitations have been discussed in previous reports (6,13,14,30). The quality of the administrative data extracted from the DMSS is dependent on the completeness, validity, consistency, timeliness, and accuracy of the data contained within the system (22). Coding errors associated with incident case diagnoses cannot be ruled out when using large administrative databases for epidemiologic research purposes. Misclassification of the outcome of interest introduces the potential for information bias, which may have resulted in underestimation of the true incidence of osteoarthritis in the present study; however, the likelihood of any differential misclassification is limited because these data are representative of multiple providers throughout the Military Health System who were unaware of whether participants were exposed to the factors of interest (30). Nondifferential misclassification likely results in the rate ratio being diluted and shifted toward the null (55).

Because we used an established general administrative definition for osteoarthritis, we were unable to examine the incidence rates at specific sites. Definitions used for incident cases of osteoarthritis may also influence observed incidence rates (6,13). Therefore, the results of the present study are probably most comparable to those of studies that have used similar definitions for incident cases of osteoarthritis, rather than to those of studies that have relied on patient self-report, radiographic criteria, or a combination of both (6,13). Because the population in the present study was relatively young, healthy, physically active, and employed, this group may have unique risk factors (e.g., rank, service) as well as protective factors (e.g., low body mass index), and generalization of the observed results may be limited to similar groups. Finally, in modeling the average percentage increase in the incidence rate of osteoarthritis with increasing age category, we assumed a linear relationship, which may have underestimated the magnitude of change.

Despite the limitations listed above, there are several strengths associated with using data from the DMSS in the current study, and many of these have been described previously (14,30). The present study is the largest known population-based study to examine the incidence of osteoarthritis in a relatively young and physically active population that is at increased risk for traumatic joint injuries—a group that has been understudied in relation to osteoarthritis. Therefore, the findings of this study may be applicable to younger individuals with athletic or occupational exposure to joint loading tasks. Few studies have examined the incidence rates for osteoarthritis, and those that have were conducted in general populations or have focused on specific sites (6,8,13). More than 100,000 incident cases were documented during the present study, in contrast

to the next largest population-based study, which documented just over 42,000 cases (6). This was possible because the DMSS captures incident cases and accurate exposure data for the entire population of active duty service members, and data were available for the population of interest during the entire study period. Therefore, the present study provided an opportunity to examine the incidence rate for osteoarthritis in a large and physically active population that receives their medical care within a closed healthcare system.

The current study utilized a large administrative database to examine the incidence of osteoarthritis and the influence of occupational and demographic risk factors on the rate of this debilitating condition using an established case definition (6,13,34). The Armed Forces Health Surveillance Center exerts a considerable amount of effort to ensure a standardized and consistent approach to data processing and validation, and only those records considered complete are processed into the DMSS (22). As a result, it is likely that nearly every patient encounter in a military treatment facility, as well as civilian-purchased care, was documented in the DMSS during the study period.

In conclusion, within active duty military populations, female sex, increased age, black race, service in the Army, and enlisted rank were associated with an increased incidence of osteoarthritis. The incidence of osteoarthritis within active duty military populations increases at a significantly higher rate with advancing age when compared to rates in the general population. Due to the high rates of traumatic joint injury within the military population, further research is needed to determine the incidence of posttraumatic osteoarthritis and to further delineate the risk factors associated with this condition within military populations.

AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be published. Dr. Cameron had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study conception and design. Cameron, Hsiao, Owens, Burks, Svoboda.

Acquisition of data. Cameron, Hsiao, Owens, Burks, Svoboda.

Analysis and interpretation of data. Cameron, Hsiao, Owens, Burks, Svoboda.

