



**Calhoun: The NPS Institutional Archive**  
**DSpace Repository**

---

Faculty and Researchers

Faculty and Researchers' Publications

---

2015

## Success of high tibial osteotomy in the United States military

Waterman, Brian R.; Hoffmann, Jeffrey D.; Laughlin, Matthew D.; Burks, Robert; Belmont Philip J. Jr.

Sage

---

Waterman, Brian R., et al. "Success of high tibial osteotomy in the United States military." *Orthopaedic Journal of Sports Medicine* 3.3 (2015): 2325967115574670.  
<https://hdl.handle.net/10945/71356>

---

This publication is a work of the U.S. Government as defined in Title 17, United States Code, Section 101. Copyright protection is not available for this work in the United States.

*Downloaded from NPS Archive: Calhoun*



Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

**Dudley Knox Library / Naval Postgraduate School**  
**411 Dyer Road / 1 University Circle**  
**Monterey, California USA 93943**

<http://www.nps.edu/library>

# Success of High Tibial Osteotomy in the United States Military

MAJ Brian R. Waterman,<sup>\*†</sup> MD, MC USA, CPT Jeffrey D. Hoffmann,<sup>†</sup> MD, MC USA, CPT Matthew D. Laughlin,<sup>†</sup> DO, MC USA, COL Robert Burks,<sup>‡</sup> PhD, COL Mark P. Pallis,<sup>†</sup> DO, MC USA, COL John M. Tokish,<sup>§</sup> MD, MC USAF, and COL Philip J. Belmont Jr,<sup>†</sup> MD, MC USA

*Investigation performed at William Beaumont Army Medical Center, El Paso, Texas, USA*

---

**Background:** Historically, high tibial osteotomy (HTO) has been performed to treat isolated medial gonarthrosis with varus deformity.

**Purpose:** To evaluate the occupational outcomes of HTO in a high-demand military cohort.

**Study Design:** Case-control study; Level of evidence, 3.

**Methods:** A retrospective analysis of active duty service members undergoing HTO for coronal plane malalignment and/or intra-articular pathology was performed using the Military Health System between 2003 and 2011. Demographic parameters and surgical variables, including rates of perioperative complications, secondary surgery, activity limitations, and medical discharge, were extracted from electronic medical records. For the current study, cumulative failure was defined as conversion to knee arthroplasty or postoperative medical discharge for persistent knee dysfunction. Univariate and multivariate analyses were performed to identify statistical associations with cumulative failure after HTO.

**Results:** A total of 181 service members (202 HTOs) were identified at an average follow-up of 47.5 months (range, 24-96 months). Mean age was 35.7 years (range, 19-55 years), and the majority were men (93%) and of enlisted rank (78%). All index procedures utilized a valgus-producing, opening wedge technique. Concomitant or staged procedures were performed in 87 patients (48%), including 40 ligamentous, 48 meniscal, and 48 chondral procedures. Complications occurred in 19.3% of knees (n = 39), with unplanned reoperation in 26 knees (12.8%). Fifty-three patients (40.7%) had minor activity limitations during military duty post-operatively. Eleven knees (5.4%) underwent conversion to total knee arthroplasty. The cumulative failure rate was 28.2% (n = 51) at 2- to 8-year follow-up. Patient age younger than 30 years at the time of surgery was associated with an independently higher risk of failure, whereas sex, concomitant/staged procedures, and perioperative complications were not significantly associated with subsequent failure.

**Conclusion:** At short- to midterm follow-up, nearly 72% of all service members undergoing HTO returned to military duty and were free from conversion knee arthroplasty.

**Keywords:** high tibial osteotomy; varus; cartilage; military

---

First described by Jackson<sup>13</sup> in 1958, high tibial osteotomy (HTO) has classically been performed for the treatment of advanced medial unicompartamental arthritis of the knee with an associated varus deformity. The isolated use of HTO as a temporizing measure for symptomatic medial gonarthrosis has diminished over the past few decades.<sup>29</sup> However, several studies have shown that HTO remains a durable procedure for patients returning to intense activity or impact physical activity with unicompartamental disease,<sup>7</sup> particularly in military cohorts where knee arthroplasty may not be prudent. The emerging role of HTO as a chondroprotective measure has also been increasingly

recognized, and its surgical indications have expanded to complement a variety of joint-preserving procedures for young patients with subtle malalignment and concomitant knee pathology. In these circumstances, improved mechanical alignment should offload the symptomatic medial compartment, while improving the clinical outcomes associated with concurrent chondral,<sup>6,16</sup> ligamentous,<sup>1,19</sup> and meniscal reconstruction procedures.<sup>27</sup>

