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original research

Incidence and Characteristics of Meniscal Injuries in Cadets at a Military School, 2013–2015

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Context: Meniscal injury is common among military service members.

Objective: To examine the incidence and characteristics of meniscal injuries in cadets at a single military institution between 2013 and 2015.

Design: Cohort study.

Setting: Meniscal-injury data were collected at the Center of Rehabilitation Training, the People's Liberation Army University of Science and Technology.

Patients or Other Participants: A total of 2479 cadets participating in physical activities between 2013 and 2015.

Main Outcome Measure(s): Injury rates, injury proportions by body mass index, risk ratios (RRs), and injury proportion ratios were reported with 95% confidence intervals (CIs).

Results: The overall incidence rate was 10.08 (95% CI = 6.84, 14.84) per 1000 person-years. A multiple-comparisons test revealed differences in the relative injury rate in overweight or obese cadets versus normal-weight cadets and underweight cadets ($\chi^2 = 8.98$, $P = .01$). No differences were found between injured normal-weight cadets and underweight cadets ($P = .66$, RR = 1.39, 95% CI = 0.32, 6.06) or between injured overweight or obese cadets and injured underweight cadets ($P = .24$, RR = 0.42, 95% CI = 0.09, 1.91). The absolute injury rate was higher for overweight and obese cadets compared with normal-weight cadets ($P < .01$, RR = 0.30, 95% CI = 0.13, 0.69). The overall proportional distribution for patterns of injury was 2:1 (medial to lateral) for meniscal injuries. Grade 2 injuries were the most common.

Conclusions: The high frequency and level of severity of meniscal injuries may negatively affect the readiness and health of cadets. High body mass index was a risk factor for meniscal injury.

Key Words: physical activities, injury epidemiology, injury surveillance

Key Points

- The incidence rate of meniscal injury was 10.08 per 1000 person-years.
- Injured overweight or obese cadets had a higher absolute rate of meniscal injuries than did injured normal-weight cadets.
- Medial-meniscal injuries were twice as frequent as lateral-meniscal injuries.
- Cadets with a high body mass index were at greater risk for meniscal injury.

Military cadets are required to participate in sports, recreation, and physical training as part of their education. As cadets strive to improve their performance, injury rates often increase. Musculoskeletal injuries place a significant burden on military service members and the military health system and are a leading cause of disability discharge.[1] Among musculoskeletal injuries, meniscal injury is a common knee condition with an incidence of 8.27 per 1000 person-years among active-duty US military service members.[2] In addition, the incidence of meniscal tears among military cadets has been reported to be 10 times higher than that of the civilian population.[2] Meniscal injury has negative effects on morbidity, training time, resources, and performance[3] and commonly occurs at military training establishments worldwide.[1]

Information detailing the types of injuries, such as location, activity, and mechanism, is essential for understanding the injury epidemiology of a community.[4] Moreover, the identification of injury-associated activities is an early step in the injury-prevention process.[5] The menisci in the medial and lateral tibiofemoral knee compartments are critical to normal joint function.[6] Meniscal injuries have also been associated with long-term dysfunction, degenerative joint changes, and osteoarthritis of the knee.[2] We therefore aimed to examine meniscal-injury epidemiology among cadets at the College of Basic Education for Commanding Officers, the People's Liberation Army (PLA) University of Science and Technology.

METHODS

Participants and Study Design

This investigation assessed the epidemiology of meniscal injuries over a 2-year period, from August 2013 to August

Table 1. The Distribution of Meniscal Injuries by Body Mass Index

Body Mass Index (kg/m^2)	Injured? (n)			
	Yes	No	Total (n)	Injured (%)
<18.5	2	195	197	1.02
18.5–24.0	14	1898	1912	0.73
>24.0	9	361	370	2.43

2015, within the cadet population at the College of Basic Education for Commanding Officers. Ethical approval for this study conformed to the standards of the Declaration of Helsinki, and the protocol was approved by the institutional review board of the PLA University of Science and Technology.

Over the course of the 2 years, the population included all cadets in attendance during the study period (August 2013 to August 2014, n = 1636; August 2014 to August 2015, n = 843; in total, N = 2479). During this period, all injured cadets took part in rehabilitation training at the Center of Rehabilitation Training, the PLA University of Science and Technology. During rehabilitation, all study participants were required to provide individual clinical records and individual clinical judgments, which were recorded by a physical therapist and athletic trainers. Data fields included age of injury, grade of injury, injury diagnosis, anatomic location of injury, whether treatment was for a new injury or follow-up for a previous injury, and the *time lost to injury*, defined as the period of detraining. Detraining referred to missed physical training and any other training activities. Diagnosis was based on the care provider's clinical judgment and was described using the Stoller et al[7] classification system. The diagnosis of meniscal tear by magnetic resonance imaging was performed by radiologists.

