

The American Journal of Sports Medicine

<http://ajs.sagepub.com/>

Risk Factors for Chronic Exertional Compartment Syndrome in a Physically Active Military Population

Brian R. Waterman, Jet Liu, Ronald Newcomb, Andrew J. Schoenfeld, Justin D. Orr and Philip J. Belmont, Jr

Am J Sports Med 2013 41: 2545 originally published online August 2, 2013

DOI: 10.1177/0363546513497922

The online version of this article can be found at:

<http://ajs.sagepub.com/content/41/11/2545>

Published by:



<http://www.sagepublications.com>

On behalf of:



American Orthopaedic Society for Sports Medicine

Additional services and information for *The American Journal of Sports Medicine* can be found at:

Email Alerts: <http://ajs.sagepub.com/cgi/alerts>

Subscriptions: <http://ajs.sagepub.com/subscriptions>

Reprints: <http://www.sagepub.com/journalsReprints.nav>

Permissions: <http://www.sagepub.com/journalsPermissions.nav>

>> [Version of Record](#) - Nov 1, 2013

[OnlineFirst Version of Record](#) - Aug 2, 2013

[What is This?](#)

Risk Factors for Chronic Exertional Compartment Syndrome in a Physically Active Military Population

Brian R. Waterman,^{*†} MD, Jet Liu,[‡] BS, Ronald Newcomb,[†] DO, Andrew J. Schoenfeld,[†] MD, Justin D. Orr,[†] MD, and Philip J. Belmont Jr,[†] MD

Investigation performed at Department of Orthopaedic Surgery and Rehabilitation, William Beaumont Army Medical Center, El Paso, Texas

Background: Chronic exertional compartment syndrome (CECS) is a common source of lower extremity pain in physically active military service members. While anatomic risk factors of CECS have been proposed, there is no existing study that evaluates the correlation of demographic and occupational risk factors and the overall incidence rate of CECS in an active military population.

Hypothesis: Young, enlisted service members in the United States (US) ground military forces would demonstrate higher incidence rates of CECS in the study population because of greater exposure to at-risk dismounted activity on the battlefield and in training.

Study Design: Cohort study (prevalence); Level of evidence, 2.

Methods: A retrospective study of all US active military service members with diagnosed nontraumatic exertional compartment syndrome of the lower extremity (code 729.72 in the *International Classification of Diseases, 9th Edition*) between 2006 and 2011 was performed using the Defense Medical Epidemiology Database. Demographic and occupational risk factors such as sex, age, race, branch of military service, and military rank were individually subcategorized, and cumulative and subgroup incidence rates of CECS were calculated using a multivariate Poisson regression model.

Results: A total of 4100 diagnosed cases of CECS were identified within an at-risk population of 8,320,201, which correlates to an incidence rate of 0.49 cases per 1000 person-years. The annual adjusted incidence rate of CECS increased from 0.06 cases per 1000 person-years in 2006 to 0.33 cases per 1000 person-years in 2009. Increasing chronological age, female sex, white race, junior enlisted rank, and Army service were significantly correlated with an elevated risk for CECS.

Conclusion: This study systematically evaluated the epidemiology of CECS among an idealized subset at risk for this condition. Sex, age, race, military rank, and branch of service were all important factors associated with the incidence of CECS in this physically active population.

Keywords: chronic exertional compartment syndrome; exercise induced; epidemiology; military

Exercise-induced compartment syndrome, or chronic exertional compartment syndrome (CECS), is a frequently encountered source of lower extremity pain in athletic

*Address correspondence to Brian R. Waterman, MD, Department of Orthopaedic Surgery and Rehabilitation, William Beaumont Army Medical Center, 5005 North Piedras Street, El Paso, TX 79920-5001 (e-mail: brian.r.waterman@gmail.com).

[†]Department of Orthopaedic Surgery and Rehabilitation, William Beaumont Army Medical Center, El Paso, Texas.

[‡]Texas Tech University School of Medicine, Lubbock, Texas.