Despite its growing acceptance among younger patients, there are limited reports on clinical outcomes after HTO in this patient subset,<sup>11,14,20</sup> particularly in more high-demand cohorts.<sup>7,23,28,30</sup> The existent literature varies widely by patient demographics, surgical indications, length of follow-up, surgical technique, and presence of associated procedures, and many studies primarily focus on conversion to knee arthroplasty as an isolated

---

The Orthopaedic Journal of Sports Medicine, 3(3), 2325967115574670  
DOI: 10.1177/2325967115574670  
© The Author(s) 2015

This open-access article is published and distributed under the Creative Commons Attribution - NonCommercial - No Derivatives License (<http://creativecommons.org/licenses/by-nc-nd/3.0/>), which permits the noncommercial use, distribution, and reproduction of the article in any medium, provided the original author and source are credited. You may not alter, transform, or build upon this article without the permission of the Author(s). For reprints and permission queries, please visit SAGE's Web site at <http://www.sagepub.com/journalsPermissions.nav>.

endpoint in assessing the success after HTO.<sup>4,12</sup> Few studies to date have evaluated patient-reported and functional outcomes in athletic populations after HTO,<sup>9,23</sup> and no study has reported on the ability of HTO to return patients to occupations requiring strenuous physical performance. The purpose of this study was to evaluate the short- to midterm clinical and occupational outcomes of HTO in a physically active military population, including assessments of return to full function and rates of secondary surgery. We hypothesized that realignment HTO is effective at returning patients to a physically demanding lifestyle, and that when combined with soft tissue or chondral procedures, HTO results in reliable rates of return to military function.

## METHODS

Institutional review board approval was obtained. All US military service members undergoing osteotomy of the proximal tibia (Common Procedural Terminology [CPT] code 27457) at military treatment facilities between 2003 and 2011 were identified from the Military Health System Management Analysis and Reporting Tool database. All nonactive duty beneficiaries, individuals with less than 2 years clinical follow-up, and/or cases of miscoding (eg, femoral, tibial tubercle, or distal tibial osteotomy) were excluded in subsequent analysis. Demographic parameters (age, sex, race, military rank) and clinical variables (underlying diagnosis [International Classification of Disease, Ninth Revision; ICD-9], concomitant procedures [CPT], military treatment facility) were extracted. Retrospective review of the Department of Defense electronic medical record, Armed Forces Health Longitudinal Technology Application (AHLTA, version 3.3), was performed, and the following factors were recorded: laterality, military occupational specialty (MOS), tobacco use, surgical indications, technique and method of fixation, perioperative complications, secondary surgical procedures, clinical course, presence of activity-related joint line pain requiring activity limitations, and initiation of a medical evaluation board for military discharge due to persisting knee complaints. Incidence of perioperative complications, including wound dehiscence, deep space infection, neurovascular injury, deep venous thrombosis, nonunion, malunion, fracture, and unplanned reoperation, were quantified.

US military service members must adhere to defined standards for medical and physical fitness, such as those stipulated under Army Regulation 40-501 (Headquarters, Department of the Army, Washington, DC). These regulations are specific to each branch of military service, but

generally require successful completion of biannual physical fitness testing and periodic combat deployments. Military duty limitations are reflected on a Physical Profile (DA Form 3349) within the e-Profile electronic profiling system (version 3.17; Medical Operational Data System) and in the electronic medical record, and these data were extracted for all patients in this study. Similarly, current military status and performance of a postoperative deployment were identified from the Pentagon Defense Manpower Data Center database, and the US Army Physical Disability Agency database was cross-referenced to identify all Army service members with confirmed knee-related medical discharge. For the purposes of this study, clinical failure after primary HTO was defined as either (1) initiation of the knee-related medical discharge or (2) conversion to knee arthroplasty.