Body mass index (BMI) data were based on the standards of the National Physique Examination.[8] Each cadet was required to undergo a physical examination before university entrance. Each year, the cadet was required to repeat the physical examination. A database was used to record these data. Each cadet's BMI could therefore be retrieved from the database. The weight measured nearest the time of injury was used in the study.

Common activities included physical training for approximately 1.5 hours in the afternoon in addition to field exercises involving obstacle courses, rifle marksmanship, road marching, and orienteering.

Statistical Analyses

All data are expressed as mean ± standard deviation. The BMI was calculated as weight divided by height squared, based on the National Physique Monitoring data or a physical examination of each cadet.[8] The overall incidence rate for meniscal injuries in the study population was calculated by dividing the total number of incident injuries by the total person-years at risk and expressing the rate per 1000 person-years.[2] We used the Student *t* test to assess differences in the mean values between injured and uninjured cadets. A multiple-comparisons test was conducted to compare the BMI distributions of the injured cadets. Statistical analyses were performed using OpenEpi (version 3.03A; Emory University, Atlanta, GA). All calculations are presented with 95% confidence intervals (CIs). A value of $P < .05$ was considered statistically significant.

Table 2. Distribution of Meniscal Injuries (n = 25)

Injury Pattern	All Injuries, n (%)
Medial meniscus	17 (68)
Lateral meniscus	8 (32)

RESULTS

Anthropometric Characteristics and BMI Distributions

The BMI distributions of cadets with and without injuries are shown in Table 1. The age, height, weight, and BMI of 2479 cadets were 19.50 ± 1.6 years, 172.3 ± 5.7 cm, 66.90 ± 8.9 kg, and 22.5 ± 2.5 kg/m^2, respectively. According to the Chinese standards for BMI, a BMI < 18.5 kg/m^2 is *underweight*, 18.5 kg/m^2 ≤ BMI < 24.0 kg/m^2 is *normal weight*, and 24.0 kg/m^2 < BMI is *overweight and obese*. Among the 2479 cadets, the BMI distribution was 15.0% (n = 370) underweight, 77.1% (n = 1912) normal weight, and 8.0% (n = 197) overweight or obese.

The age, height, weight, and BMI of the cadets with meniscal injuries were 20.2 ± 1.4 years, 171.3 ± 6.0 cm, 66.3 ± 9.7 kg, and 22.5 ± 2.2 kg/m^2, respectively. Among the 25 injured cadets, 2 (8.7%) were underweight, 14 (56.0%) were normal weight, and 9 (36.0%) were overweight or obese. Overall, the injured and uninjured cadets exhibited no statistically significant differences in age, height, weight, or BMI (*P* values = .43, .65, .48, and .45, respectively). The injury rates were also compared among groups by BMI distribution. A multiple-comparisons test revealed differences in the relative injury rate among injured underweight cadets, normal-weight cadets, and overweight or obese cadets ($\chi^2 = 8.98$, $P = .01$). No differences were found between injured normal-weight and injured underweight cadets ($P = .66$, risk ratio [RR] = 1.39, 95% CI = 0.32, 6.06) or between injured overweight or obese and injured underweight cadets ($P = .24$, RR = 0.42, 95% CI = 0.09, 1.91). Overall, the absolute injury rate was higher among injured overweight or obese individuals compared with injured normal-weight cadets ($P < .01$, RR = 0.30, 95% CI = 0.13, 0.69). Thus, high BMI was considered a risk factor for meniscal injury.

Incidence and Distribution of Meniscal Injury

During the study period, 25 new meniscal injuries (n = 14, from August 2013 to August 2014; n = 11, from August 2014 to August 2015) occurred among the 2479 cadets. During the 2 years, an average of 12.5 acute meniscal injuries were diagnosed each year. The overall incidence rate was 10.08 (95% CI = 6.17, 13.99) per 1000 person-years. Cadets with a meniscal injury had no history of injury. Twelve of these meniscal injuries occurred during initial training (6 months), and 13 occurred during advanced training stages.

Patterns of Meniscal Injury

The patterns of meniscal injury are shown in Table 2. The overall proportional distribution was a ratio of 2 : 1 for

medial- to lateral-meniscal injuries. Grade 1 injuries totaled 6 (26.1%); grade 2 injuries, 14 (56.5%); and grade 3 injuries, 5 (17.4%). Grade 2 injuries were the most common. Only 2 patients underwent concurrent reconstruction of the anterior cruciate ligament.

Time Lost to Injury

Meniscal injury resulted in a total of 1695 days lost to injury. The average time lost per injury was 67.80 ± 44.41 days, and the average time lost per cadet (1695/2479) was 0.68 days.

