Primary Medial Patellofemoral Ligament Reconstruction in Military Servicemembers

Can We Reliably Restore Preinjury Function and Stability?

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Background: Medial patellofemoral ligament (MPFL) reconstruction for patellar instability is a commonly performed procedure with a reported high rate of return to preinjury activity. However, no previous study has assessed the functional outcomes of military servicemembers undergoing MPFL reconstruction.

Hypothesis: Primary MPFL reconstruction confers patellar stability, but with limited return to preinjury function and ability to maintain unrestricted military active duty status.

Study Design: Case series; Level of evidence, 4.

Methods: Using the Management Analysis and Reporting Tool database, we conducted a retrospective review of active duty servicemembers throughout the US Department of Defense Health System who underwent primary MPFL reconstruction between 2012 and 2015. Demographic variables were recorded as well as ability to return to impact activities—defined as running, jumping, rucking with a load >40 pounds (18 kg), and returning to airborne operations—and to remain on active duty status. The rates of recurrent instability and the need for subsequent surgeries were identified and assessed for statistical significance using uni- and multivariate analyses. Patients were evaluated for a minimum of 2 years postoperatively.

Results: Of the 213 patients who underwent primary MPFL reconstruction, including 34 with concomitant tibial tubercle osteotomy, 19 (8.9%) patients developed recurrent instability. The presence of bilateral patellar instability was associated with higher recurrence rate. Patients with bilateral instability comprised 47.3% of those with recurrence but only 24.9% of patients without recurrence ($P = .019$). Impact activity restrictions were present in 57.6% of patients (n = 121), with 86 patients (52.1%) undergoing medical separation from the military. Patients who were prescribed activity restriction before surgery were significantly more likely to have postoperative activity restrictions (64.5%; $P = .019$), and junior enlisted servicemembers were more likely to be medically separated from service postoperatively than higher ranking senior enlisted members or officers.

Conclusion: Only 42.4% of US military servicemembers undergoing primary MPFL reconstruction were able to return to unrestricted impact activity after surgery. Bilateral instability negatively affected return to impact activities. Military servicemembers, particularly junior enlisted members, should be counseled on this poor prognosis for a full return to unrestricted activity postoperatively.

Keywords: patellar instability; medial patellofemoral ligament; military; return to duty

Patellar dislocation represents up to 3% of all knee injuries among military patients.[18] The mechanism of injury often combines a noncontact rotational injury moving from flexion to extension across the knee with a planted foot.[27] There is a predilection for affecting the youth, with a reported peak incidence between 15 and 19 years of age.[15,27] The primary restraint to lateral patellar maltracking is the medial patellofemoral ligament (MPFL), conferring 50% to 60% resistance to lateral translation and withstanding loads >200 N.[3,8,13,15] Patients with a high-impact activity level are particularly susceptible to recurrent patellar instability because a load-bearing impact maximally stresses the MPFL during the first 30° of knee flexion.[8,27] The secondary factors that affect patellar tracking and stability include trochlear morphology, femoral anteversion, lateral retinacular tension, muscular coordination and strength,

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and radiographic parameters of anatomy and rotational alignment, including tibial tubercle–trochlear groove (TT-TG) distance of <20 millimeters.[3,12,15,21] Studies have demonstrated that patients with a dysplastic trochlea, increased Q angle, patella alta, and a large TT-TG (15-20 mm) have underlying anatomic characteristics that predispose them to patellar dislocation.[2,3,21]

Nonoperative treatment after initial patellar dislocation carries up to a 40% recurrent instability rate.[5,18] Given the high demand for lower extremity mechanics placed on many active duty soldiers, primary MPFL reconstruction is a widely used surgical technique to address patellar instability and improve recurrent dislocation rates.[1,3,9,10,22,23,28] Previous studies have confirmed that reconstructing an incompetent MPFL is preferential to repair or plication because of more favorable recurrence rates with reconstruction, with a statistically lower failure rate of 6.6% in the reconstruction cohort versus 26.9% in the repair group.[15,28] However, there are limited follow-up data to guide counseling our high-impact and elite athletes about return to sport, and there are no data regarding military-specific return to duty after MPFL reconstruction.[14,28] Recurrent patellar dislocation can pose a particular challenge to certain high-impact military subspecialities, such as troops parachuting into ground combat scenarios or navigating uneven terrain requiring deep knee flexion. Oftentimes, these troops are maneuvering with weighty battle gear and heavy shoulder packs, further dictating a difficult treatment environment for the soldier prone to patellar dislocation.[4]

The purpose of this study was to determine return to active duty military status after primary MPFL reconstruction for patellar instability. A secondary subgroup analysis was performed to determine if certain patient-specific parameters, including demographic characteristics and military rank, contributed to successful military retention. We hypothesized that surgical treatment would result in a high rate of return to duty and retention in the military.

