

Association between body mass index and 90-day postoperative complications after insertional Achilles debridement and suture-anchor reattachment: a retrospective cohort study

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Abstract

Background

Obesity has been associated with complications after Achilles tendon surgery, but evidence specific to insertional Achilles tendinopathy is limited and conflicting. We evaluated the association between body mass index and 90-day complications after a standardized insertional Achilles operation.

Methods

This retrospective procedure-level cohort included all eligible primary operations at a single tertiary referral center from 2013 through 2025. The primary outcome was any adjudicated complication within 90 days. BMI was evaluated with an adjusted three-knot restricted cubic spline and summarized by an odds ratio per 5 kg/m². Logistic regression used patient-clustered robust standard errors and adjusted for age, diabetes, and smoking status at initial surgical evaluation. The BMI ≥ 35 kg/m² comparison was post hoc. Time to documented return to usual activity was analyzed with an adjusted Cox model.

Results

Among 217 procedures in 194 patients, 32 had a 90-day complication (14.7%). The adjusted spline demonstrated an association between BMI and complications (global $p = 0.030$) with evidence of nonlinearity ($p = 0.023$). Each 5-kg/m² increase in BMI was associated with higher average odds of a complication (adjusted OR 1.43, 95% CI 1.11–1.85; $p = 0.006$). In the post hoc analysis, complications occurred after 21 of 82 procedures with BMI ≥ 35 kg/m² (25.6%) and 11 of 135 with BMI < 35 kg/m² (8.1%; adjusted OR 3.89, 95% CI 1.71–8.85; $p = 0.001$). Seventeen wound complications occurred (7.8%). BMI was not associated with time to documented return to usual activity (adjusted HR 0.91 per 5 kg/m², 95% CI 0.74–1.11; $p = 0.355$).

Conclusions

Higher BMI was associated with greater 90-day complication risk after primary insertional Achilles surgery, with a nonlinear relationship across the observed range. BMI ≥ 35 kg/m² may be a pragmatic counseling reference, but it was selected post hoc and is not a validated threshold or stand-alone contraindication. Compared with prior insertional Achilles series, this study used a standardized 90-day endpoint, nonlinear BMI modeling, blinded complication adjudication, and methods accounting for repeated procedures.

Background

Insertional Achilles tendinopathy is a degenerative disorder at the tendon-calcaneus interface that can produce chronic posterior heel pain, activity limitation, and impaired function. It is distinct from midsubstance tendinopathy and acute Achilles tendon rupture because the pathologic process occurs at the insertion and often coexists with calcific change, retrocalcaneal bursitis, or a posterosuperior calcaneal prominence [1–3]. Initial care generally includes activity modification, footwear changes, heel lifts, physical therapy, loading programs, and other nonoperative measures [1, 4, 5].

When symptoms remain limiting despite nonoperative treatment, operative care may include insertional tendon debridement, excision of the Haglund deformity or insertional enthesophyte, and repair or reattachment of the Achilles insertion with suture anchors [2, 3, 6–11]. Most published series report meaningful improvement after surgery, but wound problems, neurologic symptoms, thromboembolic events, reinjury, and other postoperative complications remain important considerations [7, 8, 12, 13]. The posterior heel has a relatively thin soft-tissue envelope, and operative exposure often requires substantial tendon and soft-tissue handling. Patient-level factors may therefore be relevant to risk counseling.

Higher body mass index (BMI) has been associated with the development of Achilles tendinopathy and with complications after tendon surgery, although the evidence is heterogeneous [14–16]. Direct evidence in insertional Achilles surgery is limited and conflicting. Ptak and Rigby found no difference in complication rates among BMI groups in a 78-patient detachment and reattachment cohort [17]. Morrisette and colleagues reported more wound breakdown among patients with obesity after Haglund resection, although the operative procedures were not identical to a uniform insertional debridement and reattachment construct [18]. More recently, Hower and colleagues reported higher wound dehiscence in 33 patients with BMI ≥ 40 kg/m² within a 123-patient insertional Achilles cohort, while the difference in overall complications did not meet conventional statistical significance [19]. These studies leave uncertainty regarding the shape of the BMI-risk relationship and the most appropriate way to counsel patients across the BMI spectrum.

Studies of acute Achilles rupture repair have also reported inconsistent associations between obesity and wound, infectious, thromboembolic, and medical complications [20–22]. Findings from acute rupture repair cannot be assumed to apply directly to insertional Achilles surgery because the indication, surgical exposure, tendon pathology, and reconstruction differ.

The primary objective of this study was to evaluate the association between BMI and an adjudicated postoperative complication within 90 days after primary insertional Achilles debridement, Haglund excision, and standardized suture-anchor reattachment. Secondary objectives were to describe complication rates across clinical BMI categories, evaluate a post hoc BMI ≥ 35 kg/m² cut point, characterize wound complications, and assess the association between BMI and time to documented return to usual activity. We hypothesized that higher BMI would be associated with greater 90-day postoperative complication risk.

Methods

Study design, setting, and ethics

This retrospective procedure-level cohort study was conducted at Mayo Clinic in Rochester, Minnesota, a single tertiary referral center. Qualifying procedures performed between January 2, 2013, and December 23, 2025, were eligible. The medical record was reviewed through March 23, 2026, which provided at least 90 days of postoperative complication ascertainment for every included procedure. This retrospective medical-record review was reviewed by the Mayo Clinic Institutional Review Board and determined to be exempt (IRB No. 25-013518). Informed consent was not required. The manuscript was prepared in accordance with the STROBE recommendations for cohort studies [23].