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

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

and military cohorts. With prolonged, intense physical activity, elevated intracompartmental pressures and increased metabolic demands contribute to relative tissue ischemia, nerve dysfunction, and secondary leg pain. While anatomic risk factors such as chronic fascial thickening with poor tissue compliance³ and limited capillary density⁴ have been proposed, few demographic and occupational risk factors have been identified in active patient populations. Similarly, the reported incidence of CECS in the general population is poorly defined and may vary widely, ranging between 10% and 60% in selected groups.^{13,15,17}

No formal studies have evaluated the overall incidence rate and risk factors of CECS in a high-risk cohort, such as the United States (US) military. To this end, the current study sought to describe the role of age, sex, race, military rank, and branch of military service on the incidence rate of CECS in the US military, using the Defense Medical Epidemiology Database (DMED). This dataset has been reliably utilized in the past to quantify the incidence rate of, and risk

factors for, general orthopaedic conditions in the military population.^{8,11,20} The capacity of this dataset to be meaningfully translated to the civilian population of the US has also been addressed.^{5,8,11,14,20} On the basis of previous studies, we hypothesized that young, enlisted service members in the ground military forces would demonstrate higher incidence rates of CECS in the study population because of greater exposure to at-risk dismounted activity on the battlefield and in training.

MATERIALS AND METHODS

After we obtained institutional review board approval, all US active-duty military service members with diagnosed nontraumatic exertional compartment syndrome of the lower extremity (code 729.72 of the *International Classification of Diseases, 9th Edition [ICD-9]*) between 2006 and 2011 were identified via electronic query of the DMED. The methodology of this dataset has been extensively described in prior publications.^{5,8,11,14,20} It should be recognized that the DMED captures all diagnoses for military service members whether they are rendered at a military installation or by civilian practitioners.

Military service members have intense physical requirements that may vary by branch of service and military occupational specialty (MOS), including the following at-risk activities: daily aerobic fitness, weight training, tactical field exercises, and military movements with heavy fighting loads (eg, 60 to >80 lb [27 to >36 kg]). Additionally, service members must meet specified height and weight standards and successfully complete a physical fitness test as measured by 3 events: timed push-up, sit-up, and aerobic event. Lastly, military personnel must maintain the physical capacity to perform up to a 12-month combat deployment in an austere environment.

Unadjusted incidence rates (IRs) were calculated using subcategorized demographic and occupational risk factors including sex, age, race, branch of military service, and military rank. Age was organized according to the following categories: <20, 20-24, 25-29, 30-34, 35-39, and ≥40 years. Racial categories were identified as white, black, or "other," where "other" includes Hispanic/Latino, Native American/Alaskan/Pacific Islander, Asian, other race, mixed race, and no race reported. Military service branches included Army, Marine Corps, Navy, and Air Force. Military rank was classified as junior enlisted (lowest 4 ranks in any branch), senior enlisted (noncommissioned officers), junior officer (lowest 3 officer ranks in any branch, including warrant officers), and senior officer (highest 6 officer ranks in any branch). Only "first occurrence" ambulatory data with a primary diagnosis of CECS were used in the analysis to exclude episodes in which repeat coding of the same injury transpired during follow-up evaluations.

Age, race, and sex were considered primary risk factors with immediate translation to the general civilian population. Military rank and branch of service may be viewed as proxies for activity level and at-risk occupational exposure, with Army and Marine Corps branches of service and junior enlisted personnel expected to have elevated activity levels as compared

with other subcategories within the cohorts of interest.¹³ Calendar year was also evaluated to determine temporal trends in the diagnosis of CECS of the lower extremity.