METHODS

Institutional review board approval was received for this study. The Military Health System (MHS) and the Management Analysis and Reporting Tool databases were used to retrospectively identify all US military servicemembers and other military medical beneficiaries who received direct or purchased care through the MHS and underwent an MPFL reconstruction at military treatment facilities between 2012 and 2015. Current Procedural Terminology (CPT) codes (27427, 27424, 27422, and 27420) were used to identify patients undergoing an MPFL reconstruction, combined with the International Classification of Diseases, Ninth Revision, codes 717.89 718.36, 718.86, and 836.3 for a diagnosis related to patellar dislocation and instability.

Inclusion criteria were defined as active duty servicemembers aged 18 to 44 years undergoing a primary MPFL reconstruction by the review of their clinical chart and operative report. Patients were excluded if they were not on active duty status, underwent a procedure other than primary MPFL reconstruction, underwent concomitant multiligamentous knee reconstruction, or had prior ipsilateral knee surgery.

Figure 1 shows the flowchart of patient inclusion and exclusion. The majority of patients were excluded because of coding overlap or having undergone a ligament surgery other than MPFL reconstruction. An additional 51 patients were excluded because they underwent a stability procedure other than MPFL reconstruction, including isolated tibial tubercle osteotomy (TTO) or lateral release, 31 patients were excluded for having undergone MPFL repair, and 12 patients were excluded for having undergone prior ipsilateral knee surgery. The remainder of excluded patients had an incomplete record or a nonmilitary, dependent status.

Of the 630 patients identified by database review, 213 met inclusion criteria (mean age, 26.85 ± 5.65 years; 175 men) (Table 1). Overall, the included patients had a mean follow-up period of 5.57 years (range, 4.02-7.19 years).

An independent, retrospective electronic medical record review of encounters from the Armed Forces Health Longitudinal Technology Application was performed by 2 investigators (C.M.M., M.B.) to confirm clinical diagnosis and treatment intervention as well as to collect secondary study variables, including age, sex, military status, military occupation, self-reported pain scale obtained at each clinical appointment (recorded according to a 10-point visual

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Ethical approval for this study was obtained from Dwight David Eisenhower Army Medical Center (project No. 1708077).

