Firefighters Have a Higher Incidence of Trochlear Chondral Lesions than the Normal Population

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Abstract *Background:* Firefighters' knees are subjected to significant dynamic and static forces, resulting in increased knee complaints and a higher relative risk of osteoarthritis, compared with aged-matched office workers. Firefighters wear or carry a total of 80 to 100 lbs. of gear while performing intensive physical activity. *Purpose/Question:* The purpose of this study was to determine whether a central femoral trochlear lesion was observed in firefighters undergoing knee arthroscopy for other diagnoses. *Methods:* A retrospective chart review of 159 knees in 146 firefighters undergoing arthroscopy for treatment of acute meniscal injury or anterior cruciate ligament reconstruction over a 14-year period was undertaken. Patient demographics, physical examination results, trochlear lesion size and grade, and

firehouse type (engine vs. ladder company) and firefighter position (seniority) were recorded. Comparisons of characteristics in those with and without trochlear lesions were performed. *Results:* The average patient age was 42.2 years (range, 27 to 64 years). Ninety-eight knees (62%) had trochlear lesions and 33 knees (51%) had matching patellar lesions. Patients with lesions were older (43.2 vs. 40.5 years). Mean trochlear lesion size was 19.5 ± 13.7 mm by 18.9 ± 12.4 mm. Lesion grade distribution was grade 1 or 2 in 24 knees (24%) and grade 3 or 4 in 67 knees (44%). Trochlear lesion presence was associated with a body mass index of over 30. Current engine company members had more advanced lesions. *Conclusions:* A "firefighter's trochlea" was present in the majority of firefighters undergoing knee arthroscopy. Higher age and longer tenure as a firefighter prior to surgery were associated with more advanced lesions. Firefighters working in engine companies at the time of arthroscopy were at a greater risk of developing low-grade lesions but not high-grade lesions. Firefighters move between ladder and engine companies, thus a definitive association with company type cannot be reached in this retrospective study. This lesion may reflect the increase in patellofemoral biomechanical stresses secondary to the physical demands of the occupation.

Level of Evidence: Prognostic Study: Level IV

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Introduction

Firefighters compose a unique occupational population required to perform physically demanding and psychologically stressful activities. Previous studies have noted firefighters have fatigue and sleep complaints, as well as musculoskeletal and cardiovascular disorders [14, 15, 17]. They are required to carry over 75 lbs. of equipment [4]. Bos et al. reported firefighters have increased knee (20%) and ankle (10%) complaints compared to age-matched office workers [1]. Vingard et al. reported that

firefighters and other blue-collar workers sustain increased dynamic and static forces on their knee and hip joints that subject them to increased relative risk of osteoarthritis [21].

The Fire Department of the City of New York (FDNY) is the largest municipal fire department in the world, consisting of over 11,000 officers and firefighters and over 4000 uniformed emergency medical services (EMS) workers [5]. The senior authors have treated over 2000 FDNY members in the past 20 years and noted that firefighters presenting for knee complaints associated with meniscal and ligamentous injury often had patellofemoral crepitus on physical exam. This was frequently asymptomatic at the time of evaluation. In this same population, knee arthroscopy for ligamentous or meniscal injury frequently revealed a distal and central trochlear cartilage lesion. The presence of the lesion corresponded with the presence of this localized patellofemoral crepitus. This lesion was located in the distal trochlea, and in many cases, was not well visualized without specific retraction of the retropatellar fat pad, which was often hypertrophic and/or fibrotic. In addition, it often occurred in the absence of a matching patellar lesion. To our knowledge, this lesion has not previously been described in the literature in the firefighter population.

The purpose of the present study was to identify and characterize trochlear lesion that seemed to be characteristic of firefighters: a chondral lesion located centrally and distally in the femoral trochlea of firefighters undergoing knee arthroscopy for other conditions, such as meniscus or anterior cruciate ligament (ACL) pathology. Hjelle et al. reported a 6% incidence of trochlear lesions in knees undergoing arthroscopy [8]. We hypothesized that the firefighter population would have a higher incidence of trochlear lesions at arthroscopy, given the heavy loads and repetitive climbing and squatting activities required by their position. We also hypothesized that the presence and size of the trochlear lesion would be related to the duration of employment as a firefighter in the FDNY, the type of company (engine or ladder), and the firefighter's body mass index (BMI) and position (seniority) in the company.

Materials and Methods

The study was approved by the Institutional Review Board and performed at the institution of the senior authors. In this retrospective chart review, FDNY firefighters undergoing knee arthroscopy for symptomatic meniscal tears or ACL insufficiency by the senior authors over a 14-year period were included. Firefighters undergoing surgery for patellofemoral complaints related to traumatic shear injuries were specifically excluded.

