Meeting Paper

Return to Duty in Military Servicemembers After High Tibial Osteotomy Not Associated With Preoperative Radiographic Parameters

A Retrospective Analysis

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Background: Evidence on return to sports/work after high tibial osteotomy (HTO) is limited, especially in a young, high-demand population.

Purpose: To (1) identify whether preoperative knee pathology or intraoperative correction was associated with successful return to duty (RTD) and (2) assess whether postoperative complications and reoperation were associated with failure to RTD.

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

Methods: We performed a retrospective cohort study of a consecutive series of patients in the Military Health System aged 18 to 55 years with medial compartment osteoarthritis who underwent HTO between 2003 and 2018. Concomitant meniscal and cartilage procedures were included, while cases with concomitant ligamentous procedures were excluded. The inclusion criteria were as follows: active-duty military status, minimum 2-year follow-up, preoperative knee radiographs, and pre- and postoperative long-leg alignment radiographs. Preoperative Kellgren-Lawrence grades and pre- and postoperative hip-knee-ankle angles were measured. The primary outcome was RTD. Failure was defined as knee-related medical separation from the military or conversion to total knee arthroplasty. The secondary outcome was reoperation.

Results: A total of 55 HTOs were performed in 50 patients who met the inclusion criteria, with a mean age of 39 years old (range, 22.8-55 years). The mean follow-up was 5 years (range, 2.1-10.7 years). Ten knees (18.2%) failed HTO (1 conversion to total knee arthroplasty, 9 medical separations), 15 additional knees (27.3%) had permanent activity restrictions, and 30 knees (54.5%) returned to duty without restrictions. Reoperation occurred in 36.4% of knees and was associated with medical separation (P = .039). Younger age was associated with medical separation (P = .003) and permanent restrictions (P = .006). Patients with a postoperative varus deformity of $>5^\circ$ were more likely to undergo medical separation (P = .023).

Conclusion: In a young, high-demand population, HTO succeeded in returning 54.5% of knees to full duty without restriction despite 36.4% of knees requiring reoperation. Residual varus deformity or reoperation was associated with lower RTD rates. No association was identified between RTD and preoperative osteoarthritis grading or deformity.

Keywords: alignment; articular cartilage; knee; military training; return to sports

High tibial osteotomy (HTO) is performed to alter the loading patterns of the knee joint in cases of unicompartmental arthritis and in conjunction with treatment for anterior cruciate ligament rupture, posterolateral corner insufficiency, and meniscal or cartilage injury.[1,2,12,14-16,22] In

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isolated medial compartment arthritis with concomitant varus alignment, considerable debate in the literature exists about when unicompartmental arthroplasty (UKA) is more appropriately indicated.[18] Despite significant advances in implants for UKA, restrictions are often placed after that procedure because of the increased risk of revision surgery for young patients continuing with high occupational demands such as military servicemembers.[6,13] HTO has been utilized as an alternative to UKA in this population, with evidence supporting a faster and higher rate of return to impact activities.[7]

Failure of HTO has often been defined as conversion to total knee arthroplasty (TKA) since HTO is offered as a means to delay the need for joint replacement. One study evaluating risk factors for conversion to TKA found age, arthritis severity, and postoperative weightbearing axis to be significantly associated with conversion.[8] However, the indications for HTO in that study included an age of >40 years, which is older than most military servicemembers. Similarly, in a Canadian population-based registry study, older age was an independent risk factor for conversion, although the youngest patient included was 39 years old.[11] A large prospective study found that greater arthritis severity at the time of HTO was the strongest predictor of conversion to TKA, and conversion rates were lower in patients with correction to neutral or slight overcorrection to a valgus alignment.[17]

These findings are inadequate to counsel the young patient seeking to return to high occupational demands. Simply delaying or avoiding conversion to TKA may not be a sufficient marker of success. A recent systematic review evaluating return to work (RTW) and return to sports (RTS) after HTO recognized considerable heterogeneity in reporting RTS and RTW rates varying from 56% to 100% and 41% to 100%, respectively.[13] Only 1 of the 33 studies defined the criteria for RTS or RTW. In addition, the mean age was 50.3 years, and only 1 study consisted of a military population. Furthermore, the lone study in a military population did not assess radiographic parameters after HTO.[21]

Given the paucity of clearly defined criteria and risk factors for failure to RTS or RTW in a young population with high occupational demands, our goal was to identify whether preoperative knee pathology or intraoperative correction was associated with successful return to duty (RTD) in a military population. A secondary aim was to assess whether postoperative complications and reoperation were associated with RTD failure.