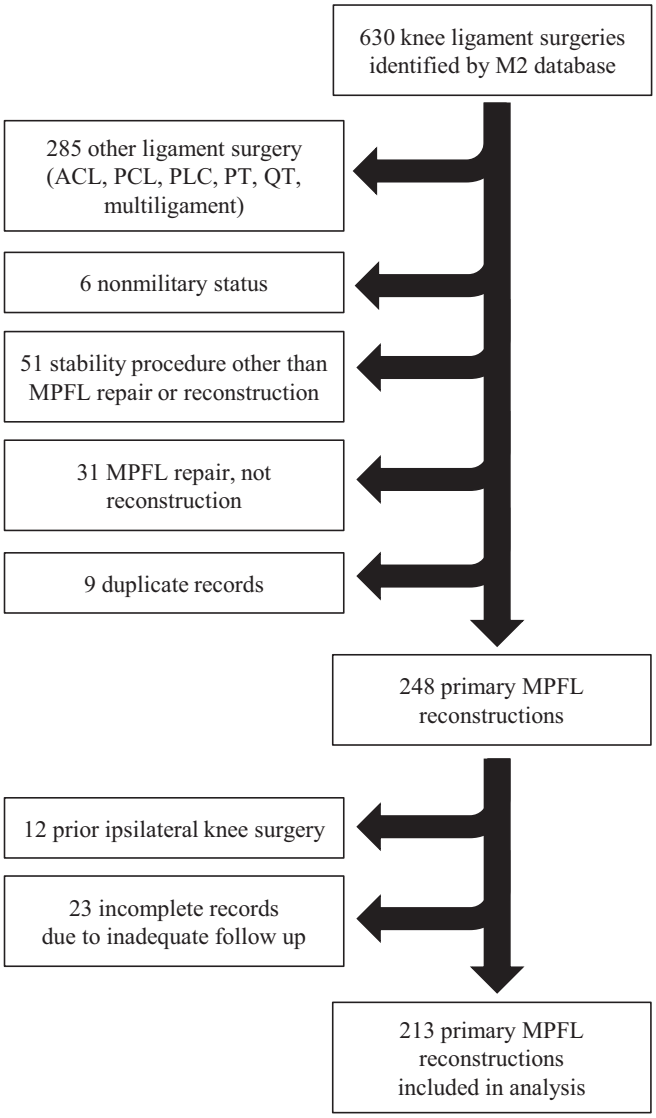

Figure 1. Flowchart of patients' inclusion and exclusion. ACL, anterior cruciate ligament; M2, Management Analysis and Reporting Tool; MPFL, medial patellofemoral ligament; PCL, posterior cruciate ligament; PLC, posterolateral corner; PT, patellar tendon; QT, quadriceps tendon.

analog scale [VAS]), perioperative complications, and concomitant and/or subsequent surgical procedures. Surgical failure was defined as subsequent patellar dislocation, need for secondary stabilization surgery, knee-related impact activity restriction, or knee-related medical discharge from the military. Impact activity restrictions were assessed by chart review and defined as physician orders prohibiting running, jumping, or rucking with a load >40 pounds (18 kg).

Because of the specific, often physically demanding nature of military service, each branch of the armed forces utilizes semiannual physical fitness tests and biometric data collection to ascertain readiness for military duties. Servicemembers are able to self-select alternative aerobic test events, such as bicycling, rowing, or swimming in lieu of running, without penalty. Many servicemembers are also required to perform group-based daily physical fitness activities, which may include calisthenics, tactical exercises, and deployment simulations called field exercises.[16] Servicemembers who are unable to satisfy these physical requirements are either provided with a profile limiting their fitness activities or medically discharged from military service.[15] Medical discharge data were identified using a Physical Evaluation Board assessment to determine fit-for-duty status. These data were cross-referenced against the US Army Physical Disability Agency database to determine the ability to characterize physical activity restrictions and the ability to remain on active duty status. Patients who finished their military commitment and separated were not classified as those with a knee-related medical discharge.

TABLE 1
Patient Characteristics (N = 213)

Characteristic	No. of Patients
Age group	
<30 y	156
30-40 y	53
>40 y	4
Sex	
Male	175
Female	38
Military rank	
Junior enlisted (pay grade, <E5)	142
Senior enlisted (pay grade, E5-E9)	63
Officer	8

Statistical Analysis

The primary outcome measure in this study was the rate of unrestricted military retention after primary MPFL reconstruction. Clinical and demographic characteristics were assessed with measures of central tendency. Statistical analyses were performed using SAS Version 9.2 (SAS Institute). We assessed statistical significance using the chi-square and Fisher exact tests. Univariate and Poisson multivariate regression analyses were utilized to test continuous and count data, respectively, relative to the stated hypotheses. Data were reported via odds ratios, adjusted for identified risk factors associated with poor outcomes and defined rates of failure. These models were applied to assess for change in pain scores, ability to remain on active duty, return to impact activities, recurrent instability, and need for subsequent surgery after MPFL reconstruction.

All risk factors were included in the multivariate models simultaneously with defined breakdowns for demographic variables to include age (<30, 30-40, and >40 years), the VAS score (<5, 5-7, and >7), and military rank (junior enlisted [pay grade, <E5], noncommissioned officers [E5-E9], and officers [>E9]). For all analyses, $P < .05$ was deemed significant.