## Statistical Analysis

Univariate and Poisson multivariate, regression analyses were utilized to determine the association between the identified variables and defined rates of failure in the current study, and odds ratios (ORs) with 95% CIs were quantified. Significant independent predictors were determined to be those that maintained *P* values <.05, with OR and 95% CI exclusive of 1.0. Calculations were performed using SAS software with the assistance of a biostatistician (version 9.2; SAS Institute).

## RESULTS

Of 522 cases isolated from the database, a total of 181 active duty service members underwent 202 HTOs, with mean follow-up of 47.5 months (range, 24-96 months) (Table 1 and Figure 1). The mean patient age was 35.7 years (range, 19-55 years), and the majority of the cohort was male (93%) and of enlisted military rank (78%). A total of 114 patients (63%) had undergone prior knee surgery, including 69 ligamentous, 88 meniscal, and 49 chondral procedures.

On examining surgical technique, all cases used a medial, valgus-producing, opening wedge HTO. Approximately 85% of surgeries utilized plate fixation, while the remainder employed either an external/ring fixation or unspecified constructs. Concomitant or staged procedures were performed in 87 service members (48%), including 48 ligamentous, 48 meniscal, and 40 chondral procedures, whereas a total of 21 patients underwent staged, bilateral HTO (Table 1).

Postoperatively, 39 complications occurred among 34 patients (Table 2). Of these, 26 complications (12.8%) were classified as major and required unplanned secondary

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

<sup>†</sup>Department of Orthopaedic Surgery and Rehabilitation, William Beaumont Army Medical Center, El Paso, Texas, USA.

<sup>‡</sup>Naval Postgraduate School, Monterey, California, USA.

<sup>§</sup>Steadman Hawkins Clinic of the Carolinas, Greenville Health System, Greenville, South Carolina, USA.

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.

One or more of the authors declared the following potential conflicts of interest or source of funding: M.P.P. owns stock or stock options in Johnson & Johnson; J.M.T. is a consultant for Arthrex, DePuy, and Mitek; and P.J.B. receives royalties from SLACK Inc.

TABLE 1  
Patient Demographics and Clinical Profile<sup>a</sup>

Variable	
Total patients, n	181
Total knees, n	202
Laterality, n (%)	
Unilateral	160 (88)
Bilateral	21 (12)
Sex, male/female, n (%)	169 (93)/12 (7)
Age, y, mean (range)	35.7 (19-55)
Race, n (%)	
White	95 (53)
Black	46 (25)
Asian	3 (1.7)
Other/unknown	37 (20)
Military rank, n (%)	
Enlisted	141 (78)
Officer	40 (22)
Branch of military service, n (%)	
Army	122 (67)
Air Force	24 (13)
Navy	21 (12)
Marines	13 (7.2)
Coast Guard	1 (0.6)
Deployment record, n (%)	
Preoperative	34 (19)
Postoperative	15 (8.3)
Tobacco use, n (%)	35 (26)
Fixation construct, n (%)	
Plate	171 (85)
External/ringed fixator	12 (5.9)
Unspecified	19 (9.4)
Prior surgery	
Any, n (%)	114 (63)
Meniscal, n	88
Chondral, n	49
Ligamentous, n	69
Concomitant /staged surgery	
Any, n (%)	87 (48)
Meniscal, n	48
Debridement	25
Repair	5
Transplantation	18
Chondral, n	40
Microfracture	11
Chondroplasty	11
Osteochondral autograft transfer	10
Autologous chondrocyte implantation	7
Particulated juvenile allograft chondrocyte implantation	1
Ligamentous, n	48
Anterior cruciate ligament	33
Posterolateral corner	3
Posterior cruciate ligament	6
Medial collateral ligament	4
Unspecified	2

<sup>a</sup>Percentages were calculated per number of patients in each group, with the exception of the percentages of each type of high tibial osteotomy (HTO) construct used, which is relative to the total number of HTOs performed in each group.