The study size was determined by the number of procedures meeting the final eligibility criteria during the approved study period. All eligible procedures were included, and no sampling was performed. No formal a priori sample-size calculation or post hoc power analysis was performed. Statistical precision was characterized with 95% confidence intervals.

Case identification and eligibility

Potentially eligible procedures were identified through institutional database searches using Current Procedural Terminology codes 27654 and 28118. Results from either code were combined with the participating surgeons' operative case records. Duplicate entries and records clearly unrelated to the target operation were removed during initial reconciliation. A total of 225 potentially eligible procedures underwent detailed medical-record review.

Procedures were eligible when the indication was chronic insertional Achilles tendinopathy and the index operation was a primary insertional Achilles debridement, excision of the Haglund deformity or posterosuperior calcaneal prominence, and Achilles repair or reattachment using the standardized suture-anchor construct. Acute Achilles rupture or reconstruction, index revision surgery, and procedures involving flexor hallucis longus tendon transfer were excluded. Concomitant noninsertional Achilles disease did not preclude inclusion when insertional disease was present and the qualifying insertional procedure was performed. No adult-only age criterion was imposed. Eight procedures were excluded: one because BMI could not be calculated, two index revision procedures, two acute rupture or reconstruction procedures, and three procedures involving flexor hallucis longus tendon transfer. The final cohort included 217 procedures in 194 unique patients.

Surgical procedure and perioperative care

All included procedures were performed by four fellowship-trained orthopedic foot-and-ankle surgeons; three principal surgeons performed 216 of the 217 procedures. A posterior midline longitudinal approach was used. The paratenon was routinely preserved and repaired. Diseased insertional tendon was

debrided, the Haglund deformity or posterosuperior calcaneal prominence was excised, and the Achilles insertion was repaired or reattached with the same double-row suture-anchor bridge construct across surgeons. Historical operative labels such as “excision,” “resection,” or “debridement” were treated as abbreviated descriptions of this standardized operation after clinical confirmation.

Postoperative immobilization, weight-bearing progression, transition to supportive footwear, and physical therapy generally followed a standardized institutional pathway throughout the study period. No major change in the routine pathway occurred. Minor patient-specific modifications were permitted according to wound healing, symptoms, comorbidities, and clinical progress. Venous thromboembolism prophylaxis generally consisted of aspirin 81 mg twice daily or 325 mg once daily, typically for approximately 6 weeks and through the period of non-weight bearing or early restricted weight bearing. Regimen and duration could be modified for contraindications, pre-existing anticoagulation, weight-bearing progression, and individualized thromboembolic or bleeding risk. Exact patient-level dose and duration were not consistently abstracted and were not analyzed.

Data collection and quality control

Two research assistants independently reviewed every medical record using a standardized data-collection form that incorporated variable definitions and outcome-classification criteria established before medical-record abstraction began. Discrepancies were reconciled through discussion and repeat review of the source medical record. A subsequent comprehensive re-audit served as a quality-control step to verify uniform application of the prespecified definitions, reconcile coding discrepancies, and confirm event dates and final classifications before the analytic dataset was locked and the final statistical analyses were performed.

Cases with unresolved uncertainty regarding complication status, subtype, or severity were independently adjudicated by two fellowship-trained orthopedic foot-and-ankle surgeons who were blinded to patient BMI. Disagreements were resolved by consensus before final outcome assignment. Separate pre-consensus ratings were not retained, so an inter-rater agreement statistic was not calculated.

Exposure and covariates

BMI was calculated for each procedure from contemporaneous height and weight measurements obtained at the same preoperative encounter or immediately preceding surgery. BMI was calculated as weight in kilograms divided by height in meters squared. Unrounded values were used for continuous modeling, spline analyses, and category assignment; rounded values were used only for descriptive presentation. BMI was categorized as < 25.0, 25.0-29.9, 30.0-34.9, 35.0-39.9, 40.0-44.9, or ≥ 45.0 kg/m² for descriptive analyses.

Diabetes mellitus was coded as present when an established diagnosis was documented at the time of surgery, regardless of treatment method. Prediabetes and isolated abnormal glucose measurements were not classified as diabetes. Smoking status represented active smoking at the initial surgical evaluation. Patients identified as active smokers were counseled to discontinue smoking and underwent preoperative blood nicotine testing. Surgery proceeded after a negative test, typically corresponding to approximately 4–6 weeks of abstinence. Sex was abstracted as documented in the medical record at the time of surgery.

Outcomes

The primary outcome was at least one adjudicated postoperative complication occurring within 90 days of surgery. The available electronic health record was reviewed through postoperative day 90 for every procedure, regardless of the duration of routine clinic follow-up. The composite included wound or incisional complications, confirmed venous thromboembolism, clinically meaningful neuritic symptoms, formal nerve injury, clinically abnormal edema or swelling, inflammatory or suture-related reaction, documented reinjury or mechanical failure, and another clinically significant postoperative event requiring additional evaluation or treatment. A procedure with more than one subtype was counted once in the composite; subtype categories were not mutually exclusive.

A minor wound complication was defined as clinically abnormal delayed healing, drainage, superficial dehiscence, erythema, blistering, dry eschar, or another wound concern requiring additional evaluation or nonoperative management beyond routine postoperative care, including outpatient oral antibiotics. A major wound complication was defined as deep infection, substantial wound dehiscence, hospitalization or intravenous antibiotic treatment for a postoperative wound infection, operative irrigation and debridement, washout, or surgical wound revision. Venous thromboembolism required a confirmed deep-vein thrombosis or pulmonary embolism. Symptoms prompting a negative thromboembolic evaluation were not classified as venous thromboembolism.