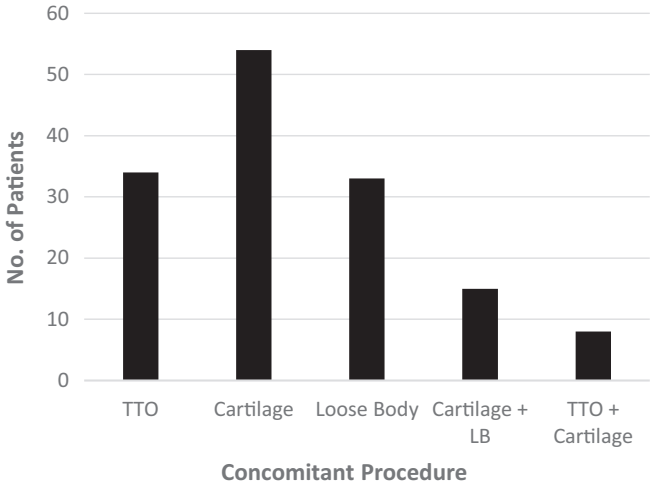

Figure 2. Concomitant procedures. LB, loose body removal; TTO, tibial tubercle osteotomy.

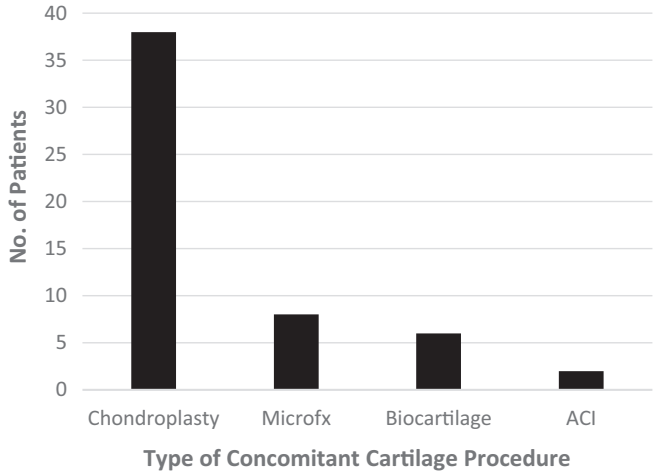

Figure 3. Concomitant cartilage procedures. ACI, autologous cartilage implantation; BioCartilage, particulated juvenile cartilage implantation; Microfx, microfracture.

Military rank was of particular interest because of its secondary impact on physical fitness demands and ability to adapt and overcome. For example, a junior enlisted servicemember is usually a new recruit required to participate in a group physical fitness session on a daily basis, at the supervision of a senior leader, and with limited control over the specific activities performed. For a junior enlisted servicemember to be excused from a particular physical fitness activity, the servicemember must have a written profile prescribed by a medical provider stating the specific details of and time frame for the restriction. A junior servicemember with a history of patellar dislocation may be tasked with performing at-risk maneuvers before being evaluated by a medical provider and obtaining a profile, thus placing him or her at particular susceptibility for recurrence. Contrast this with the senior officer who may be tasked with performing individual fitness activities at his or her own frequency, pace, location, and so forth, and therefore, senior officers may be more adaptable to accommodate an injury or a predisposed state.

RESULTS

Cartilage damage was documented in 115 patients at the time of index surgery, including in 76 of the 137 patients who had sustained a traumatic patellar dislocation. A concomitant procedure was performed in 95 patients (44.6%), with the most common being a cartilage procedure (n = 54; 56.8%), followed by a TTO (n = 34; 35.8%) (Figure 2).

Of the 115 patients with documented cartilage examination, 46.9% (n = 54) underwent concomitant cartilage surgery (Figure 3). The predominant cartilage procedure was chondroplasty in 38 patients, followed by microfracture in 8 patients and BioCartilage in 6. Two patients underwent autologous chondrocyte implantation (ACI) procedures concomitant with primary MPFL reconstruction. It is important to mention that although these 2 patients had an ipsilateral knee arthroscopy for the purpose of ACI cartilage harvest before MPFL reconstruction, they were not excluded from the analysis due to undergoing a planned staged procedure.

TABLE 2
Results of Univariate Analysis of Risk Factors for Recurrent Patellar Instability[a] after MPFL Reconstruction

Variable	No Recurrence (n = 189; 91%)	Recurrence (n =19; 9%)	*P* Value
Revision surgery	5 (3)	4 (21)	**.0002**
Preoperative profile	110 (58)	10 (53)	.523
Cartilage damage at time of surgery	93 (49)	9 (47)	.911
Concomitant cartilage surgery	46 (24)	5 (26)	.859
Age, <30:30-40:>40, n	136:49:4	15:4:0	.712
History of injury	122 (65)	13 (68)	.805
TTO	32 (17)	2 (11)	.428
Bilateral	47 (25)	9 (47)	**.0192**
Allograft	98 (52)	9 (47)	.308

[a]Data are reported as No. of patients (%) unless otherwise indicated. Bolded *P* values indicate statistically significant between-group differences ($P < .05$). MPFL, medial patellofemoral ligament; TTO, tibial tubercle osteotomy.