Multivariable Poisson regression was subsequently utilized to estimate the IR of CECS of the lower extremity in strata with preset controls and at-risk variables of interest. Adjusted incidence rate ratios (IRRs), derived by comparison of risk factors in subcategories of interest to predetermined referents, were generated along with 95% confidence intervals (CIs). By convention, referents were identified as the variable within the subcategory of interest that maintained the lowest unadjusted IR. For the category of race, only the variables of white or black were considered as viable potential referents because of the heterogeneity that exists in the racial category of "other." All statistical analyses were performed with SAS (SAS Institute, Cary, North Carolina), and a *P* value less than .05 was deemed statistically significant. To be considered important independent predictors of CECS, risk factors had to maintain an IR above the population mean and demonstrate an IRR and 95% CI exclusive of 1.0 as compared with their referent.

RESULTS

During the study period, a total of 4100 cases of CECS were identified in an at-risk population of 8,320,201 person-years. There was an average of 683 incident cases of CECS diagnosed per year between 2006 and 2011, with an overall unadjusted IR of 0.49 cases per 1000 person-years. The adjusted annual IR increased from 0.06 cases per 1000 person-years in 2006 to 0.33 cases per 1000 person-years in 2009 (Table 1).

Independently categorized demographic and occupational risk factors such as sex, age, race, military rank, and branch of service expressed varied IRs of CECS throughout the study period (Tables 2 and 3). When evaluating by age, a sequential increase in IRR was noted in each successive age group, with service members >40 years old demonstrating the highest IRR for CECS, nearly 9 times (IRR, 8.77; 95% CI, 7.31-10.52) greater than those <20 years old. Female service members had significantly higher IRRs for CECS than their male counterparts (IRR, 1.11; 95% CI, 1.01-1.21). When evaluated by race, white service members had significantly higher IRRs than black service members (IRR, 1.14; 95% CI, 1.05-1.24), while service members of other races demonstrated no statistically significant difference.

When evaluating by military rank, junior enlisted personnel had the highest IRR for CECS (IRR, 8.54; 95% CI, 7.04-10.36), and enlisted service members overall demonstrated significantly higher IRs than their officer counterparts. Army service members had the highest rates of CECS, followed by Air Force, Marine Corps, and Navy, respectively (Table 2).

DISCUSSION

Chronic exertional compartment syndrome of the lower extremity has long been recognized within the military

TABLE 1
IRs of CECS Among US Military Service Members by Calendar Year, 2006-2011^a

Calendar Year	No. of Cases	Person-Years	Unadjusted IR ^b	Increase From Previous Year, %	Adjusted IR ^c (95% CI)	Increase From Previous Year, %
2006	144	1,361,504	0.11	—	0.06 (0.05-0.07)	—
2007	751	1,360,444	0.55	422	0.32 (0.29-0.35)	418
2008	758	1,375,058	0.55	0	0.31 (0.28-0.35)	-1
2009	842	1,430,271	0.59	7	0.33 (0.30-0.36)	5
2010	818	1,378,298	0.59	1	0.33 (0.30-0.37)	0
2011	787	1,414,626	0.56	-6	0.31 (0.28-0.34)	-7

^aCECS, chronic exertional compartment syndrome; IR, incidence rate.

^bPer 1000 person-years.

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

TABLE 2
Unadjusted and Adjusted IRs and Adjusted IRRs of CECS Among US Military Service Members, 2006-2011^a

Category	No. of Cases	Person-Years	Unadjusted IR ^b	Adjusted IR (95% CI) ^c	Adjusted IRR (95% CI) ^c
Sex					
Male	3476	7,123,978	0.49	0.26 (0.24-0.28)	N/A
Female	624	1,196,223	0.52	0.29 (0.26-0.32)	1.11 (1.01-1.21)
Race					
Black	735	1,422,040	0.52	0.27 (0.24-0.29)	N/A
Other	455	1,097,961	0.41	0.26 (0.23-0.29)	0.97 (0.87-1.10)
White	2910	5,800,200	0.50	0.30 (0.28-0.33)	1.14 (1.05-1.24)
Military rank					
Junior enlisted	1934	3,644,024	0.53	0.71 (0.66-0.76)	8.54 (7.04-10.36)
Junior officers	277	829,764	0.33	0.27 (0.24-0.31)	3.24 (2.62-4.00)
Senior enlisted	1752	3,308,854	0.53	0.36 (0.34-0.39)	4.37 (3.66-5.23)
Senior officers	137	537,559	0.25	0.08 (0.07-0.10)	N/A
Branch of service					
Army	2059	3,189,887	0.65	0.40 (0.37-0.43)	2.72 (2.45-3.01)
Navy	446	1,980,190	0.23	0.15 (0.13-0.16)	N/A
Air Force	1164	1,989,453	0.59	0.37 (0.34-0.41)	2.54 (2.28-2.84)
Marine Corps	431	1,160,671	0.37	0.26 (0.23-0.29)	1.78 (1.56-2.03)