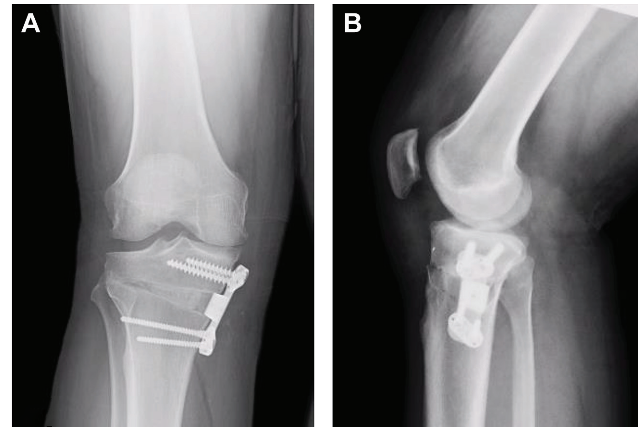

Figure 1. (A) Postoperative anteroposterior and (B) lateral knee radiographs after high tibial osteotomy.

METHODS

Institutional review board approval was obtained and informed consent was waived for this retrospective cohort study of patients in the Military Health System who underwent medial opening-wedge HTO (Figure 1) between 2003 and 2018. Patients were identified using Current Procedural Terminology code 27457 for HTO. Procedures were performed with the surgeon's preferred technique for fixation and occurred at multiple treatment facilities throughout the Military Health System. All patients were between 18 and 55 years old at the time of surgery and presented with osteoarthritis isolated to the medial compartment with or without concomitant knee injuries.

Patients undergoing concomitant meniscal and cartilage procedures were included, while those undergoing

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concomitant ligamentous procedures were excluded, as they were viewed as having a separate pathology—that is, alignment correction primarily to protect a ligamentous reconstruction as opposed to primarily for the treatment of osteoarthritis. Patients undergoing lateral closing wedge HTOs were also excluded. The inclusion criteria were as follows: active-duty status at the time of the index procedure, minimum 2-year follow-up, and both preoperative knee radiographs and pre- and postoperative long-leg alignment radiographs.

The primary outcome was RTD. RTD was subcategorized into RTD success (remaining on active duty without restriction) and RTD modified success (remaining on active duty with permanent activity restrictions). Failure was defined as knee-related medical separation from the military, mention of a medical evaluation board in the electronic medical record, or conversion to TKA. Medical separations from the military occur due to a servicemember's inability to deploy or perform required physical fitness tests or occupational-specific duties within a year from surgery. Medical evaluation boards are recommended to assess fitness for duty when a servicemember has a prolonged recovery or is not expected to RTD within 1 year. The secondary outcome was reoperation for any reason.

The electronic health record for each patient was utilized to collect clinical and demographic information—including age, sex, military rank, branch of service, presence of diabetes mellitus, body mass index (BMI), and smoking status. All operative and progress notes were reviewed to determine surgical technique, laterality, and presence of concomitant knee pathology and procedures. The need for revision or conversion to TKA was recorded. Complications were identified, and the need to return to the operating room was recorded. The preoperative Kellgren-Lawrence grade was recorded from preoperative knee radiographs (Figure 2), and pre- and postoperative hip-knee-ankle (HKA) angles and categorical weightbearing axis (varus, neutral, or valgus) were measured on long-leg alignment radiographs (Figure 3) using methods previously described.[5,10,19] Permanent activity restrictions, initiation of a medical board to determine suitability for continued military service, or medical discharge for reasons related to the operative extremity were recorded.

Statistical analyses were performed using JMP Statistical Discovery software Version 16.0 (SAS Institute). All continuous variables were described using means and standard deviations, while categorical variables were described using frequencies and percentages. Each continuous variable was evaluated for normality. This was performed both numerically and graphically. Age, BMI, preoperative HKA angle, postoperative HKA angle, and HKA angle differences were assessed using the Shapiro-Wilk test. Shapiro-Wilk testing showed normal distributions for all variables except BMI. A normal quantile plot was also utilized to evaluate normality. All normally distributed continuous variables were analyzed using parametric tests, whereas BMI and categorical variables were analyzed utilizing nonparametric tests. The Pearson chi-square test was used to evaluate RTD for categorical variables and the Fisher exact test was used when frequencies were below the threshold required for chi-square analysis. $P < .05$ was used to determine statistical significance.