Recurrence Analysis

A total of 19 (9.1%) patients developed recurrent instability. A univariate analysis was used to identify risk factors for recurrent instability, including the use of patient age, preoperative activity restriction, allograft tendon for MPFL reconstruction, bilateral patellar instability, history of traumatic etiology of instability, and concomitant surgeries performed. Complete data variables were

TABLE 3
Univariate Analysis of Risk Factors for Postoperative Knee-Related Activity Restriction After MPFL Reconstruction[a]

Variable	No Postoperative Restriction (n = 89; 42%)	Postoperative Restriction (n = 121; 58%)	*P* Value
Revision surgery	2 (2)	7 (6)	.212
Preoperative profile	43 (48)	78 (64)	**.0192**
Cartilage damage at time of surgery	43 (48)	61 (50)	.988
Concomitant cartilage surgery	19 (21)	32 (26)	.421

[a]Data are reported as No. of patients (%). Bolded *P* value indicates statistically significant between-group difference ($P < .05$). MPFL, medial patellofemoral ligament.

available in 208 cases (97.7%). Of the 208 patients with complete data, 47.3% of those with recurrent instability had preexisting bilateral patellar instability ($P = .019$). Patients with recurrent patellar instability were more likely to undergo revision stabilization (21.0% vs 2.6%; $P = .0002$) (Table 2).

After surgery, VAS pain scores improved from a mean (±SD) of 3.62 ± 2.4 preoperatively to 2.27 ± 2.39 at the final follow-up. Subsequent surgery included 41 additional procedures in 35 patients (16.4%), with TTO hardware removal being the most common (n = 12), followed by soft tissue manipulation/lysis of adhesions (n = 11), isolated cartilage procedure (n = 6), and TTO (n = 5). In sum, 7 (3.2%) patients underwent a revision surgery for recurrent patellar dislocation. After recurrence, 1 patient underwent a revision of the original TTO and 4 patients underwent revision of their MPFL due to graft malposition. One patient underwent a revision due to improper graft tension 4 months after index reconstruction. Two patients experienced subsequent ipsilateral knee procedures during the study period but unrelated to recurrent patellar instability (1 traumatic quadriceps tendon rupture 11 months after MPFL reconstruction; 1 traumatic patellar fracture through the inferior patellar tunnel 4 months after MPFL reconstruction). Secondary osteoarthritis was diagnosed in 11.7% of patients (n = 25), of whom 88.0% had impact activity restrictions at the final follow-up. One patient underwent a patellofemoral joint arthroplasty 21 months after isolated MPFL reconstruction for progression of secondary osteoarthritis.

Postoperative Activity and Military Retention

Definitive explanations of any activity restriction were documented in the medical records of 210 of the 213 patients. Medical separation or retention data was documented in 165 patients. Overall, impact activity restrictions were present in 57.6% of patients (n = 121), with 86 patients (52.1%) undergoing medical separation from the military.

TABLE 4
Univariate Analysis of Risk Factors for Knee-Related Military Separation After MPFL Reconstruction[a]

Variable	Medical Separation (n = 86; 52%)	Return to Duty (n =79; 48%)	*P* Value
Revision surgery	5 (6)	3 (4)	.548
Preoperative profile	59 (69)	41 (52)	.132
Cartilage damage at time of surgery	46 (53)	41 (52)	.861
Concomitant cartilage surgery	23 (27)	19 (24)	.692

[a]Data are reported as No. of patients (%). MPFL, medial patellofemoral ligament.

TABLE 5
Univariate Analysis of Rank as a Risk Factor for Knee-Related Military Separation after MPFL Reconstruction[a]

Variable	Medical Separation (n = 86; 52%)	Return to Duty (n = 79; 48%)	*P* Value
Junior enlisted	59 (69)	30 (38)	**.0001**
Senior enlisted	26 (30)	43 (54)	**.0017**
Officer	1 (1)	6 (8)	**.0412**

[a]Data are reported as No. of patients (%). Bolded *P* values indicate statistically significant between-group differences ($P < .05$). MPFL, medial patellofemoral ligament.