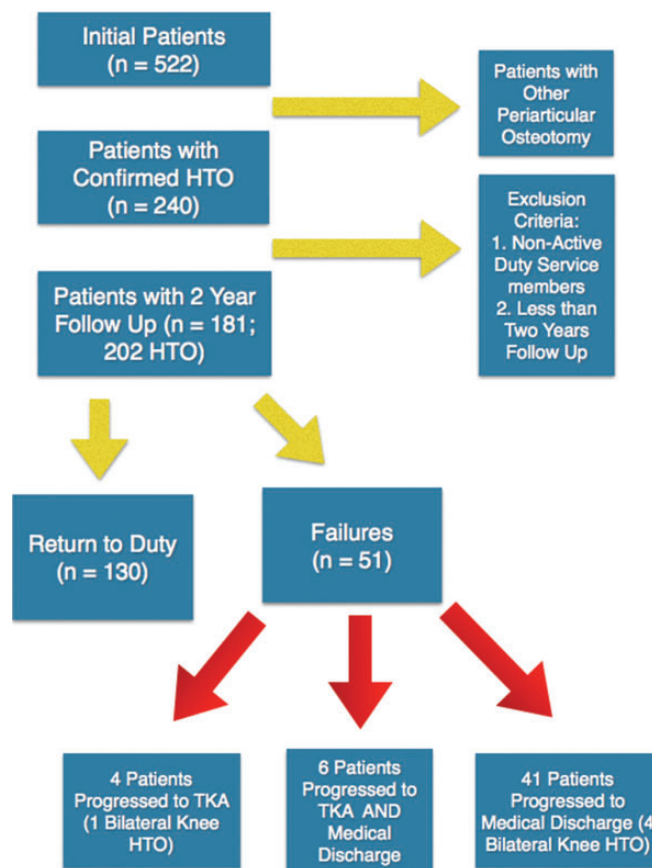


Figure 1. Return to duty and failure rates of high tibial osteotomy (HTO). TKA, total knee arthroplasty.

surgery, including deep infection (n = 8), overcorrection (n = 4), osteotomy nonunion (n = 3), fracture (n = 3), hardware failure (n = 5), wound dehiscence (n = 2), and flexion contracture (n = 1). Following surgery, 27 knees (13%) experienced hardware irritation or hardware-related symptoms, of which 23 had subsequent hardware removal. Revision HTO was required in 16 knees (7.9%).

Of 181 service members, 10 (5.5%) patients underwent conversion to total knee arthroplasty (TKA) at an average 38.1 months (SD, ±13.7 months; range, 14-49 months), including 1 patient with bilateral TKA, and 47 (26.0%) patients had initiation of a medical discharge for persistent knee complaints. Six service members who underwent conversion to TKA also received a medical discharge. The cumulative failure rate, defined as either conversion arthroplasty and/or knee-related medical discharge, was 28.2% (n = 51; concomitant/staged procedures, n = 33) at a mean follow-up of 47.5 months (Figure 1). Of those service members remaining on active duty and free from conversion to TKA or medical discharge (n = 130), 53 (40.7%) were unable to return to full duty and required minor permanent activity limitations, most commonly a low-impact aerobic event (eg, timed walk, bicycle, or swim event) for routine fitness training. Furthermore, 77 (42.5%) patients undergoing HTO remained fully cleared for duty without limitations, and 15 (8.3%) patients successfully completed

TABLE 2  
Complication Rates and Reoperation  
After High Tibial Osteotomy<sup>a</sup>

	Incidence of Given Complication, n (%)	Knees Requiring Operative Intervention for Given Complication, n (%)
Infection	9 (4.5)	8 (4.0)
Hardware failure	8 (4.0)	5 (2.5)
Nonunion	5 (2.5)	3 (1.5)
Overcorrection	4 (2.0)	4 (2.0)
Pulmonary embolism	3 (1.5)	0 (0)
Wound dehiscence	2 (1.0)	2 (1.0)
Fracture	4 (2.0)	3 (1.5)
Nerve injury	3 (1.5)	0 (0)
Flexion contracture	1 (0.8)	1 (0.8)
Total	39 (19.3)	26 (12.8)

<sup>a</sup>Percentages are taken out of total number of knees (n = 202).