Neuritic symptoms required new postoperative symptoms characterized as burning pain, dysesthesia, paresthesia, hypersensitivity, or nerve-distribution pain. Nonspecific postoperative pain did not qualify. Abnormal swelling was counted only when it was considered clinically concerning and prompted additional evaluation, testing, treatment, or specific concern for another complication. Inflammatory or suture-related reactions required a clinically meaningful localized response or symptomatic suture irritation that prompted evaluation or treatment. Reinjury or mechanical failure required a documented traumatic event, clinician-attributed reinjury, tendon failure or avulsion, or imaging or operative evidence of failure.

Revision surgery for persistent or recurrent insertional symptoms was recorded separately and did not independently qualify as a complication. Reoperation performed to treat an acute qualifying complication was recorded under that underlying complication. Events first documented after 90 days

were retained and summarized descriptively but were not included in the principal regression outcome because longer-term observation varied among procedures.

Return to usual activity was a secondary time-to-event outcome. It was defined as the best-estimated postoperative date when the patient returned to work, sport, or usual activity at a level described by the patient or clinician as normal or essentially normal. Dates were determined through medical-record review and represented the estimated date of actual return rather than only the clinic encounter when return was documented. Procedures without documented return were right-censored at the final available postoperative follow-up.

Statistical analysis

Continuous variables were summarized as mean $\pm$ standard deviation or median with interquartile range, as appropriate. Categorical variables were summarized as counts and percentages. Baseline characteristics were described overall and by the post hoc BMI < 35 and ≥ 35 kg/m² groups without baseline hypothesis testing. Ninety-day complication rates across the six BMI categories were accompanied by Wilson 95% confidence intervals and compared descriptively with an exact global test.

BMI was identified a priori as the principal exposure and was initially evaluated continuously. During final model assessment, its functional form was examined with a three-knot restricted cubic spline using knots at the 10th, 50th, and 90th percentiles of BMI. The spline model adjusted for age at surgery, diabetes, and smoking status at initial surgical evaluation. Patient-clustered robust standard errors accounted for multiple procedures within the same patient. A global Wald test evaluated the overall BMI association, and a separate Wald test evaluated the nonlinear component. Marginal standardized 90-day complication probabilities were calculated across the observed BMI range by predicting each procedure at each BMI value while retaining its observed covariates, then averaging across the cohort. Confidence intervals used the patient-clustered robust covariance matrix.

A linear BMI model, reported per 5-kg/m² increase, provided a parsimonious average summary. A BMI ≥ 35 kg/m² analysis was selected after review of the six categorical complication rates and was treated as post hoc and exploratory. For this comparison, observed risk differences and confidence intervals were estimated with a patient-level cluster bootstrap using 200,000 resamples. Covariate-adjusted marginal standardized probabilities and their difference were derived from the adjusted binary logistic model with patient-clustered robust inference.

Sensitivity analyses included a binomial-logit generalized estimating equation with an exchangeable working-correlation structure, restriction to the first eligible procedure per patient, Firth penalized logistic regression [24], additional adjustment for procedure year, additional adjustment for sex, exclusion of the single procedure contributed by the fourth surgeon, and surgeon adjustment among the three principal surgeons. Individual surgeon coefficients were not interpreted. Wound-specific regression was exploratory because only 17 wound events occurred and used Firth penalized logistic regression.

Time to documented return to usual activity was analyzed with Cox proportional-hazards regression adjusted for BMI per 5 kg/m², age, diabetes, and smoking status at initial surgical evaluation. Patient-clustered robust standard errors were used, and the proportional-hazards assumption was assessed with Schoenfeld residuals. Hazard ratios below 1 indicate a lower instantaneous rate of documented return. Kaplan-Meier estimates by the post hoc BMI $\geq$ 35 kg/m² cut point were descriptive.

The adjusted association between continuous BMI and 90-day complications constituted the principal analysis. The linear BMI estimate, BMI categories, BMI $\geq$ 35 kg/m² cut point, subtype analyses, all-follow-up complications, and return-to-activity analyses were supporting, secondary, or exploratory. No formal adjustment for multiple comparisons was performed. All tests were two-sided, $p < 0.05$ was considered statistically significant for the principal analysis, and effect estimates are reported with 95% confidence intervals. All final statistical analyses were performed using R version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria). Package versions and the complete analytic environment were preserved in the institutional reproducibility archive.

All procedures in the principal analysis had complete data for BMI, age, diabetes, smoking status, patient clustering, and 90-day complication status; therefore, no imputation was performed. One otherwise potentially eligible procedure was excluded because BMI could not be calculated. Missing secondary descriptive variables were analyzed with available cases and the applicable denominator. Procedures without documented return to activity were right-censored and were not treated as having missing outcome data.

Results

Cohort characteristics

Of 225 potentially eligible procedures that underwent full chart review, eight were excluded: one because BMI could not be calculated, two index revision procedures, two acute rupture or reconstruction procedures, and three procedures involving flexor hallucis longus tendon transfer. The final cohort included 217 procedures in 194 unique patients; 23 patients contributed two eligible procedures. A total of 135 procedures had BMI $<$ 35 kg/m² and 82 had BMI $\geq$ 35 kg/m². Mean age was 56.5 ± 12.4 years, 133 procedures involved female patients (61.3%), and mean BMI was 33.4 ± 6.7 kg/m². Median postoperative follow-up was 156 days (IQR, 83–287) (Table 1). The cohort flow is shown in Additional file 1, Supplementary Figure S3.