REFERENCES

1. Lawrence RC, Felson DT, Helmick CG, Arnold LM, Choi H, Deyo RA, et al, for the National Arthritis Data Workgroup. Estimates of the prevalence of arthritis and other rheumatic conditions in the United States. Part II. Arthritis Rheum 2008;58:26–35.
2. United States Bone and Joint Decade. Arthritis and related conditions. In: The burden of musculoskeletal diseases in the United States. Rosemont (IL): American Academy of Orthopaedic Surgeons; 2008. p. 71–96.
3. Yelin E, Murphy L, Cisternas MG, Foreman AJ, Pasta DJ, Helmick CG. Medical care expenditures and earnings losses among persons with arthritis and other rheumatic conditions in 2003, and comparisons with 1997. Arthritis Rheum 2007;56:1397–407.
4. Elders MJ. The increasing impact of arthritis on public health. J Rheumatol Suppl 2000;60:6–8.
5. Oliviero F, Ramonda R, Punzi L. New horizons in osteoarthritis. Swiss Med Wkly 2010;140:w13098.
6. Kopec JA, Rahman MM, Berthelot JM, Le Petit C, Aghajanian J, Sayre EC, et al. Descriptive epidemiology of osteoarthritis in British Columbia, Canada. J Rheumatol 2007;34:386–93.
7. Felson DT, Hannan MT, Naimark A, Berkeley J, Gordon G, Wilson PW, et al. Occupational physical demands, knee bending, and knee osteoarthritis: results from the Framingham Study. J Rheumatol 1991;18:1587–92.
8. Felson DT, Zhang Y, Hannan MT, Naimark A, Weissman BN, Aliabadi P, et al. The incidence and natural history of knee osteoarthritis in the elderly: the Framingham Osteoarthritis Study. Arthritis Rheum 1995;38:1500–5.
9. Lohmander LS, Englund PM, Dahl LL, Roos EM. The long-term consequence of anterior cruciate ligament and meniscus injuries: osteoarthritis. Am J Sports Med 2007;35:1756–69.
10. Englund M, Lohmander LS. Risk factors for symptomatic knee osteoarthritis fifteen to twenty-two years after meniscectomy. Arthritis Rheum 2004;50:2811–9.
11. Schouten JS, de Bie RA, Swaen G. An update on the relationship between occupational factors and osteoarthritis of the hip and knee. Curr Opin Rheumatol 2002;14:89–92.
12. Buckwalter JA, Lane NE. Athletics and osteoarthritis. Am J Sports Med 1997;25:873–81.
13. Kopec JA, Rahman MM, Sayre EC, Cibere J, Flanagan WM, Aghajanian J, et al. Trends in physician-diagnosed osteoarthritis incidence in an administrative database in British Columbia, Canada, 1996–1997 through 2003–2004. Arthritis Rheum 2008;59:929–34.
14. Scher DL, Belmont PJ Jr, Mountcastle S, Owens BD. The incidence of primary hip osteoarthritis in active duty US military servicemembers. Arthritis Rheum 2009;61:468–75.
15. Zhang Y, Niu J, Kelly-Hayes M, Chaisson CE, Aliabadi P, Felson DT. Prevalence of symptomatic hand osteoarthritis and its impact on functional status among the elderly: the Framingham Study. Am J Epidemiol 2002;156:1021–7.
16. Dillon CF, Rasch EK, Gu Q, Hirsch R. Prevalence of knee osteoarthritis in the United States: arthritis data from the Third National Health and Nutrition Examination Survey 1991-94. J Rheumatol 2006;33:2271–9.
17. Felson DT, Naimark A, Anderson J, Kazis L, Castelli W, Meenan RF. The prevalence of knee osteoarthritis in the elderly: the Framingham Osteoarthritis Study. Arthritis Rheum 1987;30:914–8.
18. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of knee symptoms and radiographic and symptomatic knee osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol 2007;34:172–80.
19. Amoroso PJ, Canham ML. Chapter 4. Disabilities related to the musculoskeletal system: Physical Evaluation Board data. Mil Med 1999;164:1–73.
20. Songer TJ, LaPorte RE. Disabilities due to injury in the military. Am J Prev Med 2000;18:33–40.