TABLE 3  
Univariate Analysis of Factors Associated With  
Clinical Failure After High Tibial Osteotomy<sup>a</sup>

Factor	Rate Ratio	95% CI	P Value
Sex	1.14	0.35-3.65	.83
Tobacco use	1.19	0.65-2.17	.575
Race			
Black	1.44	0.76-2.72	.266
Other	1.29	0.61-2.71	.845
White	1	N/A	N/A
Rank (enlisted vs officer)	1.32	0.64-2.72	.445
Branch of service			
Army	1.77	0.63-4.97	.278
Air Force	1	N/A	N/A
Navy	1.71	0.48-6.07	.404
Marines	1.85	0.46-7.38	.386
Coast Guard	6	0.67-53.68	.109
Age, y (2 groups)			
<30	1.89	1.08-3.32	.026
≥30	1	N/A	N/A
Age, y (6 groups)			
<24	3.15	0.85-11.64	.085
25-29	2.96	0.83-10.62	.096
30-34	2.07	0.55-7.82	.281
35-39	1.2	0.31-4.62	.796
40-44	1.98	0.56-6.94	.287
≥45	1	N/A	N/A
No prior procedure	1.91	1.00-3.65	.05
Concomitant/staged procedures	1.98	1.12-3.52	.02
Presence of complication	1.54	0.89-2.67	.126
Revision surgery	1.2	0.48-3.02	.695

<sup>a</sup>N/A, not applicable.

postoperative combat deployment, including 3 service members who completed multiple deployments.

Poisson regression and multivariate analyses demonstrated no statistically significant association with failure

TABLE 4  
Multivariate Analysis of Factors Associated With  
Clinical Failure After High Tibial Osteotomy<sup>a</sup>

Demographic	Rate Ratio	95% CI	P Value
Sex	1.42	0.43-4.70	.566
Tobacco use	1.13	0.60-2.13	.6969
Race			
Black	1.79	0.90-3.58	.0991
Other	1.43	0.65-3.14	.3754
Rank (enlisted vs officer)	0.94	0.44-2.04	.8839
Branch of service			
Army	2.31	0.79-6.77	.126
Air Force	1	N/A	N/A
Navy	2.86	0.72-11.40	.136
Marines	2.58	0.56-11.94	.224
Coast Guard	16.26	1.38-191.70	.027
Age, y (2 groups)			
<30	1.8	1.00-3.22	.049
≥30	1	N/A	N/A
Age, y (6 groups)			
<24	2.7	0.67-0.82	.1613
25-29	2.94	0.76-11.42	.1201
30-34	1.83	0.46-7.30	.3896
35-39	1.37	0.34-5.50	.6558
40-44	1.75	0.48-6.40	.3968
≥45	1	N/A	N/A
No prior procedure	1.87	0.96-3.65	.0658
Concomitant/staged procedures	1.65	0.89-3.06	.1107
Presence of complication	1.33	0.73-2.42	.3449
Revision surgery	1.09	0.39-3.07	.8724

<sup>a</sup>Category referents: Sex = female referent; tobacco = no use referent; race = White referent; rank = officer referent; complication = no complication referent; revision surgery = no revision referent; age (2 groups) = ≥30 years referent; age (6 groups) = ≥45 years referent; no prior procedure = prior referent; concomitant/staged (both categories) = no concomitant/staged procedure referent. N/A, not applicable.

by sex, race, rank, branch of service, tobacco use, presence of complication, or revision surgery ( $P > .05$ ). Univariate analysis demonstrated an increased rate of failure for patients with concomitant and/or staged procedure; however, this failed to achieve statistical significance on multivariate analysis (Tables 3 and 4). When analyzing patients <30 years to those ≥30 years, failure for service members <30 years old was nearly 2-fold greater (OR, 1.80; 95% CI, 1.00-3.22;  $P = .049$ ) than for those ≥30 years old.

## DISCUSSION

Rates of success after opening wedge HTO for advanced medial knee arthrosis are variable in the current literature, with estimates ranging from 70% to 98% at 5- to 10-year follow-up and 50% to 60% at >15 years postoperatively.<sup>8,22</sup> However, clinical success has traditionally been narrowly and subjectively defined, with consideration of only survivorship from TKA. Similarly, this methodology fails to account for functional endpoints associated with suboptimal patient outcomes, including an inability to return to

the same occupational activity after index knee surgery. Functional reports of HTO in young, athletic patient populations are also limited,<sup>3,14</sup> particularly when combined with other intra-articular knee procedures.<sup>2,10,16,19,21,31</sup> To this end, the current investigation reports on the clinical, functional, and occupational outcomes of 181 physically active military service members undergoing HTO with 2- to 8-year follow-up. Of this cohort, 72% of patients returned to military duty without secondary conversion to knee arthroplasty.