The initial clinical evaluation, operative note, and intraoperative photographs were reviewed by the senior authors (AMK and JAH). Data collected included age, gender, BMI, presence and grade of any trochlear lesion discovered at surgery, years employed as a firefighter prior to surgery, self-reported activity level, firefighter position, and type of firehouse (ladder, engine, or "other," which included rescue company). In addition, physical examination findings were recorded, as well as the presence of any patellar chondral lesion. Cartilage injury grade was assessed intraoperatively by the treating surgeon using the modified Outerbridge classification system.

Statistical Analysis

Patient characteristics were described using means and standard deviations for continuous variables and frequencies and percentages for discrete variables. Assessment and confirmation of normality for the continuous variables were conducted using Shapiro-Wilk tests. Differences between firefighters with and without the presence of a trochlear lesion were analyzed using independent sample *t* tests for continuous variables and χ -square tests for categorical variables. One-way analysis of variance (ANOVA) and χ -square tests were conducted to analyze differences in lesion severity levels (no lesion, grades 1 and 2, grades 3 and 4). Multivariable binary logistic regression models were built to identify potential risk factors for the presence of a trochlear lesion, while controlling for any potential confounding. Similarly, multinomial logistic regression models were built to identify those risk factors to predict the likelihood of having a grade 1 or 2 lesion or a grade 3 or 4 lesion relative to no identified lesion. All patient characteristics were considered eligible candidate variables for the regression modeling. In order to maximize goodness of fit of the data and avoid overfitting the model, iterative stepwise processes were performed to reduce the model to its final identified variables. Variables that maintained a *p* value of 0.15 or below were retained in the final model, while *p* values of $p < 0.05$ were considered statistically significant. Odds ratios and their respective 95% confidence intervals are reported for all regression models. All analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA).

Results

One hundred fifty-nine knees in 146 firefighters undergoing arthroscopy for treatment of acute meniscal injury or anterior cruciate ligament reconstruction between 1992 and 2006 were identified from the case logs of the senior surgeon authors (AMK and JAH). A summary of patient demographics is shown in Table 1. Average patient age at presentation was 42.2 years. Average BMI was 29.3 kg/m². Forty-six patients had a BMI ≥ 30 kg/m². The firefighters averaged 17.5 years on the job prior to surgery, and 74% reported their preoperative activity levels as either "moderate/regular" or "vigorous/intense." The majority of the cohort was in the Firefighter 1 (FF1) position. An equal number of engine and ladder company members were identified.

Ninety-one knees had a femoral trochlear chondral lesion. Mean lesion size was 19.5 ± 13.7 mm by 18.9 ± 12.4 mm. Grade 1 or 2 trochlear lesions were found in 24 knees, and grade 3 or 4 lesions were found in 67 knees.

Age was found to be a predictor of both trochlear lesion presence ($p = 0.034$) and higher lesion grade ($p = 0.028$). BMI also correlated significantly with trochlear lesion presence ($p = 0.013$), and those with BMI of 30 kg/m² or higher were more likely to have lesions $p = 0.002$. Those with BMI of 30 or higher also had higher grade lesions ($p = 0.012$, Table 2). Multivariable analysis further confirmed that

Table 1 Patient demographics

Characteristic	Mean (SD) or <i>N</i> (%)
Age (years)	42.2 (7.7)
BMI (kg/m ²)	29.3 (3.7)
Obese (BMI ≥ 30)	46 (32%)
Trochlear lesion	
No lesion	61/152 (40.1%)
Grade 1 or 2	24/152 (16.0%)
Grade 3 or 4	67/152 (44.1%)
Pre-operative activity level	
Light/inactive	33/128 (25.8%)
Moderate/regular	60/128 (46.9%)
Vigorous/intense	35/128 (27.8%)
Years on job prior to surgery	17.5 (8.1)
Firefighter position	
FF1	104/150 (69.3%)
FF2-FF4	9/150 (6.0%)
Lieutenant/Captain/BC/FM	43/150 (28.7%)
Firehouse type	
Engine	59/118 (50.0%)
Ladder	59/118 (50.0%)

BC battalion chief, BMI body mass index, FF firefighter, FM firehouse manager

patients with BMI of 30 kg/m² or higher had an odds ratio of 3.01 of having a trochlear lesion (Table 3). Likewise, these patients had a nearly five times higher likelihood of low-grade lesions and a more than three times higher likelihood of high-grade lesion than patients with BMI lower than 30 kg/m² (Table 3).