^aCECS, chronic exertional compartment syndrome; IR, incidence rate; IRR, incidence rate ratio; N/A, not applicable because this category was used as the referent category.

^bPer 1000 person-years.

^cAdjusted for sex, age, race, rank group, and service.

TABLE 3
IRRs of CECS Among US Military Service Members by Age Group, 2006-2011^a

Age Group, y	No. of Cases	Person-Years	Unadjusted IR ^b	Adjusted IR (95% CI)	Adjusted IRR (95% CI) ^c
<20	174	543,860	0.32	0.11 (0.09-0.13)	N/A
20-29	1963	4,710,807	0.42	0.17 (0.16-0.19)	1.60 (1.37-1.87)
30-39	1029	2,188,404	0.47	0.32 (0.29-0.34)	2.90 (2.44-3.46)
40+	934	877,130	1.06	0.95 (0.87-1.04)	8.77 (7.31-10.52)

^aCECS, chronic exertional compartment syndrome; IR, incidence rate; IRR, incidence rate ratio; N/A, not applicable because this category was used as the referent category.

^bPer 1000 person-years.

^cAdjusted for sex, race, rank group, and service. The <20-year-old group was used as the referent category.

community. While early descriptions are attributed to civilian physicians, Vogt is credited as being one of the earliest medical sources to describe the atraumatic onset of ischemic necrosis of the anterior tibialis muscle among

American soldiers.^{7,19} This condition would later be defined using the military appellation of "march gangrene."² The pathophysiology of CECS has been debated in subsequent series involving military cohorts.^{1,10,13,16,19}

However, because of its infrequent presentation, no known studies have systematically evaluated the epidemiology of CECS or described risk factors associated with its development.

With 4100 cases of CECS among active-duty military service members, the current study revealed the overall incidence to be approximately 1 in 2000 persons per year. The diagnosis of traumatic compartment syndrome of the leg showed a significant increase over the course of this study (Table 1), likely reflective of the fact that *ICD-9* coding for this condition was only formally introduced in 2005. While there is inconsistency in diagnostic criteria¹⁷ and specificity, the increased annual IRs at the beginning of the study can be largely attributed to greater awareness among treating physicians of coding for CECS, while the later sustained high IRs of CECS likely reflect the increasing tempo of current military engagements, rapid deployment cycles, and cumulative physical burdens among service members over the study period. The major strength of the current study is the large sample size of active-duty service members captured in the military health care system and included in the DMED. Further, this study includes a unique population of highly functional patients to best determine the incidence of CECS in such an active cohort.

Early studies have emphasized the prevalence of CECS among young, active male patients, while more recent investigators reported no difference between men and women.^{3,12,13} Despite these studies, a contemporary series of 611 military service members undergoing fasciotomy for CECS revealed the preponderance among this traditional male cohort, with approximately 92% of patients being male and being a mean age of 28 years.¹⁸ However, the current study challenges this traditional dogma, with higher IRs encountered among female patients and those of greater chronological age. Edmundsson et al⁴ also highlighted the presence of CECS among older patients as well as women among 63 consecutive patients presenting to a tertiary referral center. Given the closed patient population and consecutive enrollment, our findings may better reflect the burden of CECS among athletic cohorts. In addition, because of its design and utilization of the DMED, this study may be less limited by sampling bias, study power, and/or differences in rates of at-risk exposure. With the current military conflicts, the fighting force has expanded significantly, particularly among nontraditional demographic groups (eg, older age, female), which stands in sharp contrast to historical cohorts composed primarily of young, active male recruits. Given the uniform standards for physical fitness and routine occupational demands among junior military service members, older cohorts with an undetected predisposition toward CECS might develop clinically significant symptoms, whereas this may not have been previously appreciated given the lack of at-risk activity. Additionally, we cannot exclude a certain age-related phenomenon or morphological changes within the fascia or vasculature of the leg in response to repetitive loading common to the military.