DISCUSSION

The overall incidence rate of meniscal injury was 10.08 (95% CI = 6.84, 14.84) per 1000 person-years. Meniscal injuries manifest with pain, swelling, and frequent articular obstructions, thereby reducing performance and, in some cases, leading the affected cadets to suspend their military careers. Meniscal injury in younger patients is likely to be the consequence of an acute traumatic event.[9] However, authors[10] of a previous study indicated that because military training involves a physical component and soldiers and trainees are often involved in more than 1 training activity over a given time period, establishing a direct causal link between physical activities and injuries over time is difficult. Moreover, Knapik et al[11] recently suggested that these injuries exhibit a gradual onset, and they could not identify a specific injury-inducing event. It is also possible that many of the gradual-onset injuries were aggravated by running, marching, or other repetitive weight-bearing activities.[11]

It is widely known that soldiers require a certain level of overall fitness to meet the physical demands of military tasks.[12] Jumping, crawling, rolling, stopping, starting, bounding, climbing, pushing, sprinting from cover to cover, and carrying heavy loads for long distances while maintaining the ability to complete the mission at hand are common tasks in which the knee joint is subject to constant physical stresses.[12] In our study, the incidence of meniscal tears was much higher than the rate reported by Jones et al.[2] The incidence rate among active-duty US service members aged 20 to 24 years was only 4.25 per 1000 person-years.[2] At present, although the factors determining injury risk are multifactorial and complex, several major risk factors (either intrinsic or extrinsic) for musculoskeletal injuries have been identified, such as demographic characteristics, anatomic factors, running mileage, and aerobic fitness level.[5] For example, previous researchers[5,13–15] have reported that low levels of fitness, slower 2-mile run times, and excessive running are associated with a greater risk of injury. Many critical movements in military physical tasks such as sprinting, jumping, and climbing, which require muscle strength and power as well as adequate size and quality of connective tissue (ie, ligaments, cartilage, and tendons), are executed as forcefully and quickly as possible.[16] For example, thickening of the knee-joint cartilage in elite weight lifters is known to represent a potential adaptation mechanism.[17] However, in practice, excessive endurance training does not equip cadets to perform high-intensity occupational tasks. Although this topic must be explored more extensively, sustained aerobic training acts as a negative adaptive stimulus in connective tissue or muscle hypertrophy, strength, and power, which may lead to a decrease in force production.[16] When an individual is performing high-intensity tasks, the risk of knee injury therefore increases. Thus, the mismatch between intrinsic capacity and extrinsic demands may contribute to the higher overall risk for meniscal injury observed in our study population. It is also possible that a lack of exercise experience or low levels of physical fitness may have resulted in the increased number of meniscal injuries we noted.

We found that the distribution of medial- to lateral-meniscal injuries was 2 : 1. Previous investigators[2,18,19] have shown that in patients requiring meniscectomy, the medial meniscus is injured between 2 and 4 times more frequently than the lateral meniscus. The proportional distribution seen in our study was therefore similar to the distribution of meniscal injuries among patients requiring surgical intervention. Moreover, as previously suggested, the disproportionate number of medial-meniscal injuries has been attributed to anatomical differences between the medial and lateral menisci[2]; the medial meniscus is firmly attached to the joint capsule and is less mobile than the lateral meniscus, making it is more susceptible to injury.[6]

In addition, it is critical to identify and focus on modifiable risk factors for preventing meniscal injury. In the present study, overweight or obese cadets were at greater risk of meniscal injury compared with cadets of normal weight. Recently, Knapik[20] indicated that because the presence of additional fat increases the intensity of physical activity, the musculoskeletal system must experience more rapid fatigue and repetitive stress; thus, for soldiers with high BMIs, the injury risk might be increased. Furthermore, given the lack of muscle mass or strength in the supporting structures (ligaments, bones) required to perform certain physical tasks, cadets with low BMIs may also face increased injury risk.[20] However, in the present study, we observed no significant difference in the relative injury rate between injured normal-weight and underweight cadets. Given that all cadets must complete regular fitness tests, it is likely that the underweight cadets spent longer periods training and thereby achieved higher levels of overall fitness. At present, although most risk factors associated with meniscal injury are unknown, research[4] has clearly indicated that a significant proportion of injuries are considered preventable and may be mitigated with human-performance programs. Thus, military activity-specific repetitive-movement patterns and injury-risk minimization through preventive or corrective neuromuscular training of movement impairments should be incorporated and emphasized in military populations.[21]

One limitation of our study was its reliance on a physician's diagnosis of meniscal injury without the use of a standardized test. However, all diagnoses were made at the same magnetic resonance imaging center, which may have prevented interobserver variability. Another limitation of our study was that all data were collected from a single institution. Therefore, the incidence of meniscal injuries reported here might not be applicable to other military settings. In addition, no effort was made to examine any anatomical factors or health care costs related to the management of these injuries; these topics will be the subject of future analyses.