Age did not correlate significantly with lesion size ($r = -0.017$; $p = 0.957$). Likewise, lesion presence and size were not associated with physical examination findings of crepitus, knee effusion, or knee pain ($p \geq 0.05$ for all). There was a significant association between lesion grade and presence of an effusion, with effusion present in 53% of knees with grades 3 and 4 chondral wear ($p = 0.015$). However, given that our patient cohort consisted of patients with concomitant knee injuries requiring surgery, the clinical relevance of the predictable nature of effusion may be somewhat confounded. Of note, 59 of 96 firefighters (61.5%) were found to have patellar lesions. The grade of the patellar lesion did not vary significantly with the grade of the trochlear lesion ($p = 0.574$). Likewise, firefighter self-reported activity level did not vary significantly with either trochlear lesion presence ($p = 0.978$, Table 2) or severity ($p = 0.984$, Table 2).

There was no significant relationship between the presence of a trochlear lesion and duration of employment prior to surgery (Table 2). However, duration of employment prior to surgery had a significant relationship with lesion severity: firefighters with low-grade lesions were employed 5.3 years fewer than those with high-grade lesions ($p = 0.011$, Table 2). Firefighters with a trochlear lesion were more likely to have had 20 or more years on the job (49.5%) than those with no lesion (40.7%), but that was not statistically different compared with those who had no trochlear lesion ($p = 0.304$). Likewise, the group of firefighters with grade 3 or 4 lesions had the highest proportion of careers of 20 years or longer (50 vs. 40.7%, $p = 0.003$).

Table 2 Univariate analysis: trochlear lesion absence or presence and lesion grade

Characteristic	Univariate analysis			Univariate analysis		
	Lesion absent mean (SD) or <i>N</i> (%)	Lesion present mean (SD) or <i>N</i> (%)	<i>p</i> value	Lesion grade 0 mean (SD) or <i>N</i> (%)	Lesion grade 1/2 mean (SD) or <i>N</i> (%)	Lesion grade 3/4 mean (SD) or <i>N</i> (%)
Age (years)	40.5 (7.3)	43.2 (7.8)	0.034	40.5 (7.3)	40.6 (6.5)	44.0 (8.3)
BMI (kg/m ²)	28.1 (3.1)	29.8 (3.9)	0.013	28.1 (3.1)	30.4 (3.6)	29.7 (4.1)
Obese (BMI ≥ 30)	7/46 (16%)	39/46 (85%)	0.002	7 (16%)	10 (43%)	26 (41%)
Preoperative activity level						
Light/inactive	11/42 (26%)	22 (26%)	0.978	11/42 (26%)	5/21 (24%)	15/57 (26%)
Moderate/regular	19/42 (45%)	40 (47%)		19/42 (45%)	9/21 (43%)	27/57 (47%)
Vigorous/intense	12/42 (29%)	23 (27%)		12/42 (29%)	7/21 (33%)	15/57 (26%)
Years on job prior to surgery	16.5 (8.2)	18.3 (8.1)	0.201	16.5 (8.2)	14.4 (6.8)	19.7 (8.2)
Firefighter (FF) position						
FF1	39/59 (66%)	64 (67%)	0.159	39/59 (66%)	16/24 (67%)	43/65 (66%)
FF2-FF4	6/59 (10%)	3 (3%)		6/59 (10%)	1/24 (4%)	2/65 (3%)
Lieutenant/Captain/BC/FM	14/59 (24%)	29 (30%)		14/59 (24%)	7/24 (29%)	20/65 (31%)
Firehouse type						
Engine	20/44 (46%)	39 (53%)	0.446	20/44 (45%)	13/16 (81%)	23/53 (43%)
Ladder	24/44 (55%)	35 (47%)	0.455	24/44 (55%)	3/16 (19%)	30/53 (57%)

BC battalion chief, BMI body mass index, FF firefighter, FM firehouse manager
Statistically significant *p* values are listed in italics.

Table 3 Multivariable analysis: trochlear lesion absence or presence and lesion grade

Characteristic	Multivariable analysis Odds ratio (95% confidence interval)	Multivariable analysis	
		Grade 1/2 (95% confidence interval)	Grade 3/4 (95% confidence interval)
Age (years)	1.05 (0.98–1.12)	1.04 (0.94–1.15)	1.05 (0.98–1.13)
BMI ≥ 30 (kg/m ²)	3.01 (1.01–8.99)	4.74 (1.09–20.41)	3.31 (1.07–10.20)
Preoperative activity level			
Moderate/regular	—		
Vigorous/intense	—	—	—
Years on job prior to surgery	—	—	—
Firefighter position			
FF 2–4	—	—	—
Lieutenant/Captain/BC/FM	—		
Firehouse type: engine	—	5.94 (1.28–27.63)	1.09 (0.41–2.92)