In light of the unique physical demands of active-duty service, military service members are at risk for developing CECS. Junior enlisted personnel had the highest IRR

within the category of rank, and Army service was associated with the highest IRR for CECS among the military branches. Senior enlisted and commissioned officers generally have lesser physical demands than their junior enlisted counterparts^{5,14} as well as the ability to moderate activity levels to accommodate certain limitations. Conversely, routine aerobic physical fitness, dismounted field exercises, and prolonged marching with heavy load-bearing equipment may contribute to the increased IR of CECS among junior enlisted personnel, particularly those in combat arms branches and ground military forces vis-à-vis the Air Force and Navy. Given the uneven terrain, mountain topography, and atypical warfare within the Afghanistan theater of operations, land-based operations required greater dismounted activity among more agile, mobile units, largely among Army and Marine Corps forces. Jones and colleagues⁹ have previously demonstrated similar trends in injury epidemiology and health care utilization when evaluating by branch of military service. In their analysis of all medical encounters for nondeployed, active-duty personnel between 2000 and 2006, Army service members had the highest rates of overall injury and specifically lower extremity overuse injuries within the Department of Defense, while the Navy demonstrated the lowest rates. Furthermore, Air Force and Marine Corps personnel showed similarly increasing rates of overuse lower extremity injuries over the study period, although no measures of statistical significance were performed.

While Marine Corps personnel also share many of the activity-related risks associated with Army service, the IR for the Marine Corps did not exceed the population average. This may be indicative of cultural attitudes toward health care utilization specific to that branch of service, a finding that has been recognized in other works conducted with the DMED.¹³ Those in the Marine Corps with CECS may be more reticent to seek care for this condition or separate from the service through other means before a diagnosis can be made. We recognize that this may represent an element of underreporting that cannot be controlled for, and this is reflective of some of the limitations associated with the use of current military datasets.⁶

Other limitations include the fact that we cannot mitigate the potential role of provider miscoding or errors in clinical diagnosis, such as may occur in patients with underlying medial tibial stress syndrome or isolated fascial defects. However, given the predisposition toward CECS, surveillance and screening mechanisms for such conditions are well developed within the military health care system. As well, the data are based on patient-driven clinic visits, and those who have symptomatic CECS but do not seek medical care would not be identified in the data. An additional limitation is the absence of radiographic studies or confirmatory manometry testing performed in association with an exercise challenge. While these tests are generally performed in the military setting as part of the standard evaluation of CECS, their results are not registered with the DMED. The occupational and demographic risk factors evaluated in this study are also limited to those contained within the DMED, and MOS, exposure to a combat/

training environment, and/or temporal trends cannot be fully controlled for. However, we believe that these results can be appropriately used to compare with other physically active patient populations with frequent exposure to high-demand sporting (eg, running, ball sports) or occupational activities (eg, police, firefighters).

CONCLUSION

The average annual incidence of CECS among US military service members during the years of 2006 to 2011 was found to be approximately 0.49 per 1000 at-risk person-years. Using multivariate analysis, female sex, increasing chronological age, white race, junior enlisted rank, and Army service were factors significantly associated with higher IRs of CECS in the current study. While judicious clinical judgment and careful history and physical examination remain the hallmarks for diagnosis of this condition, our results suggest that the prevalence of CECS among nontraditional demographic subgroups, such as female patients and older service members, may have been previously underreported. Further research is needed to evaluate the role that these factors may play in influencing clinical outcomes, including their effect on the results of nonoperative and surgical management.