21. Rubertone MV, Brundage JF. The Defense Medical Surveillance System and the Department of Defense Serum Repository: glimpses of the future of public health surveillance. Am J Public Health 2002;92:1900–4.
22. Army Medical Surveillance Activity. Defense medical epidemiological database users guide: version 3.6.4. Silver Spring (MD): Armed Forces Health Surveillance Center; 2004.
23. Sleet DA, Jones BH, Amoroso PJ. Military injuries and public health: an introduction. Am J Prev Med 2000;18:1–3.
24. Cameron KL, Owens BD, DeBerardino TM. Incidence of ankle sprains among active-duty members of the United States Armed Services from 1998 through 2006. J Athl Train 2010;45:29–38.
25. Wolf JM, Dawson L, Mountcastle SB, Owens BD. The incidence of scaphoid fracture in a military population. Injury 2009;40: 1316–9.
26. Wolf JM, Mountcastle S, Owens BD. Incidence of carpal tunnel syndrome in the US military population. Hand (NY) 2009;4: 289–93.
27. Wolf JM, Sturdivant RX, Owens BD. Incidence of de Quervain's tenosynovitis in a young, active population. J Hand Surg Am 2009;34:112–5.
28. Owens BD, Dawson L, Burks R, Cameron KL. Incidence of shoulder dislocation in the United States military: demographic considerations from a high-risk population. J Bone Joint Surg Am 2009;91:791–6.
29. Owens BD, Mountcastle SB, Dunn WR, DeBerardino TM, Taylor DC. Incidence of anterior cruciate ligament injury among active duty US military servicemen and servicewomen. Mil Med 2007; 172:90–1.
30. Hsiao M, Owens BD, Burks R, Sturdivant RX, Cameron KL. Incidence of acute traumatic patellar dislocation among active-duty United States military service members. Am J Sports Med 2010;38:1997–2004.
31. Hauret KG, Jones BH, Bullock SH, Canham-Chervak M, Canada S. Musculoskeletal injuries description of an under-recognized injury problem among military personnel. Am J Prev Med 2010; 38:S61–70.
32. Hauret KG, Taylor BJ, Clemmons NS, Block SR, Jones BH. Frequency and causes of nonbattle injuries air evacuated from operations Iraqi Freedom and Enduring Freedom, U.S. Army, 2001-2006. Am J Prev Med 2010;38:S94–107.
33. Department of the Army. Army regulation 40–501: Standards of medical fitness. Washington (DC): Department of the Army; 2010. URL: http://www.apd.army.mil/pdffiles/r40_501.pdf.
34. Centers for Disease Control and Prevention. National Arthritis Data Workgroup ICD-9-CM diagnostic codes for arthritis and other rheumatic conditions. Atlanta: Centers for Disease Control and Prevention; 2004. URL: www.cdc.gov/arthritis/data_statistics/pdf/arthritis_codes_2004.pdf.
35. Knowles SB, Marshall SW, Guskiewicz KM. Issues in estimating risks and rates in sports injury research. J Athl Train 2006;41: 207–15.
36. Greenland S, Rothman KJ. Measures of occurrence. In: Rothman KJ, Greenland S, Lash TL, editors. Modern epidemiology. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2008. p. 32–50.
37. Murphy L, Schwartz TA, Helmick CG, Renner JB, Tudor G, Koch G, et al. Lifetime risk of symptomatic knee osteoarthritis. Arthritis Rheum 2008;59:1207–13.
38. Murphy LB, Helmick CG, Schwartz TA, Renner JB, Tudor G, Koch GG, et al. One in four people may develop symptomatic hip osteoarthritis in his or her lifetime. Osteoarthritis Cartilage 2010; 18:1372–9.