BMI < 30; preoperative activity level, light/inactive; firefighter position, Firefighter 1; firehouse type, ladder
 BC battalion chief, BMI body mass index, FF firefighter, FM firehouse manager

There was no relationship between firefighter rank and trochlear lesion presence or severity (Table 2). The relationship of a busy vs. less-busy company was not included secondary to the transitory nature of firefighters throughout the career. We did not have data available concerning the duration of time spent in each respective firehouse or at each rank. Firehouse type had no correlation with lesion presence or absence. The ANOVA initially suggested that engine company members were more likely to exhibit low-grade lesions than ladder company members (81 vs. 19%, $p = 0.023$, Table 2). For high-grade trochlear lesions, the groups were not significantly different (43 vs. 57%). When examined within the multivariable analysis, engine company members had an almost six times increased likelihood of having a low-grade lesion than ladder company members. Engine company members were 9% more likely than ladder company members to exhibit a high-grade lesion (Table 3).

Discussion

In a retrospective chart review of our experience, we found a unique trochlear lesion present in the majority of firefighters who had undergone knee arthroscopy for seemingly unrelated meniscal or ligamentous injuries. We have referred to this as “firefighter’s trochlea.” The lesion appeared within the first 20 years of employment, and longer preoperative work-year duration was associated with more advanced lesions. Firefighters with a BMI of 30 kg/m² or higher were more likely to have trochlear lesions and more likely to have high-grade lesions.

Limitations to this study include a relatively small sample size, given the size of the FDNY, and the confounding factor of concomitant knee pathology. Furthermore, firefighters may transfer or be assigned to engine or ladder companies and to busy or less-busy firehouses. This confounded the analysis of firehouse activity levels characterized by the number of structural fires attended annually or number of runs. Finally, the preoperative and intraoperative data were collected by the

treating surgeons in the course of normal clinical care, and thus, our retrospective review could make no attempt at inter-observer reliability measurement.

The FDNY consists of 11,051 uniformed firefighters, 218 firehouses, and 37 EMS stations, and it serves a population of over 8.5 million people [5]. Members of this fire department have a comparably higher injury rate than their regional peers. In 2006, the northeast region had the highest fireground injury rate, five injuries per 100 fires, in the USA. The rate was over double the remainder of the USA. The majority (27.4%) of injuries reported between 2012 and 14 were muscular pain, sprain, or strain [20]. Overexertion is reported as the cause of muscular sprain or strain. A 2012 report on firefighter injuries in the USA found that musculoskeletal injuries were 89% more costly to fire departments than non-musculoskeletal injuries [19]. Therefore, identification of the trochlear lesion, and in future work the clinical implications of this lesion, could have widespread financial implications for fire departments.

This study has shown a significant relationship between higher BMI and lesion presence and severity. Gomez et al. described a relationship between elevated BMI and injury rates in high school football linemen [7]. Players had a greater lower-extremity injury rate with BMI ranges from 24 to 36 kg/m², with an odds ratio of 1.86 at 32 kg/m² to 3.0 at 28 kg/m². A relationship to percentage body fat was also shown; football players with over 20% body fat had a significantly increased injury rate per 1000 h of playing time. In our study of firefighters, those with BMI of 30 kg/m² or higher exhibited three times higher likelihood of a trochlear lesion compared to those with BMI of 30 kg/m² or lower. It is not known whether the elevated BMI reflects high body fat or increased muscle mass in this group. In addition, the classification of BMI of 30 kg/m² or higher as “obese” has limited utility in firefighters, due to their high level of activity and intense training. The BMI-related risk is compounded by the additional weight of a minimum of 80 to 100 lbs. of protective wear. This relationship is not clearly established, and the etiology of firefighters’ injury rates is likely multifactorial.

Firefighters with longer presurgery years of employment had more severe lesions. The 2014 published report from the National Fire Protection Association demonstrated a peak incidence of overall injury in career firefighters between the ages of 40 and 44 years [20]. Most firefighters reported being well-rested at the time of injury, but the firefighters with one or more responses to fires in the immediate 24-h period prior to the time of injury had higher percentages of injuries that resulted in time off work than firefighters who had no prior responses. Firefighter protective equipment has also been shown to more severely affect postural balance in older firefighters [16].

The trochlear lesions found in our patient population were clinically asymptomatic at the time of evaluation and surgery for other knee pathology, mainly ACL reconstruction or partial meniscectomy. It remains to be determined whether the cartilage injury impacts long-term musculoskeletal health.