Table 1
Baseline and procedural characteristics

Characteristic	Overall, N = 217	BMI < 35 kg/m ² , n = 135	BMI ≥ 35 kg/m ² , n = 82
Age at surgery, years, mean ± SD	56.5 ± 12.4	56.4 ± 14.0	56.6 ± 9.0
Female sex, n (%)	133 (61.3%)	81 (60.0%)	52 (63.4%)
BMI, kg/m ² , mean ± SD	33.4 ± 6.7	29.3 ± 3.6	40.2 ± 4.8
Diabetes mellitus, n (%)	32 (14.7%)	16 (11.9%)	16 (19.5%)
Active smoker at initial evaluation, n (%)	10 (4.6%)	4 (3.0%)	6 (7.3%)
Right-sided procedure, n (%)	122 (56.2%)	79 (58.5%)	43 (52.4%)
Operating surgeon S1, n (%)	51 (23.5%)	28 (20.7%)	23 (28.0%)
Operating surgeon S2, n (%)	99 (45.6%)	65 (48.1%)	34 (41.5%)
Operating surgeon S3, n (%)	66 (30.4%)	41 (30.4%)	25 (30.5%)
Operating surgeon S4, n (%)	1 (0.5%)	1 (0.7%)	0 (0.0%)
Procedure period, 2019–2025, n (%)	119 (54.8%)	78 (57.8%)	41 (50.0%)
Postoperative follow-up, days, median (IQR)	156 (83–287)	141 (80–254)	168 (90–353)
Values are reported by procedure. BMI ≥ 35 kg/m ² is a post hoc clinical cut point. BMI, body mass index; IQR, interquartile range; SD, standard deviation.			

The six BMI categories included 15 procedures with BMI < 25.0 kg/m², 62 with BMI 25.0–29.9 kg/m², 58 with BMI 30.0–34.9 kg/m², 45 with BMI 35.0–39.9 kg/m², 28 with BMI 40.0–44.9 kg/m², and 9 with BMI ≥ 45.0 kg/m².

Ninety-day postoperative complications

Thirty-two of 217 procedures had at least one adjudicated complication within 90 days (14.7%). Wound or incisional complications were most common, occurring after 17 procedures (7.8%), including 15 minor and 2 major events. Other events included seven procedures with neuritic symptoms, four with reinjury or mechanical failure, three with confirmed venous thromboembolism, two with abnormal swelling, and one with an inflammatory or suture-related reaction. No formal nerve injuries or other qualifying events occurred within 90 days. Complication subtypes were not mutually exclusive (Table 2).

Table 2
Ninety-day postoperative complications

Outcome	Overall, N = 217	BMI < 35 kg/m ² , n = 135	BMI ≥ 35 kg/m ² , n = 82
Any adjudicated complication	32/217 (14.7%)	11/135 (8.1%)	21/82 (25.6%)
Wound/incisional complication	17/217 (7.8%)	6/135 (4.4%)	11/82 (13.4%)
Minor wound complication	15/217 (6.9%)	6/135 (4.4%)	9/82 (11.0%)
Major wound complication	2/217 (0.9%)	0/135 (0.0%)	2/82 (2.4%)
Neuritic symptoms	7/217 (3.2%)	3/135 (2.2%)	4/82 (4.9%)
Abnormal edema/swelling	2/217 (0.9%)	0/135 (0.0%)	2/82 (2.4%)
Inflammatory/suture-related reaction	1/217 (0.5%)	1/135 (0.7%)	0/82 (0.0%)
Reinjury/mechanical failure	4/217 (1.8%)	2/135 (1.5%)	2/82 (2.4%)
Venous thromboembolism	3/217 (1.4%)	0/135 (0.0%)	3/82 (3.7%)
Formal nerve injury	0/217 (0.0%)	0/135 (0.0%)	0/82 (0.0%)
Other qualifying event	0/217 (0.0%)	0/135 (0.0%)	0/82 (0.0%)
Values are presented as n/N (%). Complication subtypes were not mutually exclusive; a procedure could contribute to more than one subtype but was counted once in the composite outcome. Rare subtype results are descriptive. BMI ≥ 35 kg/m ² represents a post hoc clinical cut point.			

Observed complication rates across the six BMI categories were 0.0% (0/15), 6.5% (4/62), 12.1% (7/58), 28.9% (13/45), 25.0% (7/28), and 11.1% (1/9), respectively (exact global $p = 0.007$; Fig. 2). The estimate in the BMI ≥ 45.0 kg/m² category was imprecise because only nine procedures were represented.

Association between BMI and 90-day complications

The adjusted restricted cubic spline showed an association between BMI and 90-day complications (global Wald $p = 0.030$) with evidence that the relationship was not strictly linear across the observed BMI range (nonlinear component $p = 0.023$). Adjusted complication probability rose most sharply through the BMI 30s and appeared to flatten at higher BMI values; confidence intervals widened near the distribution extremes. Figure 1 displays the central 90% of observed BMI values to emphasize the data-dense region, and the full-range curve is provided in Additional file 1. The spline model had a lower Akaike information criterion than the linear model (178.2 vs 183.2).

As a parsimonious average summary, each 5-kg/m² increase in BMI was associated with higher odds of a 90-day complication in both the unadjusted model (OR 1.45, 95% CI 1.14–1.85; $p = 0.003$) and the adjusted model (OR 1.43, 95% CI 1.11–1.85; $p = 0.006$) (Table 3).