ACKNOWLEDGMENT

The authors thank Julia Bader, PhD, of the University of Texas at El Paso for her statistical support in this investigation.

REFERENCES

- Almdahl SM, Samdal F. Fasciotomy for chronic compartment syndrome. *Acta Orthop Scand*. 1989;60(2):210-211.
- Blandy J, Fuller R. March gangrene: ischaemic myositis of the leg muscle from exercise. *J Bone Joint Surg Br*. 1957;39(4):679-693.
- Detmer DE, Sharpe K, Sufit RL, Girdley FM. Chronic compartment syndrome: diagnosis, management, and outcomes. *Am J Sports Med*. 1985;13(3):162-170.
- Edmundsson D, Toolanen G, Sojka P. Chronic compartment syndrome also affects nonathletic subjects: a prospective study of 63 cases with exercise-induced lower leg pain. *Acta Orthop*. 2007;78(1):136-142.
- Ernat J, Knox J, Orchowski J, Owens B. Incidence and risk factors for acute low back pain in active duty infantry. *Mil Med*. 2012;177:1348-1351.
- 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(1S):S61-S70.
- Horn CE. Acute ischaemia of the anterior tibial muscle and the long extensor muscles of the toes. *J Bone Joint Surg Am*. 1945;27(4):615-622.
- 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.
- Jones BH, Canham-Chervak M, Canada S, Mitchener TA, Moore S. Medical surveillance of injuries in the U.S. military: descriptive epidemiology and recommendations for improvement. *Am J Prev Med*. 2010;38(1S):S42-S60.
- Leach RE, Hammond G, Stryker WS. Anterior tibial compartment syndrome: acute and chronic. *J Bone Joint Surg Am*. 1967;49(3):451-462.
- Orr JD, Dawson LK, Garcia EJ, Kirk KL. The incidence of osteochondral lesions of the talus in the United States military. *Foot Ankle Int*. 2011;32(10):948-954.
- Pedowitz RA, Hargens AR, Mubarak SJ, Gershuni DH. Modified criteria for the objective diagnosis of chronic compartment syndrome of the leg. *Am J Sports Med*. 1990;18(1):35-40.
- Qvarfordt P, Christenson JT, Eklöf B, Ohlin P, Saltin B. Intramuscular pressure, muscle blood flow, and skeletal muscle metabolism in chronic anterior tibial compartment syndrome. *Clin Orthop Relat Res*. 1983;179:284-290.
- Schoenfeld AJ, Laughlin M, Bader JO, Bono CM. Characterization of the incidence and risk factors for the development of lumbar radiculopathy. *J Spinal Disord Tech*. 2012;25:163-167.
- Styf JR, Korner LM. Chronic anterior-compartment syndrome of the leg: results of treatment by fasciotomy. *J Bone Joint Surg*. 1986;68:1338-1347.
- Tubb CC, Vermillion D. Chronic exertional compartment syndrome after minor injury to the lower extremity. *Mil Med*. 2001;166(4):366-368.
- Tzortziou V, Maffulli N, Padhiar N. Diagnosis and management of chronic exertional compartment syndrome (CECS) in the United Kingdom. *Clin J Sport Med*. 2006;16(3):209-213.
- Waterman BR, Laughlin MD, Kilcoyne K, Cameron KL, Owens BD. Surgical treatment of chronic exertional compartment syndrome of the leg: failure rates and postoperative disability in an active patient population. *J Bone Joint Surg Am*. 2013;95(7):592-596.
- Webb LX, Grossling S. Exertional compartment syndrome in a Marine grunt. *Mil Med*. 1992;157(3):154-155.
- Wolf JM, Mountcastle S, Burks R, Sturdivant RX, Owens BD. Epidemiology of lateral and medial epicondylitis in a military population. *Mil Med*. 2010;175:336-339.