Few studies have evaluated return to athletic activity or high-demand occupational function after HTO. Our findings are consistent with prior reports of functional outcomes after HTO in an active civilian subset. In their report of 139 patients (mean age, 59 years) at an average 50-month follow-up, Bonnin et al<sup>5</sup> identified that 78% of patients were satisfied or very satisfied after HTO. However, only 63% of patients reported having a "normal" knee with the option to return to recreational running, and only 36% of patients reported no limitations in function due to pain or other persistent knee symptoms. Nagel et al<sup>18</sup> reported on 34 young, active patients with medial osteoarthritis and noted that 26 individuals (76%) returned to physically demanding manual labor after HTO, and 25 patients (74%) resumed regular sporting activities, including downhill skiing, tennis, jogging, and cycling. Salzman et al<sup>23</sup> noted that 91% of 65 patients were engaged in sports and recreational athletic activity at an average 36 months after HTO for medial compartment arthritis, although no patient returned to a higher level of competition.

In contrast, the current military cohort represents a younger patient population (mean age, 35.5 years) with standardized occupational requirements. In addition to frequent military deployments lasting up to 12 months, service members must also perform routine tactical field training, bear significant fighting loads (>80 lbs), and adhere to stringent physical fitness standards (eg, timed multimile run, push-ups, and sit-ups). As a result, military personnel represent a physically active population with limited capacity to self-modify the occupational demands, particularly in a combat setting. In the current study, a total of 26% of patients underwent knee-related medical discharge from the military and an additional 29% required some minor permanent duty limitations, most commonly involving impact activity. Thus, only 43% of service members were able to fully return to unrestricted active duty after HTO.

Rates and definitions for failure have varied widely within the literature. Military studies have traditionally focused on return to occupational duty after reconstructive knee surgery, and several studies have highlighted the difficulties in restoring military service members to full function.<sup>25,26</sup> Our cohort demonstrated an increased failure rate among patients younger than 30 years, which may serve as a proxy for a greater burden of activity and limited personal autonomy. However, no other demographic or occupational risk factors for failure were identified. Contrary to other published works,<sup>16</sup> we did not demonstrate any protective effect for the adjunctive use of HTO in association with other concomitant or staged

procedures when compared with isolated HTO. Additionally, the absence of prior knee surgery approached statistical significance as a risk factor after multivariate analysis, and this may correlate with prolonged disease chronicity and progression of chondral degeneration without earlier treatment. Interestingly, presence of perioperative complications and HTO revision also failed to predict ultimate functional outcomes in this study.

Our data reflect an increasing utilization of HTO as an adjunct to surgical treatment, with nearly half of patients undergoing concomitant chondral, meniscal, and ligamentous procedures. The existing literature suggests that clinical outcomes after chondral restoration procedures, such as autologous chondrocyte implantation (ACI),<sup>2,3</sup> osteoarticular autograft transfer surgery (OATS),<sup>17</sup> and osteochondral allograft transplantation,<sup>26</sup> for focal chondral defects might significantly benefit from mechanical offloading. Subtle corrective osteotomies have also optimized survivorship with medial meniscal allograft transplantation<sup>27</sup> and may synergistically act to delay the progression of medial joint line degeneration when compared with meniscal transplantation alone. While some selected authors have proposed its use to correct sagittal slope in selected cases of cruciate reconstruction,<sup>24</sup> HTO has largely been described for the initial<sup>1</sup> or secondary treatment of posterolateral corner insufficiency,<sup>24</sup> and to a lesser extent, anterior cruciate ligament rupture.<sup>5,31</sup> In this instance, HTO and posterolateral corner reconstruction can concomitantly address joint line obliquity while addressing the varus thrust gait pattern associated with these injuries.

The complication profile after opening wedge HTO has been inconsistently reported, with comprehensive rates ranging up to 37% to 55%.<sup>15</sup> In contrast to prior smaller series, the current study is among the largest within a young, active cohort and documents an overall complication rate of 19.3%, with unplanned reoperation occurring in 12.8% of knees. Deep surgical site infection (4.5%), hardware failure (4%), and nonunion (2.5%) were the most common significant complications, whereas overcorrection and fracture of the lateral hinge were collectively noted in 4%. Martin et al<sup>15</sup> reviewed adverse events after opening wedge HTO and reported complications among 114 of 323 patients (35.2%), with a 7% severe adverse events rate and a 2.7% reoperation rate. However, their cohort was composed of an older patient subset (mean age, 46.3 ± 9.3 years) with primarily medial osteoarthritis and varus malalignment (62.2%), and only 17% of patients had concomitant procedures. While higher than traditionally described, the complication and reoperation rates among military service members undergoing HTO reflect the prevalence and complexity of combined knee injuries, as well as the diverse range of operating surgeons and surgical experience when compared with prior published series.