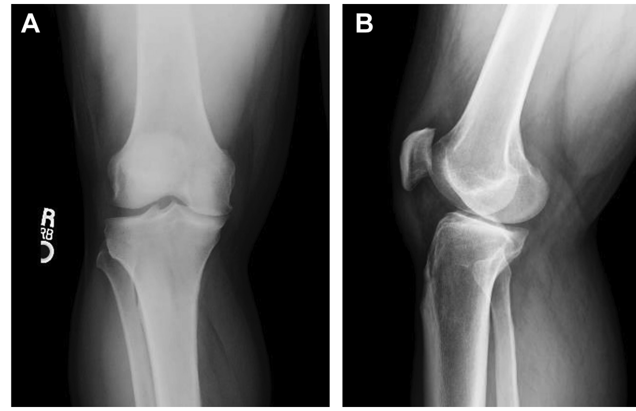

Figure 2. (A) Preoperative anteroposterior and (B) lateral knee radiographs demonstrating Kellgren-Lawrence grade 3 osteoarthritis characterized by moderate osteophytes, definitive joint space narrowing, and subchondral sclerosis of the medial tibial plateau.

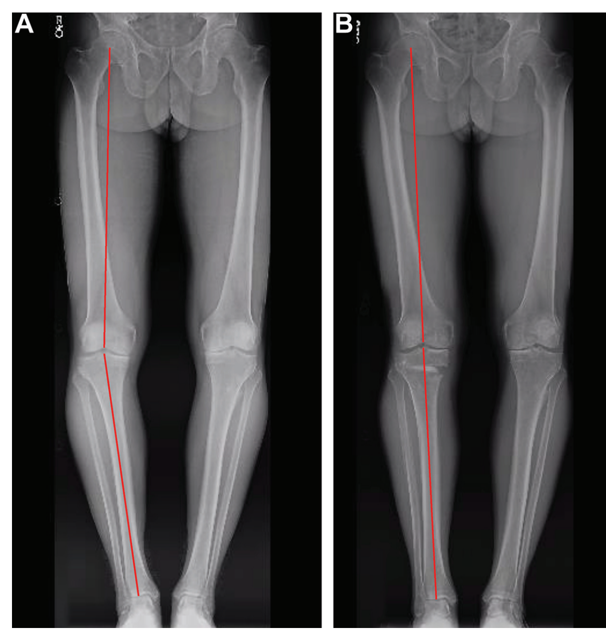

Figure 3. (A) A preoperative long-leg alignment radiograph demonstrating a hip-knee-ankle angle of 9.2° of varus. (B) A long-leg alignment radiograph after high tibial osteotomy with correction to 0.1° of valgus.

RESULTS

A total of 272 HTOs were initially identified. After applying the inclusion and exclusion criteria, 55 HTOs were included in the analysis (Figure 4) for 50 patients with

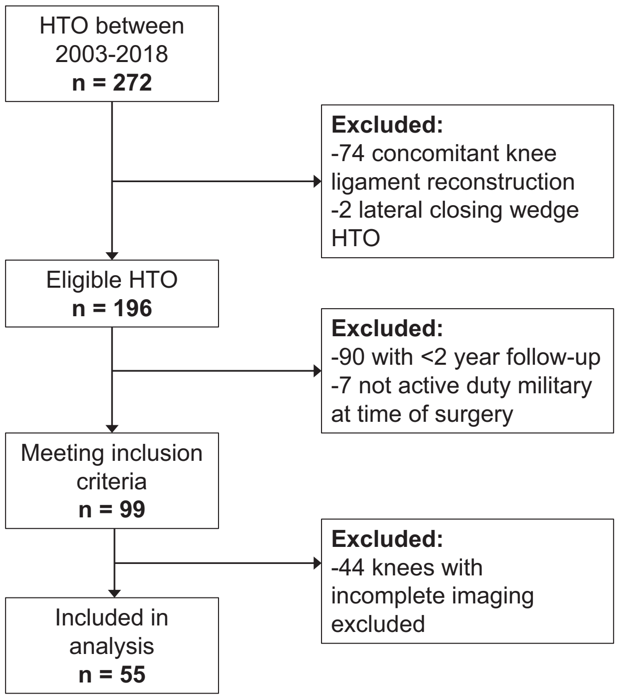

Figure 4. CONSORT flow diagram. CONSORT, Consolidated Standards of Reporting Trials; HTO, high tibial osteotomy.