Of the 51 patients who underwent concomitant cartilage procedure, 19 were able to return to full duty. Concomitant cartilage surgery had no significant impact on return to duty (51.9% vs 53.5%; $P = .692$) or the presence of postoperative activity restriction (26.4% vs 21.3%; $P = .421$). Of the variables studied, only preoperative activity restriction was predictive of a postoperative activity restriction (64.5%; $P = .019$) (Table 3). No risk factors were identified for failure to meet military retention standards in the 86 patients who underwent knee-related medical separation from the military (Table 4).

Rank and Military Retention

A univariate analysis was performed to determine if rank was a significant risk factor for military separation after MPFL reconstruction (Table 5). Interestingly, each of the 3 rank categories (junior enlisted, senior enlisted, and officer) was statistically significant, indicating that rank is an independent risk factor for medical separation. As expected, patients in the junior enlisted category, representing the lowest ranks of servicemembers, had the strongest association with medical separation (68.6%; $P = .0001$) and were 1.76 times more likely to be separated than in those in the senior enlisted category. Similarly, senior enlisted servicemembers were 1.85 times more likely to return to duty as compared with the junior enlisted (95% CI, 1.05-3.24; $P = .0322$).

DISCUSSION

Returning the injured patient to unrestricted physical activity after musculoskeletal injury and/or surgery is the paramount goal for both the orthopaedic surgeon and patient. This is particularly relevant to the active duty military population, as military orthopaedic surgeons seek to heal injured servicemembers to maintain force readiness. Although patellar instability is a fairly common condition treated in active duty military servicemembers, we found that the ability to return to full activities after MPFL reconstruction surgery was discouraging, with 57.6% of patients having impact activity restrictions after surgery and 52.1% undergoing medical separation from the military despite a relatively low rate of recurrent instability (9.1%). In this series, 7 patients underwent a revision surgery for recurrent patellar dislocation (3.2%), commensurate with previously reported postoperative recurrence rates.[17] Despite the low rate of recurrence and revision, difficulties in returning military patients to the preoperative level of functional activities could represent the high burden of concordant chondral pathology experienced by this cohort as well as the specific high-impact nature of the servicemembers' military occupation.

Acute osteochondral lesions may occur at an incidence of 10% to 40% with initial patellar dislocation; however, previous reports have failed to identify an association between osteochondral defect or loose body and recurrent patellar instability.[7] While the current study data suggest that concomitant cartilage surgery may have no significant impact on return to duty or medical separation from the military (vs no cartilage procedure; $P = .692$), 11.7% of servicemembers who exhibited osteoarthritis at initial presentation had more than double the risk of being on impact activity restrictions or being referred for a medical separation board after undergoing MPFL reconstruction.

In counseling patients after an initial patellar dislocation, it is important to consider factors that may predispose the patient to recurrence, as this may preclude prolonged military service. The results of this study suggest that in the absence of underlying structural abnormalities, military orthopaedic surgeons should consider patient characteristics, including rank, presence of bilateral instability, and any underlying osteoarthritis, when counseling a patient whose injury may not be conducive to military service. The current study failed to identify a significant association between patient sex, consistent with previously reported data.[7,27] Furthermore, the servicemembers who were prescribed preoperative activity restrictions were at increased risk of having postoperative activity restrictions and potential military separation ($P = .0192$). Therefore, military medical providers should include this potentially negative prognostic factor in discussing expected outcomes with their patients.

As hypothesized, military rank was an independent risk factor for separation after MPFL reconstruction. The junior enlisted servicemembers in this study were 1.76 times more likely to be separated as compared with senior enlisted servicemembers (95% CI, 1.01-3.07; $P = .0473$), likely largely due to the more generic group-focused physical training and demands placed on the lower ranks, and highlighting the broader ability for senior enlisted servicemembers and officers to perform individualized physical training that could better accommodate postoperative activity restrictions. The cohort of officers indicated a trend toward significance in returning to duty when compared directly with junior enlisted servicemembers (odds ratio, 2.54 [95% CI, 0.79-8.16]). However, the difference was not statistically significant ($P = .1168$), possibly because of the small sample size of the officers ($n = 7$).