The limitations of our study include its retrospective nature, which restricts our ability to fully characterize the severity and classification of intra-articular injury (eg, size of chondral defect, extent of meniscectomy), prior surgical interventions, radiographic measurements, surgical decision making, and measurement of pain and other patient-

reported parameters. Additionally, activity limitations specified in the electronic medical record under the military profile system may not adequately reflect a service member's decision making and measurement of pain and may also represent protective measures imposed by the treating surgeon. Data on military occupational specialty were also not uniformly available, thereby limiting our ability to stratify clinical outcomes based on occupational demands among more active cohorts, such as those in combat arms. Our study may also be underpowered to discern other pertinent factors predictive of failure after HTO in this population. Defined outcome endpoints in the current study may also under- or overestimate the rate of short- to mid-term clinical failures in military service members. Last, the absence of patient-reported outcome measures may limit the identification of patients with suboptimal results in terms of pain and function.

Despite these limitations, the current investigation supports the use of HTO in young, active patients with medial gonarthrosis, with 71.8% of patients successfully returned to military duty at short- to midterm follow-up. While HTO may not completely resolve pain or symptomatic knee complaints associated with early medial compartment arthrosis, our study suggests its efficacy in preserving knee function and restoring patients to an active lifestyle. Future prospective investigations are required to fully elucidate the functional outcomes among active duty service members undergoing HTO. Further studies within this young, active cohort should expand upon the traditional, limited definitions of HTO survivorship and attempt to incorporate broader use of validated, patient-reported outcome measures with activity level scales.