a mean age of 39 years (range, 22.8-55 years). The mean follow-up was 5 years (range, 2.1-10.7 years). In this active-duty population, 25% of cases were officers, while 75% of cases were enlisted servicemembers. Our cohort was made up of 89% male patients without diabetes mellitus or active smoking habits. The mean BMI at the time of HTO was 29.6 kg/m^2. A total of 36 HTOs were isolated, while 12 (21.8%) had concomitant cartilage procedures, and 7 (12.7%) had concomitant meniscal procedures. There were 7 meniscal debridements and 1 meniscal allograft transplantation. There were 4 osteochondral graft transplants, 6 microfractures, and 1 internal fixation of an osteochondritis dissecans lesion.

Ten knees (18.2%) failed HTO (1 conversion to TKA, 9 medical separations), 15 additional knees (27.3%) had permanent activity restrictions, and 30 knees (54.5%) returned to active duty without restriction. Of the 55 HTOs, reoperation occurred in 36.4% at a mean of 401 days (range, 1-1327 days) after HTO. Reoperation was associated with medical separation (*P* = .039) and trended toward permanent activity restrictions for those who remained in the military (*P* = .102). Reoperation occurred for unplanned removal of hardware (n = 7), irrigation and debridement (n = 4), revision HTO (n = 3), meniscal transplant (n = 2), conversion to TKA (n = 1), meniscal repair (n = 1), spinal cord stimulator placement (n = 1), and decompressive fasciotomies (n = 1). Of the 30 patients who successfully underwent RTD without restrictions, 26.7% had reoperation (5 unplanned hardware removals, 2 irrigation and debridements, and 1 meniscal repair).

There was 1 intraoperative complication during the index HTO, with transection of the popliteal artery/vein and tibial nerve requiring interposition graft, primary repair, and subsequent brace wear for foot drop. There were 19 additional postoperative complications: symptomatic hardware (n = 5), superficial infection (n = 4), overcorrection (n = 2), deep infection (n = 2), compartment syndrome (n = 1), chronic regional pain syndrome (n = 1), nonunion (n = 1), fracture (n = 1), hardware failure (n = 1), and deep venous thrombosis (n = 1).

Younger age was associated with both medical separation (*P* = .003) and permanent restrictions (*P* = .006) after HTO. The following variables were not significantly associated with permanent activity restrictions: concomitant procedures (*P* = .652), sex (*P* = .229), BMI (*P* = .613), preoperative deformity (*P* = .265), and degree of deformity correction (*P* = .864). The following variables were not significantly associated with medical separation: concomitant procedures (*P* = .469), sex (*P* = .268), BMI (*P* = .586), smoking (*P* = .350), preoperative deformity (*P* = .146), and degree of deformity correction (*P* = .413). There was a trend toward military officers not undergoing medical separation compared with enlisted personnel (*P* = .055).

Tables 1 to 3 show radiographic parameters and their association with RTD. Alignment was analyzed, demonstrating no significant differences between groups (Table 1). The preoperative Kellgren-Lawrence grade showed no statistical significance with respect to the rate of return to the operating room or the level of success after HTO (Table 2). Alignment was assessed categorically (valgus/lateral to the lateral tibial spine, neutral/between the tibial spines, or varus/medial to the medial tibial spine) and showed no statistical significance (Table 3). When comparing patients with $<5°$ residual deformity to those with $>5°$ of residual valgus, the latter were more likely to undergo medical separation (*P* = .023).

DISCUSSION

The chief findings of our study were that in a young, high-demand population with a mean age of 39 years old, nearly 55% returned to active duty without restriction and an additional 27% were able to RTD with permanent activity restrictions. Younger age was associated with both medical separation and permanent restrictions after HTO, while radiographic parameters—including preoperative alignment and arthritis severity—were not shown to be significant predictors. All-cause reoperations occurred in 36% of knees and were associated with medical separation.