Table 3
Association between BMI and 90-day complications

BMI analysis	Model or test	Estimate	95% CI	p value
Three-knot restricted cubic spline	Adjusted global BMI association	Wald $\chi^2=7.01$ (2 df)	Not applicable	0.030
Three-knot restricted cubic spline	Adjusted nonlinear component	Not applicable	Not applicable	0.023
BMI per 5 kg/m ²	Unadjusted OR	1.45	1.14–1.85	0.003
BMI per 5 kg/m ²	Adjusted OR	1.43	1.11–1.85	0.006
BMI ≥ 35 vs < 35 kg/m ²	Unadjusted OR, post hoc	3.88	1.72–8.75	0.001
BMI ≥ 35 vs < 35 kg/m ²	Adjusted OR, post hoc	3.89	1.71–8.85	0.001
Odds ratios estimate the association with at least one adjudicated complication within 90 days. Adjusted models included age at surgery, diabetes mellitus, and active smoking at the initial surgical evaluation, with patient-clustered robust standard errors. BMI ≥ 35 kg/m ² was evaluated post hoc. BMI, body mass index; CI, confidence interval; OR, odds ratio.				

In the post hoc categorical analysis, 90-day complications occurred after 21 of 82 procedures in patients with BMI ≥ 35 kg/m² (25.6%) and 11 of 135 procedures in patients with BMI < 35 kg/m² (8.1%). This corresponded to an observed absolute difference of 17.5 percentage points (patient-cluster bootstrap 95% CI, 6.9–28.6 percentage points). After marginal standardization for age, diabetes, and smoking status at initial surgical evaluation, estimated complication probabilities were 25.5% (95% CI, 15.8%–35.3%) for BMI ≥ 35 kg/m² and 8.2% (95% CI, 3.5%–12.9%) for BMI < 35 kg/m², an adjusted difference of 17.4 percentage points (95% CI, 6.5–28.3 percentage points; $p = 0.002$). The adjusted odds ratio for BMI ≥ 35 kg/m² was 3.89 (95% CI 1.71–8.85; $p = 0.001$) (Table 3).

Sensitivity analyses

The linear BMI estimate was consistent in the generalized estimating equation analysis (OR 1.43 per 5 kg/m², 95% CI 1.11–1.84; $p = 0.005$), first-procedure-only analysis (OR 1.42, 95% CI 1.08–1.86; $p = 0.012$), procedure-year-adjusted model (OR 1.45, 95% CI 1.11–1.89; $p = 0.006$), Firth penalized model (OR 1.41, 95% CI 1.08–1.85; $p = 0.011$), and sex-adjusted model (OR 1.43, 95% CI 1.11–1.86; $p = 0.006$). Exclusion of the single procedure performed by the fourth surgeon did not materially change the estimate (OR 1.43, 95% CI 1.10–1.84; $p = 0.007$). Among procedures performed by the three principal surgeons, additional adjustment for surgeon produced a similar result (OR 1.51, 95% CI 1.12–2.02; $p = 0.007$). Full model results are provided in Additional file 1.

Wound complications and later events

Wound complications occurred after 6 of 135 procedures with BMI < 35 kg/m² (4.4%) and 11 of 82 procedures with BMI ≥ 35 kg/m² (13.4%). Because only 17 wound events occurred, the wound-specific

model was considered exploratory. A Firth penalized model yielded an OR of 3.36 for BMI ≥ 35 kg/m² (95% CI 1.25–9.85; $p = 0.016$), but the estimate was imprecise and was not treated as confirmatory.

Four additional procedures had their first qualifying event after postoperative day 90, resulting in 36 procedures with a complication during all available follow-up (16.6%). These later events were retained for descriptive completeness but were not used for formal BMI inference because longer-term follow-up duration varied.

Documented return to usual activity

Documented return to usual work, sport, or activity occurred after 79 procedures (36.4%); 138 procedures were right-censored at their final postoperative follow-up. BMI was not associated with time to documented return in the adjusted Cox model (HR 0.91 per 5-kg/m² increase, 95% CI 0.74–1.11; $p = 0.355$). The post hoc BMI ≥ 35 kg/m² comparison was also not significant (HR 0.74, 95% CI 0.47–1.16; $p = 0.186$). Schoenfeld-residual testing showed no evidence of nonproportional hazards for BMI or for the model globally. Detailed estimates and Kaplan-Meier curves are provided in Additional file 1.

Discussion

The principal finding of this study was that higher BMI was associated with greater risk of an adjudicated complication within 90 days after primary insertional Achilles debridement, Haglund excision, and standardized suture-anchor reattachment. The association was supported by a nonlinear spline model and remained similar across analyses that addressed repeated procedures, sparse events, procedure year, sex, and surgeon. In a post hoc clinically oriented comparison, procedures in patients with BMI ≥ 35 kg/m² had an observed complication rate of 25.6%, compared with 8.1% below BMI 35. The adjusted absolute difference was approximately 17 percentage points. BMI was not independently associated with time to documented return to usual activity.

The direct literature on BMI and insertional Achilles surgery is small and has produced different conclusions. Ptak and Rigby found no significant difference in complications among BMI groups in 78 patients who underwent Achilles detachment and reattachment [17]. In contrast, Hower and colleagues reported wound dehiscence in 24.2% of patients with BMI ≥ 40 kg/m² and 8.9% of those with BMI < 40 kg/m², while the difference in overall complications was not statistically significant [19]. Morrisette and colleagues studied 370 Haglund resections and found more wound breakdown among patients with obesity, although differences across obesity her subclasses were not significant [18]. The present findings are directionally consistent with the latter two studies, but direct numerical comparison is limited by differences in surgical exposure, BMI grouping, outcome definitions, follow-up windows, and adjustment for confounding.