## REFERENCES

- Arthur A, LaPrade RF, Agel J. Proximal tibial opening wedge osteotomy as the initial treatment for chronic posterolateral corner deficiency in the varus knee: a prospective clinical study. *Am J Sports Med.* 2007;35:1844-1850.
- Bauer S, Khan RJ, Ebert JR, et al. Knee joint preservation with combined neutralising high tibial osteotomy (HTO) and matrix-induced autologous chondrocyte implantation (MACI) in younger patients with medial knee osteoarthritis: a case series with prospective clinical and MRI follow-up over 5 years. *Knee.* 2012;19:431-439.
- Bode G, von Heyden J, Pestka J, et al. Prospective 5-year survival rate data following open-wedge valgus high tibial osteotomy [published online November 19, 2013]. *Knee Surg Sports Traumatol Arthrosc.* doi:10.1007/s00167-013-2762-y.
- Bonasia D, Amendola A. Results of high tibial osteotomy: review of the literature. *Int Orthop.* 2010;34:155-160.
- Bonnin MP, Laurent JR, Zedegan F, Badet R. Can patients really participate in sport after high tibial osteotomy? *Knee Surg Sports Traumatol Arthrosc.* 2013;21:64-73.
- Franceschi F, Umile GL, Ruzzini L, Marinozzi A, Maffulli N, Denaro V. Simultaneous arthroscopic implantation of autologous chondrocytes and high tibial osteotomy for tibial chondral defects in the varus knee. *Knee.* 2008;15:309-313.
- Gardiner A, Gutierrez Sevilla GR, Steiner ME, Richmond JC. Osteotomies about the knee for tibiofemoral malalignment in the athletic patient. *Am J Sports Med.* 2010;38:1038-1047.
- Gomoll AH. High tibial osteotomy for the treatment of unicompartmental knee osteoarthritis: a review of the literature, indications, and technique. *Phys Sportsmed.* 2011;39(3):45-54.
- Gougoulias N, Khanna A, Maffulli N. Sports activities after lower limb osteotomy. *Br Med Bull.* 2009;91:111-121.
- Harris JD, McNeilan R, Siston RA, Flanigan DC. Survival and clinical outcome of isolated high tibial osteotomy and combined biological knee reconstruction. *Knee.* 2013;20:154-161.
- Holden DL, James SL, Larson RL, Slocum DB. Proximal tibial osteotomy in patients who are fifty years old or less. A long-term follow-up study. *J Bone Joint Surg Am.* 1988;70:977-982.
- Hui C, Salmon LJ, Kok A, et al. Long-term survival of high tibial osteotomy for medial compartment osteoarthritis of the knee. *Am J Sports Med.* 2011;39:64-70.
- Jackson JP. Osteotomy for osteoarthritis of the knee. *J Bone Joint Surg Br.* 1958;40-B:826.
- LaPrade RF, Spiridonov SI, Nystrom LM, Jansson KS. Prospective outcomes of young and middle-aged adults with medial compartment osteoarthritis treated with a proximal tibial opening wedge osteotomy. *Arthroscopy.* 2012;28:354-364.
- Martin R, Birmingham TB, Willits K, Litchfield R, Lebel ME, Giffin JR. Adverse event rates and classifications in medial opening wedge high tibial osteotomy. *Am J Sports Med.* 2014;42:1118-1126.
- Minas T, Von Keudell A, Bryant T, Gomoll AH. The John Insall Award: a minimum 10-year outcome study of autologous chondrocyte implantation. *Clin Orthop Relat Res.* 2014;472:41-51.
- Minzlaff P, Feucht MJ, Saier T, et al. Osteochondral autologous transfer combined with valgus high tibial osteotomy: long-term results and survivorship analysis. *Am J Sports Med.* 2013;41:2325-2332.
- Nagel A, Insall J, Scuderi G. Proximal tibial osteotomy: a subjective outcome study. *J Bone Joint Surg Am.* 1996;78:1353-1358.
- Noyes FR, Barber-Westin SD, Albright JC. An analysis of the causes of failure in 57 consecutive posterolateral operative procedures. *Am J Sports Med.* 2006;34:1419-1430.
- Odenbring S, Tjörnstrand B, Egund N, et al. Function after tibial osteotomy for medial gonarthrosis below aged 50 years. *Acta Orthop Scand.* 1989;60:527-531.
- Pascale W, Luraghi S, Perico L, Pascale V. Do microfractures improve high tibial osteotomy outcome? *Orthopedics.* 2011;34:e251-e255.
- Rossi R, Bonasia D, Amendola A. The role of high tibial osteotomy in the varus knee. *J Am Acad Orthop Surg.* 2011;19:590-599.
- Salzmänn GM, Ahrens P, Naal FD, et al. Sporting activity after high tibial osteotomy for the treatment of medial compartment knee osteoarthritis. *Am J Sports Med.* 2009;37:312-318.
- Savarese E, Bisicchia S, Romeo R, Amendola A. Role of high tibial osteotomy in chronic injuries of posterior cruciate ligament and posterolateral corner. *J Orthop Traumatol.* 2011;12:1-17.
- Scully WF, Parada SA, Arrington ED. Allograft osteochondral transplantation in the knee in the active duty population. *Mil Med.* 2011;176:1196-1201.
- Shaha JS, Cook JB, Rowles DJ, Bottoni CR, Shaha SH, Tokish JM. Return to an athletic lifestyle after osteochondral allograft transplantation of the knee. *Am J Sports Med.* 2013;41:2083-2089.
- Verdonk PC, Demurie A, Almqvist KF, Veys EM, Verbruggen G, Verdonk R. Transplantation of viable meniscal allograft. Survivorship analysis and clinical outcome of one hundred cases. *J Bone Joint Surg Am.* 2005;87:715-724.
- Warne BA, Aalderink K, Amendola A. Is there a role for high tibial osteotomies in the athlete? *Sports Health.* 2011;3:59-69.
- W-Dahl A, Robertsson O, Lohmander S. High tibial osteotomy in Sweden, 1998-2007: a population-based study of the use and rate of revision to knee arthroplasty. *Acta Orthop.* 2012;83:244-248.
- Wolcott M, Traub S, Efrid C. High tibial osteotomies in the young active patient. *Int Orthop.* 2010;34:161-166.
- Zaffagnini S, Bonanzinga T, Grassi A, et al. Combined ACL reconstruction and closing-wedge HTO for varus angulated ACL-deficient knees. *Knee Surg Sports Traumatol Arthrosc.* 2013;21:934-941.