In this study, measures of preoperative knee condition severity—including preoperative arthritis severity or the need for concomitant meniscal or cartilage procedures—were not associated with the RTD rate. In a systematic review of HTO performed for osteoarthritis, cartilage defects, and symptomatic knee malalignment, Kunze et al[13] found that the RTS rate ranged from 56% to 100% and the RTW rate ranged from 41% to 100%. Return to the same activity level occurred in 66.3%, greater activity

TABLE 1
Preoperative and Postoperative Mechanical Alignment

Hip-Knee-Ankle Angle	Alignment Mean, deg	Alignment Range, deg	Success	Modified Success
Preoperative	7.2 varus	1.4-13.7 varus	*P* = .194	*P* = .192
Postoperative	1.0 valgus	10 valgus-5.6 varus	*P* = .413	*P* = .864

TABLE 2
Return to Duty Rates by Baseline Osteoarthritis Severity

Preoperative Kellgren-Lawrence Grade	Successes, % (n/N)		Modified Successes, % (n/N)		Failures, % (n/N)
0	50 (1/2)	*P* = .855	50 (1/2)	*P* = .257	0 (0/2)
1	66.7 (10/15)		20 (3/15)		13.3 (2/15)
2	48.1 (13/27)		29.6 (8/27)		22.2 (6/27)
3	66.7 (6/9)		22.2 (2/9)		11.1 (1/9)
4	100 (2/2)		0 (0/2)		0 (0/2)

TABLE 3
Return to Duty Rates by Postoperative Alignment Category

Postoperative Alignment, Weightbearing Axis Relative to Tibial Spines	Successes, % (n/N)		Modified Successes, % (n/N)		Failures, % (n/N)
Valgus, lateral to spines	45.5 (10/22)	*P* = .142	40.9 (9/22)	*P* = .335	13.6 (3/22)
Neutral, between spines	65.4 (17/26)		23.1 (6/26)		11.5 (3/26)
Varus, medial to spines	42.8 (3/7)		14.3 (1/7)		42.9 (3/7)

levels in 10.3%, and lesser activity levels in 23.4%. While the return to full duty rate of 54.5% in the present study appears comparatively low, the activity level in their civilian cohort may have differed, especially with a mean age of 50.3 years old compared with the mean age of 39 years old in the present study. In another systematic review analyzing RTW and RTS after HTO, 87.2% of patients had RTS, but only 54% of competitive athletes were noted to have returned to competition.[4] This suggests a difference in RTS rates based on the level of competition before surgery. While our study did not distinguish patients based on military occupational specialty, all patients were required to complete annual physical fitness tests. If unable to pass these tests, servicemembers would be on permanent activity restrictions or separated from military service. For reference, patients returning to full military duty without restrictions are expected to coincide with a Tegner Activity score of at least 6. Patients returning to active duty but with permanent restrictions would coincide with a Tegner Activity score[3,20] of at least 3.

Moreover, Ekhtiari et al[4] discussed that the single military study included in their review accounted for most patients who returned to work at lower levels. This highlights that RTD rates may not be equivalent to RTW rates in a civilian population, which is likely multifactorial but may reflect the occupational demands on servicemembers.[21] In the Waterman et al[21] study assessing HTO outcomes in a military patient population, radiographic parameters were not evaluated. However, they had similar rates of return to full duty (43%), RTD with minor permanent activity limitations (29%), and knee-related medical discharge (26%) in a cohort with similar occupational demands and a mean age of 35.7 years old.

The severity of arthritis and alignment correction has been shown to have an impact on HTO failure when defined as conversion to TKA. In a cohort with a mean age of 56 years old, Jin et al[8] demonstrated that medial compartment Kellgren-Lawrence grade 4 and postoperative HKA angle in any degree of varus were risk factors for HTO failure. Separately, a large prospective study demonstrated that greater arthritis severity at the time of HTO was the strongest predictor of conversion to TKA, and rates were lower for patients with correction to neutral or slight overcorrection.[17] The mean age of that cohort was 56 years old, substantially older than in our study. While the present study did not support these findings, the age differences suggest that the findings in an older population may not be generalizable to a group of patients aged <40 years old. In our cohort, with a mean age of 39 years old, there was no significant difference in RTD based on preoperative arthritis grading. However, with only 2 patients with Kellgren-Lawrence grade 4 arthritis and 9 patients with grade 3 arthritis, our ability to conclude cases of severe preoperative arthritis was limited. Limited literature exists on preoperative arthritis severity or alignment and its influence on the rate of RTS or RTW in young patients with high occupational demands.

