

Research Article

Diabetes and Untoward Outcomes after ACL Reconstruction

Dennis Sievers^{1a}, Heather A. Prentice, PhD, MPH^{2b}, Joanie Chung^{3c}, Anna Davis^{2d}, Gregory B. Maletis^{4e}, Ronald A. Navarro, MD^{2f}

¹ Department of Orthopedic Surgery, Hackensack University Medical Center, ² Kaiser Permanente Bernard J Tyson School of Medicine, Kaiser Permanente, ³ Kaiser Permanente Southern California Department of Research and Evaluation, Kaiser Permanente, ⁴ Southern California Permanente Medical Group, Kaiser Permanente

Keywords: ACL, Sports, Diabetes, Outcomes, Reconstruction, Knee

<https://doi.org/10.60118/001c.124072>

Journal of Orthopaedic Experience & Innovation

Vol. 6, Issue 1, 2025

Background

Diabetes affects approximately 536.6 million adults worldwide and 32.2 million in the United States. Prior studies across multiple specialties have reported the presence of diabetes is associated with adverse outcomes following surgical operations. While several studies have identified diabetes as a risk factor for adverse outcomes following ACL reconstruction (ACLR), literature evaluating the relationship between diabetes status and outcomes after ACLR is lacking.

Purpose

We aimed to study surgical outcomes following primary ACLR among patients with diabetes compared to those without diabetes.

Study Design

Retrospective Cohort Study

Methods

We conducted a cohort study using data from an integrated healthcare system's ACLR registry. Patients aged ≥12 receiving a primary unilateral ACLR were included

-
- a Dennis Sievers is an orthopedic surgery resident at Hackensack University Medical Center in New Jersey. Born and raised in Southern California, Dennis attended the Kaiser Permanente School of Medicine prior to moving east for residency. His interests include shoulder and elbow, hand, and trauma. In his spare time, Dennis likes to exercise, collect house plants, and explore the city.

[Conflicts of Interest Statement for Dennis Sievers](#)

- b Dr. Heather Prentice is an Operations Research Scientist II with Medical Devices Surveillance and Assessment at Kaiser Permanente. In this role, she collaborates on inter-regional research studies on implantable medical devices, post-market surveillance, comparative effectiveness, and real-world evidence. As an Associate Professor at KPSOM, Dr. Prentice serves as a co-mentor on scholarly projects where registry data from Medical Devices Surveillance and Assessment are used. She has more than 100 peer-reviewed publications. Findings from her research are used to improve patient safety and quality of care, allow for shared decision-making, and guide clinical best practices for surgical procedures involving medical devices both within the organization and externally through conferences, peer-reviewed publications, and collaboration with national and international partners.

[Visit Dr. Heather Prentice](#)

[Conflicts of Interest Statement for Dr. Heather Prentice](#)

- c [Conflicts of Interest Statement for Joanie Chung](#)

- d Dr. Davis is a health services research scientist in Kaiser Permanente Research and Quality Measurement and an Assistant Professor of Health Systems Science at the Kaiser Permanente Bernard J Tyson School of Medicine.

[Conflicts of Interest Statement for Dr. Anna Davis](#)

- e [Conflicts of Interest Statement for Dr. Gregory Maletis](#)

- f [Connect with Dr. Ronald Navarro on LinkedIn](#)

[Conflicts of Interest Statement for Dr. Ronald Navarro](#)

[Visit the Open Payments Data Page for Dr. Ronald Navarro](#)

(2005–2020). Preoperative diabetes status was the exposure of interest. The two primary outcomes were revision surgery and ipsilateral reoperation following primary ACLR, modeled using multivariable Cox proportional hazards regression that followed patients until an adverse event or loss to follow up. We also examined hospital readmission within 90 days post-surgery, modeled using logistic regression. All models compared patients with diabetes to those without diabetes, adjusting for age, gender, race, smoking status, body mass index, American Society of Anesthesiologist's score, comorbid conditions, education level, income level, exercise, and graft type.

Results

There were 18,797 primary ACLR in the study sample with 383 (2.0%) occurring in patients with diabetes. The diabetes group exercised about 90 minutes less per week than the non-diabetes group. In unadjusted bivariate descriptive analyses, patients with diabetes had a lower rate of revision surgery (1.6% vs. 3.6%, $p = 0.037$) but a higher rate of ipsilateral reoperation (10.7% vs. 8.0%, $p = 0.051$). The 90-day readmission rate was higher among patients with diabetes compared to those without diabetes (1.8% vs. 0.7%, $p = 0.016$). However, after adjusting for covariates, these associations were no longer statistically significant.