CONCLUSIONS

Overall, these findings indicate a higher incidence of medial-meniscal injuries compared with lateral-meniscal injuries. Future authors should focus on designing effective injury-prevention programs.

REFERENCES

1. Cameron KL, Owens BD. The burden and management of sports-related musculoskeletal injuries and conditions within the US military. *Clin Sports Med*. 2014;33(4):573–589.
2. Jones JC, Burks R, Owens BD, Sturdivant RX, Svoboda SJ, Cameron KL. Incidence and risk factors associated with meniscal injuries among active-duty US military service members. *J Athl Train*. 2012; 47(1):67–73.
3. Bergeron MF, Nindl BC, Deuster PA, et al. Consortium for Health and Military Performance and American College of Sports Medicine consensus paper on extreme conditioning programs in military personnel. *Curr Sports Med Rep*. 2011;10(6):383–389.
4. Abt JP, Sell TC, Lovalekar MT, et al. Injury epidemiology of US Army Special Operations forces. *Mil Med*. 2014;179(10):1106–1112.
5. Jones BH, Knapik JJ. Physical training and exercise-related injuries: surveillance, research and injury prevention in military populations. *Sports Med*. 1999;27(2):111–125.
6. Englund M, Guermazi A, Lohmander SL. The role of the meniscus in knee osteoarthritis: a cause or consequence? *Radiol Clin North Am*. 2009;47(4):703–712.
7. Stoller DW, Martin C, Crues JV III, Kaplan L, Mink JH. Meniscal tears: pathologic correlation with MR imaging. *Radiology*. 1987; 163(3):731–735.
8. Tian Y, Jiang C, Wang M, et al. BMI, leisure-time physical activity, and physical fitness in adults in China: results from a series of national surveys, 2000–14. *Lancet Diabetes Endocrinol*. 2016;4(6): 487–497.
9. Zedde P, Mela F, Del Prete F, Masia F, Manunta AF. Meniscal injuries in basketball players. *Joints*. 2015;2(4):192–196.
10. Orr RM, Pope R, Johnston V, Coyle J. Soldier occupational load carriage: a narrative review of associated injuries. *Int J Inj Contr Saf Promot*. 2014;21(4):388–396.
11. Knapik JJ, Graham BS, Rieger J, Steelman R, Pendergrass T. Activities associated with injuries in initial entry training. *Mil Med*. 2013;178(5):500–506.
12. Heinrich KM, Spencer V, Fehl N, Poston WS. Mission essential fitness: comparison of functional circuit training to traditional army physical training for active duty military. *Mil Med*. 2012;177(10): 1125–1130.
13. Heir T, Eide G. Injury proneness in infantry conscripts undergoing a physical training programme: smokeless tobacco use, higher age, and low levels of physical fitness are risk factors. *Scand J Med Sci Sports*. 1997;7(5):304–311.
14. Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW, Frykman PN. Epidemiology of injuries associated with physical training among young men in the army. *Med Sci Sports Exerc*. 1993; 25(2):197–203.
15. Knapik JJ, Sharp MA, Canham-Chervak M, Hauret K, Patton JF, Jones BH. Risk factors for training-related injuries among men and women in basic combat training. *Med Sci Sports Exerc*. 2001;33(6): 946–954.
16. Elliott MC, Wagner PP, Chiu L. Power athletes and distance training: physiological and biomechanical rationale for change. *Sports Med*. 2007;37(1):47–57.
17. Grzelak P, Domzalski M, Majos A, et al. Thickening of the knee joint cartilage in elite weightlifters as a potential adaptation mechanism. *Clin Anat*. 2014;27(6):920–928.
18. Majewski M, Susanne H, Klaus S. Epidemiology of athletic knee injuries: a 10-year study. *Knee*. 2006;13(3):184–188.
19. Englund M, Roos EM, Roos HP, Lohmander LS. Patient-relevant outcomes fourteen years after meniscectomy: influence of type of meniscal tear and size of resection. *Rheumatology (Oxford)*. 2001; 40(6):631–639.
20. Knapik JJ. The importance of physical fitness for injury prevention: part 2. *J Spec Oper Med*. 2015;15(2):112–115.
21. Teyhen D, Bergeron MF, Deuster P, et al. Consortium for health and military performance and American College of Sports Medicine Summit: utility of functional movement assessment in identifying musculoskeletal injury risk. *Curr Sports Med Rep*. 2014;13(1):52–63.

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