The present study did find that reoperation after the index procedure was negatively associated with the RTD rate. The systematic review by Kunze et al[13] identified a conversion rate to TKA of 2% and a complication rate of 6% in medial opening-wedge HTO. The conversion rate was similar in the present study at 1.8%, but the rate of HTOs requiring reoperation for complication at 36.4% differed and, importantly, was associated with medical separation from the military. While the reoperation rate was within the range previously described (5%-36.9%), it is on the higher end. In the systematic review by Kunze et al,[13] only 58% of included studies reported conversion to TKA and >20% did not report complications. Considerable heterogeneity in reporting also existed. In the retrospective study of military patients by Waterman et al,[21] their reoperation rate was also much lower at 12.8% despite assessing similar complications as in the present study, suggesting that the differences in occupational demands and the activity levels associated with younger age in the present study may not fully explain our high reoperation rate. In contrast to their study, however, in the present cohort, patients were excluded for concomitant ligamentous procedures or for lacking pre- and postoperative limb length alignment films while they were included in the aforementioned study, which may account for some of the differences in reoperation rate. Previous population-based studies have shown concurrent ligamentous reconstruction with HTO to be a protective factor for survivorship.[11]

Age at the time of HTO was demonstrated to be a significant predictor of both failure to RTD and RTD with permanent activity restrictions. This is in agreement with the findings from Waterman et al,[21] where age <30 years old was associated with a nearly 2-fold increase in the rate of failure in a similarly aged cohort. Other studies have demonstrated that older age can also predict failure. Jin et al[8] reported on 339 HTOs in a cohort with a mean age of 56 years old and found that age >65 years old was associated with increased failure. Keenan et al[9] reported significantly greater conversion rates at ages >47 years old in a cohort, with a mean age of 45 years. In a Canadian population-based registry study, older age was an independent risk factor for conversion, with a 5% increased risk for every year beyond 46 years. However, the youngest patient was 39 years old.[11] Our findings, in combination with these studies, suggest that the youngest and oldest ends of the HTO population may be predisposed to failure, either in terms of not returning to desired activities or requiring conversion to TKA, respectively. These findings highlight the differences in the criteria for success in 2 different age-groups undergoing similar surgeries. These findings suggest that appropriate patient counseling on expected outcomes will vary based on patient age.

Return to full duty has historically been used in military studies as an outcome comparable with RTS or RTW. A recent study evaluating the role of RTD as a comparable outcome measure has brought this into question, with 67% of servicemembers having returned to full duty reporting an overall lower level of activity, 27% having not returned to the same work level, and 23% having reported undergoing a medical evaluation board.[23] That study was potentially biased by the exclusion of 90% of patients available for survey and a heterogeneous population of all patients undergoing orthopaedic surgery, which may have overestimated the postoperative disability of military patients. Despite this, several considerations were accounted for in the present study to report postoperative function more accurately after HTO. RTD was distinguished between those with and without permanent activity restrictions. In addition, any mention of a medical evaluation board in the patient's medical record was considered a failure for the procedure, regardless of the eventual outcome or continuation of military service. Finally, the annual fitness tests required of servicemembers serve as a minimum level of activity that can be used by all surgeons based on the Tegner Activity level score for counseling purposes and in comparison with other studies.

This study had several limitations. Its retrospective design carries the inherent flaws typically associated with this type of research. In particular, a large proportion of HTOs meeting the inclusion criteria for this study were excluded for the lack of pre- or postoperative imaging, which may have introduced selection bias into our cohort and limited the conclusions we could draw from a limited number of patients with severe preoperative arthritis. Despite the lengthy duration of the study, which was to capture a larger series of patients, the small sample size may not have been powered to detect a difference in RTD based on preoperative arthritis. Separately, active-duty servicemembers are observed annually with mandatory health screening appointments, at which time any criteria deemed as a failure for this study would be captured. Once patients leave the military, however, the ability to determine failure is limited and may result in a higher success rate for HTO through underdocumentation. Conversely, this effect may be offset by leaving the rigors of the military lifestyle. The follow-up length was long enough to determine whether patients were able to RTD but likely was not enough to capture meaningful information for survivorship and conversion to TKA, which could have dampened the overall failure rate of HTO reported in this study. The duration of this study could have allowed for variations in treatment over time. However, attempts were made to limit these effects by narrowing the inclusion criteria to those undergoing medial opening-wedge HTO. Finally, while we did not assess patients' military occupational specialty to determine variations in occupational demand, the baseline of annual physical testing required to remain in the military offers generalizable information to counsel patients with similar expectations or needs.

CONCLUSION

In a young, high-demand population, HTO succeeded in returning 54.5% of knees to full duty without restriction despite 36.4% of knees requiring reoperation. Residual varus deformity or reoperation was associated with lower

RTD rates. No association was identified between RTD and preoperative osteoarthritis grading or deformity.

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