Conclusion

After controlling for patient characteristics and other risk factors, the presence of diabetes was not associated with a higher risk of adverse events following primary ACLR.

This article, like all JOEI articles, is available for continuing education

Reflect Now!

Click here : <https://joeipub.com/learning>

INTRODUCTION

Anterior cruciate ligament (ACL) tears are a common orthopedic injury that compromises the stability of the knee against anterior translation and rotatory motion of the tibia relative to the femur. To regain this stability, patients often elect to undergo ACL reconstruction (ACLR), with up to 130,000 procedures annually in the United States (Mall, Chalmers, Moric, et al. 2014). As with all surgical procedures, there are risks associated with ACLR, with reported rates of ACL revision surgeries in registry and large cohort studies ranging from 3 to 7% and rates of subsequent surgeries on the ipsilateral knee as high as 18% (Ahldén et al. 2012; Hettrich et al. 2013; Maletis et al. 2022).

Consideration of individual patient characteristics and comorbidities is an important step in optimizing patient outcomes following ACLR. One such comorbidity to consider is diabetes. Effecting an estimated 536.6 million adults worldwide and 32.2 million adults in the United States, diabetes is highly prevalent (Sun, Saeedi, Karuranga, et al. 2022). Many studies have reported the presence of diabetes to be associated with adverse outcomes following procedures across different surgical subspecialties; with poorly controlled diabetes having even higher rates of adverse outcomes (Goodenough, Liang, Nguyen, et al. 2015; Halkos, Puskas, Lattouf, et al. 2008; Little et al. 2002;

Yong, Weinberg, Torkamani, et al. 2018). Diabetes affects multiple organ systems and therefore has implications in surgery. For example, the myriad of sequelae from the disease, such as atherosclerosis, reduced kidney function, and hyperglycemia, can create an environment that can alter wound healing and increase the possibility of infection (Greenhalgh 2003).

When examining the impact of diabetes on outcomes following ACLR specifically, literature is sparse. While some studies have identified presence of diabetes as a risk factor for adverse outcomes, such as surgical site infection and hospitalization following ACLR (Best et al. 2021; Bokshan, DeFroda, and Owens 2017; Brophy et al. 2015; Kawata, Sasabuchi, Taketomi, et al. 2018), few have directly evaluated outcomes of those with diabetes compared to those without. Those that have investigated diabetes status did so with either a limited sample size or a limited follow up period (Brophy, Huston, Wright, et al. 2016; Manzi, Quan, Cantu, et al. 2022). Additionally, the relationship between diabetes status, preoperative exercise, and outcomes following ACLR is poorly understood.

The purpose of this study was to determine if there was a difference in risk of adverse outcomes following ACLR in patients with diabetes compared to those without diabetes. We hypothesized that patients with diabetes would experi-

ence higher rates of adverse events compared to those without.

METHODS

SETTING AND DATA SOURCES

A retrospective cohort study was performed using data from a US-based integrated healthcare system. Kaiser Permanente is an integrated health plan and delivery system that serves more than 12.6 million members in eight regions of the US.

The Kaiser Permanente ACL Reconstruction Registry (ACLRR) was the primary data source for the study. ACLRR data collection procedures have been previously published (Maletis, Funahashi, and Inacio 2013; Paxton, Inacio, and Kiley 2012). To summarize, the registry is a surveillance tool established in 2005 that records information on patient-, procedure-, implant-, surgeon- and hospital-related variables at the point-of-care at all hospitals within the Kaiser Permanente health system. Participation in the registry has been greater than 90% in all years since its inception. The integrated electronic health record (EHR) was the second data source from which data on physical activity at baseline and hemoglobin A1C (HbA1C) were obtained.

STUDY SAMPLE

For this study, patients of the Kaiser Permanente Southern California region aged ≥ 12 receiving a primary unilateral ACLR from January 1st 2005 to December 31st 2020 were included. Double bundle procedures (n=11) and patients with prior procedures in the same knee (n=488) were excluded. A total of 18,797 primary ACLRs met the inclusion criteria and comprised the study sample.

STUDY MEASURES

The exposure of interest was preoperative diabetes status based on three-year diagnosis history using the Elixhauser comorbidity index definition (Quan, Sundararajan, Halfon, et al. 2005), supplemented with diabetes status information from the Kaiser Permanente diabetes registry. We defined two primary outcomes following ACLR. Revision surgery, defined as subsequent surgery to remove and replace the graft placed during the primary ACLR; and, reoperation, defined as any other subsequent surgery on the ipsilateral knee for reasons related to the primary ACLR where the graft was left intact. Revisions and reoperations were longitudinally tracked by the ACLRR using the integrated Kaiser Permanente EHR. All patients within the registry are monitored for revision and reoperation until they either terminate healthcare membership with Kaiser Permanente or until death. Identified revisions and reoperations are manually validated by trained research associates within the registry.