This study adds novel information in several respects. The cohort is larger than the two direct insertional Achilles detachment and reattachment BMI series [17, 19]. All retained procedures used the same operative approach and suture-anchor construct. The principal outcome used a common 90-day

ascertainment window, and uncertain events were adjudicated by surgeons blinded to BMI. BMI was evaluated across its observed range rather than only as an obesity label, and repeated procedures were addressed with clustered inference and complementary sensitivity analyses.

The spline analysis suggests that the BMI-risk relationship may be more complex than a constant increase in log odds across the full BMI range. Adjusted risk increased most clearly through the overweight and obesity range and then appeared to flatten in the upper BMI range. The apparent plateau should be interpreted cautiously, as relatively few procedures were performed at the highest BMI levels, particularly above 45 kg/m². Thus, the adjusted OR of 1.43 per 5 kg/m² is better viewed as an overall average association rather than an effect that is consistent across the full BMI range.

The BMI ≥ 35 kg/m² analysis provides a clinically useful reference for counseling patients about complication risk, but it should not be interpreted as establishing a formally validated threshold. The cut point was chosen after the categorical pattern was reviewed. It corresponds to the boundary between class I and class II obesity and identified a subgroup with a large difference in observed and adjusted 90-day complication probability. For counseling, the absolute estimates are useful: approximately one in four procedures in patients with BMI ≥ 35 kg/m² had a complication within 90 days, compared with approximately one in twelve procedures below BMI 35. Taken together, these findings suggest that BMI ≥ 35 kg/m² may be a useful marker for identifying patients who warrant more focused preoperative counseling and risk discussion, while recognizing that these estimates reflect cohort-level associations rather than individualized predictions.

There are several possible reasons why higher BMI may be associated with postoperative complications. Obesity can be accompanied by greater mechanical demand, altered tendon biology, chronic low-grade inflammation, metabolic disease, and a thicker soft-tissue envelope, all of which can affect tendon and wound healing [16, 25]. For orthopedic surgeons, BMI should be incorporated into the overall preoperative risk assessment and counseling discussion, but not used in isolation to determine surgical risk or candidacy. BMI does not fully capture body composition or metabolic health, and patients with similar BMI values can have very different risk profiles. The BMI estimate changed little after adjustment for diabetes and preoperative smoking status, indicating that the observed association was not materially explained by these measured covariates, while recognizing that residual and unmeasured confounding may remain.

Wound complications were the most common postoperative problem in this cohort and occurred more often among patients with BMI ≥ 35 kg/m². The overall wound complication rate of 7.8% is comparable to rates reported after posterior midline Achilles surgery [13], and the association with higher BMI is also consistent with more recent work demonstrating greater wound breakdown after Haglund resection in patients with obesity [18]. The wound-specific analysis followed the same general pattern as the primary complication analysis, although the small number of wound events limits the strength of conclusions that can be drawn from this model. From a clinical standpoint, these findings reinforce the importance of discussing wound risk with patients at higher BMI and of paying particular attention to soft-tissue

condition, comorbidity optimization, and postoperative wound surveillance. Other complications, including venous thromboembolism, neuritic symptoms, swelling, and mechanical failure, occurred too infrequently to support reliable subtype-specific modeling and are therefore best interpreted descriptively.

In contrast, BMI was not independently associated with time to documented return to activity. This distinction is relevant when counseling patients because an increased risk of an early postoperative complication does not necessarily imply a slower documented recovery timeline. Return to work, sport, and usual activity is influenced by many factors beyond BMI, including occupational demands, baseline activity, rehabilitation participation, access to therapy, persistent symptoms, and patient expectations. Prior studies of insertional Achilles surgery have reported pain or functional improvement across BMI groups [17, 19]. The present analysis therefore supports discussing early complication risk separately from expectations regarding the broader recovery course.

For practicing orthopedic surgeons, BMI is likely most useful as part of the broader preoperative risk assessment rather than as a stand-alone criterion for surgical candidacy. A BMI of 35 kg/m² may provide a practical reference point for counseling in this cohort, but it should not be viewed as a universal cutoff or used by itself to deny or delay surgery. The decision to proceed should also account for diabetes control, nicotine exposure, skin and soft-tissue quality, vascular status, rehabilitation capacity, activity goals, and patient preferences. In patients with higher BMI, the present findings support a more deliberate discussion of wound and early complication risk, optimization of modifiable risk factors when possible, and closer attention to perioperative planning and wound follow-up.

Several features strengthen these findings. The cohort was clinically homogeneous, all procedures were assessed using the same 90-day complication window, and complete data were available for the primary multivariable model. Complications were identified through duplicate independent chart review, with uncertain events adjudicated by blinded surgeons, and BMI estimates remained similar across multiple sensitivity analyses. Modeling BMI as both a continuous and nonlinear variable reduced reliance on a single cutoff, while reporting both relative and absolute risks improved clinical interpretability.

These findings should also be considered in light of several limitations. The retrospective, single-center design is subject to incomplete documentation, residual confounding, and referral bias, and the tertiary care setting may limit generalizability. Despite predefined outcome criteria, duplicate abstraction, and blinded adjudication, complication identification still depended on the medical record. The composite outcome included events of differing clinical severity, and the study was not powered to model most rare complication subtypes. Follow-up beyond 90 days was variable; late events were summarized descriptively but were not modeled inferentially.