Engine company members, compared to ladder company members, were more likely to have lower-grade trochlear lesions. The primary function of the engine company is to place water on a fire. This is achieved through developing a water supply, stretching the fire hoses, operating nozzles, and performing the overhaul. Overhaul is defined as the phase where all remaining fire, and any potential means for rekindling, are found and extinguished or removed. Engine company members must lift an active water line and move it, involving significant time spent in a loaded, squatting position [10]. The primary function of the ladder company, also known as truck company, is to provide fireground support, including forcible entry, ventilation, search and rescue, utility control, checking walls and ceilings for fire extension, laddering upper floors and roofs, and overhaul [3]. Both ladder company and engine company firefighters sustain high patellofemoral forces related to climbing stairs, duck walking, squatting, and climbing ladders to extinguish fires that may increase the injury severity. While the requirement of carrying the water hose likely accounts for our finding of higher rates of lower-grade lesions in engine company members than ladder company members, the disappearance of this difference in higher-grade lesions in the univariate analysis renders this finding difficult to interpret.

The “firefighter’s trochlea” lesion was present in over 60% of firefighters’ knees in this group. This is a much higher incidence than the 6% seen in the general population undergoing knee arthroscopy. It should be noted, however, that in Hjelle’s study [8], the chondral lesion reported was the “main” chondral defect, and knees with more than one area of chondrosis were simply labeled as having osteoarthritis. Thus, the incidence may be somewhat higher in the normal population. In one large, prospective study of 1000 non-firefighter knee arthroscopy patients, 19% of patients had a focal chondral defect. The lesion distribution was medial femoral condyle (58%), patella (11%), lateral tibia (11%), lateral femoral condyle (9%), trochlea (6%), and medial tibia (5%). The lesions were grades 3 and 4 with an area of at least 1 cm² [8]. Another large retrospective series found chondral lesions in 2931 patients (57.3%) out of 5233 consecutive knee arthroscopies [23]. As in the previous study, 32.2% of lesions were on the medial femoral

condyle, compared to only 7.1% of lesions in the femoral trochlea. Wilder et al. found that chondral lesions are 7.5 times more likely to occur in a traumatic setting than a non-traumatic setting [24]. Similarly, Gersoff reported mechanical injury as the etiology of chondral damage in close to 80% of patients [6]. These findings suggest that the occupational exposures related to a firefighter’s workplace result in an increased risk of trochlear injury.

Examination of our data revealed that patellar lesions did not necessarily correspond with the trochlear lesions in the knees of firefighters. Fewer knees in our study exhibited patellar lesions than trochlear lesions, and the severity of the patellar lesion had no correlation with the grade of the trochlear lesion. This indicates that this phenomenon is not necessarily straightforward patellofemoral compartment arthritis. The invariable necessity of fat pad retraction to visualize these lesions in firefighters raises the possibility of the involvement of a hypertrophic or adherent fat pad in the pathologic process. Fat pad impingement, or Hoffa’s disease, has been implicated in anterior knee pain in the setting of trauma or surgical scarring [2, 9, 12, 13, 22]. No direct relationship between fat pad impingement and cartilage injury has been clearly established; patellofemoral maltracking has been noted in the setting of fat pad edema [18], and arthrosis of the patellofemoral joint has been discovered in the setting of arthroscopic debridement for recalcitrant Hoffa’s disease [11].

The “firefighter’s trochlea” was present in the majority of firefighters undergoing knee arthroscopy. Longer preoperative work-year duration was associated with both a higher incidence of lesions and more advanced lesions. This lesion likely reflects the increase in patellofemoral biomechanical stresses secondary to the physical demands of the occupation. The results of this study indicate that efforts should be made to identify a trochlear chondral lesion in firefighters during knee arthroscopy. Additional investigation is needed regarding the natural history of these lesions, the role of the infrapatellar fat pad, and whether any additional treatment (such as fat pad debridement, chondroplasty, etc.) or surveillance is indicated.

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Compliance with Ethical Standards

Conflict of Interest: Jacqueline M. Brady, MD, Haydée C. Brown, MD, Halley Smith, BA, Dana A. Mannor, MD, Anne M. Kelly, MD, and Jo A. Hannafin, MD, PhD, declare that they have no conflicts of interest. Joseph T. Nguyen, MPH, reports receiving support in part from the Clinical Translational Science Center (CTSC), National Center for Advancing Translational Sciences (NCATS), grant no. UL1-RR024996. The content is solely the responsibility of the authors and does not necessarily represent the official views of the funding source, NCATS, based in Rockville, MD.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

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Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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