39. Braga L, Renner JB, Schwartz TA, Woodard J, Helmick CG, Hochberg MC, et al. Differences in radiographic features of knee osteoarthritis in African-Americans and Caucasians: the Johnston County Osteoarthritis Project. Osteoarthritis Cartilage 2009;17: 1554–61.
40. Nelson AE, Braga L, Renner JB, Atashili J, Woodard J, Hochberg MC, et al. Characterization of individual radiographic features of hip osteoarthritis in African American and white women and men: the Johnston County Osteoarthritis Project. Arthritis Care Res (Hoboken) 2010;62:190–7.
41. Mazzuca SA, Brandt KD, Katz BP, Ding Y, Lane KA, Buckwalter KA. Risk factors for early radiographic changes of tibiofemoral osteoarthritis. Ann Rheum Dis 2007;66:394–9.
42. Zhang Y, Hannan MT, Chaisson CE, McAlindon TE, Evans SR, Aliabadi P, et al. Bone mineral density and risk of incident and progressive radiographic knee osteoarthritis in women: the Framingham Study. J Rheumatol 2000;27:1032–7.
43. Coggon D, Croft P, Kellingray S, Barrett D, McLaren M, Cooper C. Occupational physical activities and osteoarthritis of the knee. Arthritis Rheum 2000;43:1443–9.
44. Jensen LK, Mikkelsen S, Loft IP, Eenberg W, Bergmann I, Logager V. Radiographic knee osteoarthritis in floorlayers and carpenters. Scand J Work Environ Health 2000;26:257–62.
45. Sandmark H, Hogstedt C, Vingard E. Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. Scand J Work Environ Health 2000;26:20–5.
46. Lau EC, Cooper C, Lam D, Chan VN, Tsang KK, Sham A. Factors associated with osteoarthritis of the hip and knee in Hong Kong Chinese: obesity, joint injury, and occupational activities. Am J Epidemiol 2000;152:855–62.
47. Allen KD, Chen JC, Callahan LF, Golightly YM, Helmick CG, Renner JB, et al. Associations of occupational tasks with knee and hip osteoarthritis: the Johnston County Osteoarthritis Project. J Rheumatol 2010;37:842–50.
48. Yoshimura N, Sasaki S, Iwasaki K, Danjoh S, Kinoshita H, Yasuda T, et al. Occupational lifting is associated with hip osteoarthritis: a Japanese case-control study. J Rheumatol 2000;27:434–40.
49. Coggon D, Kellingray S, Inskip H, Croft P, Campbell L, Cooper C. Osteoarthritis of the hip and occupational lifting. Am J Epidemiol 1998;147:523–8.
50. Cooper C, Inskip H, Croft P, Campbell L, Smith G, McLaren M, et al. Individual risk factors for hip osteoarthritis: obesity, hip injury, and physical activity. Am J Epidemiol 1998;147:516–22.
51. Tepper S, Hochberg MC. Factors associated with hip osteoarthritis: data from the First National Health and Nutrition Examination Survey (NHANES-I). Am J Epidemiol 1993;137:1081–8.
52. Dunn WR, Lincoln AE, Hinton RY, Smith GS, Amoroso PJ. Occupational disability after hospitalization for the treatment of an injury of the anterior cruciate ligament. J Bone Joint Surg Am 2003;85-A:1656–66.
53. Sulsky SI, Mundt KA, Bigelow C, Amoroso PJ. Case–control study of discharge from the U.S. Army for disabling occupational knee injury: the role of gender, race/ethnicity, and age. Am J Prev Med 2000;18:103–11.
54. Sulsky SI, Mundt KA, Bigelow C, Amoroso PJ. Risk factors for occupational knee related disability among enlisted women in the US Army. Occup Environ Med 2002;59:601–7.
55. Gordis L. More on causal inferences: biases, confounding, and interaction. In: Gordis L, editor. Epidemiology. 4th ed. Philadelphia: Saunders Elsevier; 2009. p. 247–63.