The lack of standardized postoperative rehabilitation guidelines to direct physical therapy after MPFL reconstruction confers additional difficulty in determining a positive response to an operative intervention. The Zaman et al[28] systematic review of 53 studies demonstrated a consistent discussion of weight-bearing and range of motion guidelines (90.6% and 84.9% of studies, respectively), without the ability to develop a consensus on the specific limitations that were not otherwise explicit within the studies. The Tegner score has been cited as an assessment of athletic activity, but it does not assess a specific ability or skill level.[7,24,26,28] Other patient-reported outcomes, including the Lysholm score and the VAS score, often reveal a disconnect between recurrent instability and patient satisfaction, where redislocation does not always correlate with worse clinical outcome.[7,24,26] In fact, the Buchner et al[7] cohort of 126 patients demonstrated a final Lysholm score of 79.1 in the patients who experienced redislocation versus a score of 86.9 in the patients without redislocation, which was not significantly different. VAS pain scores in our cohort improved from 3.62 preoperatively to 2.27 at the final follow-up. Although this was statistically significant ($P < .001$), it did not meet the minimum clinically significant change of 2.7 for the VAS.[11]

Saper et al[19] assessed isometric and functional testing in a cohort of adolescent patients after MPFL reconstruction to determine if there are discrete physiometric parameters that may suggest adequate healing for return to sports. They compared limb symmetry indices across 4 single-limb hop tests and against the unaffected lower extremity at a mean of 7.4 months post-MPFL reconstruction and determined that the mean indices were 85.3% for quadriceps and 95.1% for hamstrings. As previous studies regarding functional outcome after anterior cruciate ligament reconstruction have indicated, a limb symmetry index of 90% has been set as the threshold for performing comparably with unaffected persons. The outcomes by Saper et al and Schmitt et al[20] suggest that significant athletic deficits remain more than 7 months after MPFL reconstruction. We found this to be true in our population, as only 27.6% of patients had returned to any sporting activity by the final follow-up.

Technical failures of MPFL reconstruction can be related to graft tension, tunnel malposition, or iatrogenic patellar fracture.[21] Bollier et al[6] described 5 instances in which tunnel malposition or graft tension issues caused symptoms disabling enough to indicate a need for revision. Tanaka[25]

also reported patellar fracture occurring after MPFL reconstruction due to a stress riser created by tunnel malposition. One of our patients experienced a patellar fracture in a direct fall onto a flexed knee 4 months after MPFL reconstruction; the fracture propagated through the inferior patellar tunnel and required subsequent operative fixation. We included this patient in the revision surgery group analysis, recognizing that the fracture risk was created as a result of primary MPFL reconstruction despite the patient's not experiencing recurrent instability. Fulkerson and Edgar[10] described a technique to mitigate the risk of patellar fracture by stabilizing the medial quadriceps tendon—femoral ligament without drilling into the patella. This technique favors an anatomic approach to the femoral fixation, whereas the medial patellofemoral complex has demonstrated variable insertion into the quadriceps tendon and can be affected by positioning during radiographic localization.

Limitations of our study are not insignificant. Our analysis utilizes retrospective data with inherent bias associated with this design. There are numerous CPT codes (27427, 27424, 27422, and 27420) associated with patellar instability surgery, but none of these is specific to MPFL reconstruction. Although utilizing a nationwide database allows access to an immense data set, it also presents the challenge of numerous surgeons with varied surgical techniques and postoperative rehabilitation protocols. Finally, the inconsistent documentation within the limited-duty profile system and medical separation process makes it difficult to determine the exact nature of their necessity. The limited-duty profile system allows investigators to view whether the identified patient has a physical restriction associated with lower extremity injury; however, the investigator is not able to ascertain the specific details of each lower extremity restriction for each patient.

CONCLUSION

In the current study, only 42% of US military servicemembers undergoing primary MPFL reconstruction were able to return to unrestricted impact activity after surgery. Recurrent or bilateral instability negatively affected return to impact activities. This study demonstrates that further solutions need to be developed both to prevent this rather benign-appearing injury and to treat these patients in such ways that allow them to reach their previously high levels of performance. Military servicemembers and other high-demand patients should be counseled on the factors affecting their prognosis for a full return to unrestricted military activity postoperatively.

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