BMI also remains an imperfect measure of body composition and metabolic health. Smoking status reflected active smoking at the initial surgical evaluation, although patients proceeded only after biochemical confirmation of abstinence, which may have reduced the observed smoking effect. Aspirin dose, prophylaxis duration, and rehabilitation adherence were not consistently available. Return to

activity was determined retrospectively from clinical documentation and patient report, and 138 procedures were censored without a documented return event. Finally, the BMI ≥ 35 kg/m² cutoff was identified after review of the data and should be considered a clinically useful reference rather than a validated threshold until confirmed externally.

Conclusions

Higher BMI was associated with greater 90-day postoperative complication risk after primary insertional Achilles debridement, Haglund excision, and standardized suture-anchor reattachment. The relationship was nonlinear across the observed BMI range and remained consistent across sensitivity analyses. A post hoc BMI ≥ 35 kg/m² cut point identified a subgroup with substantially higher observed complication risk and may be useful for preoperative counseling, but it should not be interpreted as a universal threshold, an individualized causal prediction, or a stand-alone contraindication to surgery. BMI was not independently associated with documented return-to-activity timing.

Abbreviations

BMI
body mass index
CI
confidence interval
CPT
Current Procedural Terminology
GEE
generalized estimating equation
HR
hazard ratio
IAT
insertional Achilles tendinopathy
IQR
interquartile range
OR
odds ratio
VTE
venous thromboembolism.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki. The Mayo Clinic Institutional Review Board reviewed this study and determined it to be exempt (IRB No. 25-013518, approved December 18, 2025). The requirement for informed consent was waived by the Mayo Clinic Institutional Review Board for this retrospective medical-record review.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

R.C. and K.P. independently performed medical-record abstraction, reconciled discrepancies through review of the source records, contributed to data management and statistical analysis, validated the final results, and jointly drafted the manuscript under the supervision of A.V. A.V. conceived and supervised the study, contributed to study design and the statistical analysis plan, participated in blinded clinical-outcome adjudication, interpreted the findings, and critically revised the manuscript. D.R. and N.T. provided clinical input, contributed to interpretation of the findings, and reviewed the manuscript. N.T. additionally participated in the blinded adjudication of uncertain complication cases. All authors reviewed and approved the final manuscript and agree to be accountable for the work.

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Not applicable.

Data Availability

The deidentified minimal dataset and analytic code supporting the findings of this study are not publicly available because of patient privacy and institutional restrictions. They may be available from the corresponding author on reasonable request, subject to institutional review, approval of the proposed use, and execution of any required data-use agreement.

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Figures

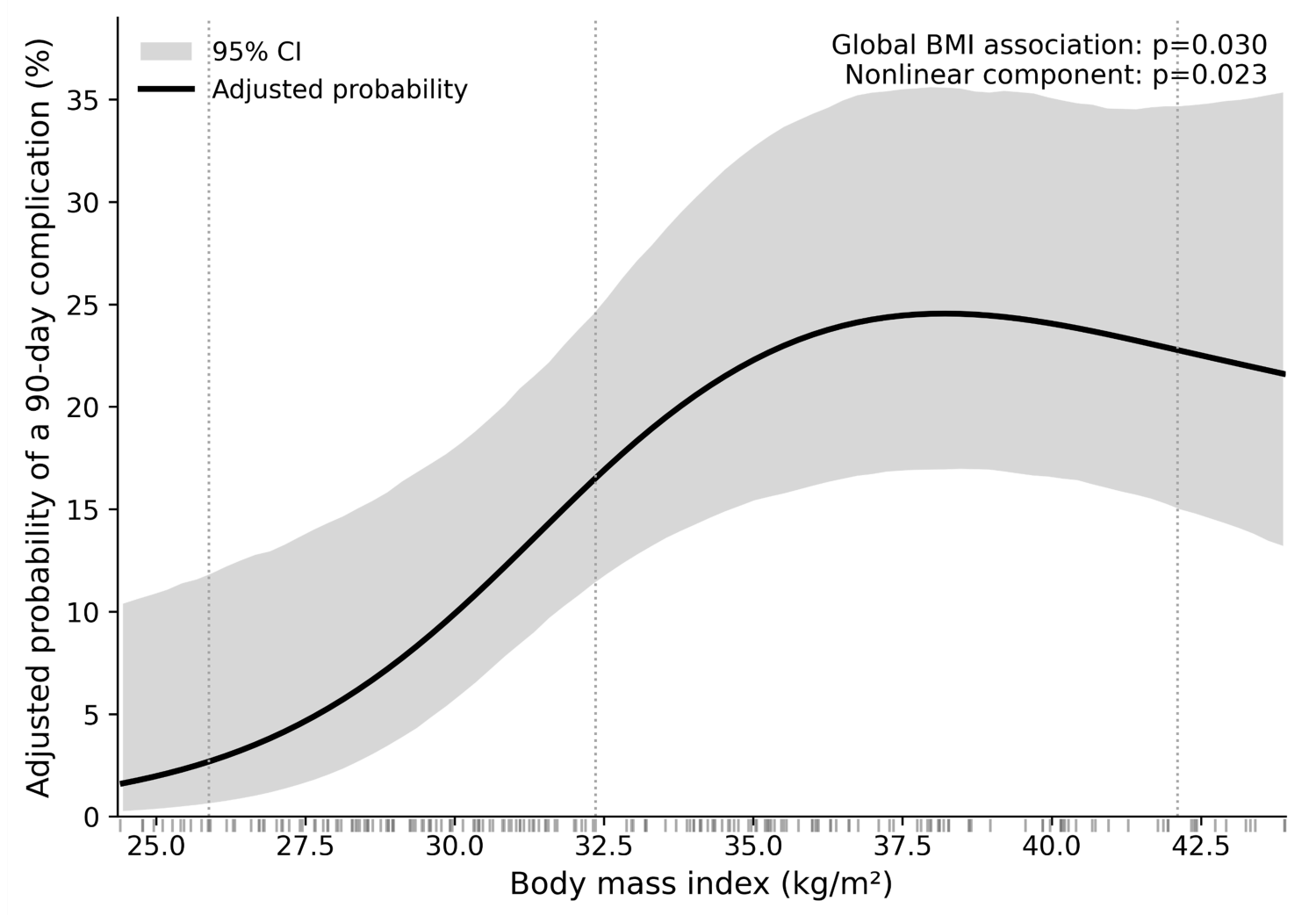


Figure 1

Adjusted complication probability across body mass index

Marginal standardized probability of an adjudicated 90-day postoperative complication across the central 90% of observed BMI values. The solid line shows estimates from the multivariable three-knot restricted cubic spline model adjusted for age, diabetes, and smoking status at initial surgical evaluation. The shaded area represents the patient-clustered robust 95% confidence interval. Vertical dotted lines mark spline knots at the 10th, 50th, and 90th BMI percentiles. Rug marks show observed BMI values. Estimates at the extremes are less precise because fewer procedures contributed data. The full observed BMI range is shown in Additional file 1, Supplementary Figure S4.

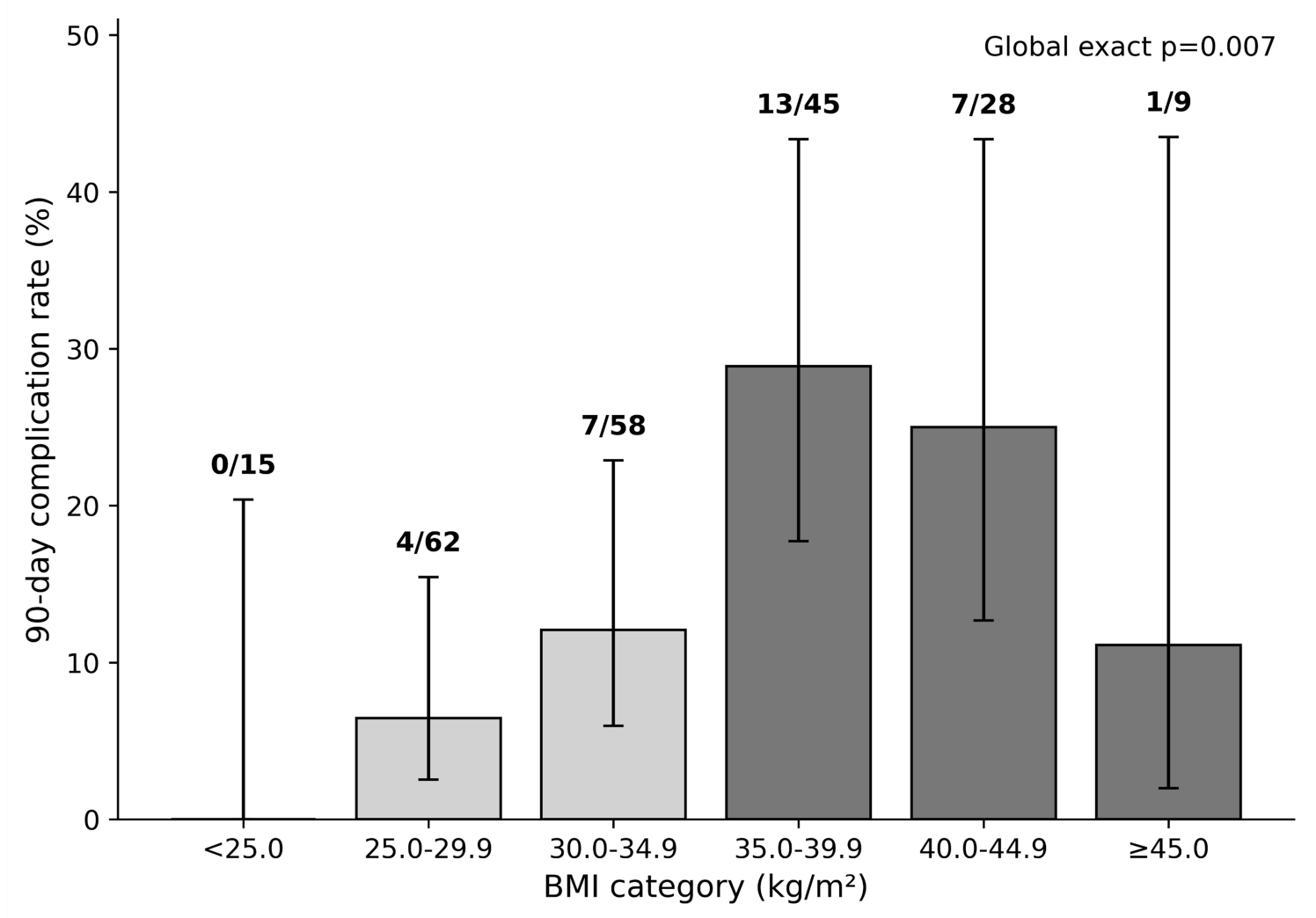


Figure 2

Observed complication rates across body mass index categories

Observed 90-day postoperative complication rates across six BMI categories. Error bars show Wilson 95% confidence intervals, and labels show events divided by procedures. Darker bars identify categories at or above the post hoc BMI 35 kg/m² reference for visual context only. The cut point is not a validated threshold.

Supplementary Files

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