As a secondary outcome, we evaluated hospital readmissions within 90 days of the index procedure. Hospital readmissions were identified using patient encounter information documented in the EHR.

COVARIATES

Age, gender, race, smoking status, body mass index (BMI), American Society of Anesthesiologist's (ASA) classification, comorbid conditions identified through the Elixhauser algorithm (Elixhauser et al. 1998; Paxton, Inacio, and Kiley 2012), education level, income level, and graft type were adjusted for as potential confounders. In addition, models were adjusted for pre-procedure exercise level, which is captured for Kaiser Permanente members during intake for routine care and reported as minutes per week. This data is not routinely captured within the ACLRR and therefore was extracted separately from electronic health records of Kaiser Permanente Southern California patients.

STATISTICAL ANALYSIS

Univariate and bivariate descriptive statistics included comparison of the distributions of demographic and clinical variables using Chi-square for categorical variables and Kruskal-Wallis tests for continuous variables.

Risk of revision and reoperation according to preoperative diabetes status were modeled as time-to-first event analyses, using multivariable Cox proportional hazards regression. Follow-up for those with the outcome was defined as the time from the ACLR date to the date of the outcome. Follow-up for patients who did not experience the outcome was the time from the ACLR date to the last date of follow-up, defined as the membership termination date, death date, or study end date (December 31, 2020), whichever came first. Patients without the outcome were censored at the last date of follow-up in analyses.

Odds of 90-day hospital readmission were evaluated using multivariable logistic regression. All models included the covariates specified as confounders and a cluster term to account for correlation between ACLRs performed by the same surgeon. The proportional hazards assumption was checked and met. A separate category was created for covariates with missing values. All analyses were two-sided and performed using SAS version 9.4 (Cary, NC). P values < 0.05 were considered statistically significant.

ETHICS STATEMENT

This study was approved by the Kaiser Permanente Institutional Review Board 13122 prior to commencement. No outside funding was obtained.

RESULTS

A total of 18,797 primary ACLRs met the inclusion criteria and comprised the study sample (Table 1). Procedures were performed by 134 surgeons at 14 healthcare centers. Of these, 18,414 (97.96%) patients did not have diabetes and 383 (2.03%) did have diabetes. Compared to patients without diabetes, those with diabetes were more likely to be older (38.9 vs 27.0; $p < .001$) and male (69.2% vs 64.0%; $p = 0.037$). They also had a higher average BMI (32.8 vs 27.2; $p < .001$). Diabetic patients also exercised less frequently on a weekly basis compared to non-diabetic patients (101.0

Table 1. Characteristics of 18,797 primary anterior cruciate ligament reconstruction patients (2005-2020), overall and by diabetes status.

	Overall	Diabetes	No Diabetes	P-value
Total N	18,797	383	18,414	
<i>Patient characteristics</i>				
Age, in years				<.001 ¹
Mean (SD)	27.3 (10.9)	38.9 (10.8)	27.0 (10.8)	
Median (IQR)	25 (18-35)	39 (32-47)	25.0 (18.0-34.0)	
Age category, n (%)				<.001 ²
<22 years	7438 (39.6)	30 (7.8)	7408 (40.2)	
≥22 years	11,359 (60.4)	353 (92.2)	11,006 (59.8)	
BMI, in kg/m²				<.001 ¹
Mean (SD)	27.3 (5.4)	32.8 (6.0)	27.2 (5.3)	
Median (IQR)	26.5 (23.5-30.2)	32.1 (28.5-36.3)	26.4 (23.5-30.0)	
Missing	607	11	596	
Female sex, n (%)	6743 (35.9)	118 (30.8)	6625 (36.0)	0.0369
Race/Ethnicity, n (%)				0.002 ²
Asian	1891 (10.1)	40 (10.4)	1851 (10.1)	
Black	1659 (8.8)	42 (11.0)	1617 (8.8)	
Hispanic	6801 (36.2)	168 (43.9)	6633 (36.0)	
Other	272 (1.4)	5 (1.3)	267 (1.4)	
White	8174 (43.5)	128 (33.4)	8046 (43.7)	
HbA1c				-
Mean (SD)	-	7.1 (1.7)	-	
Median (IQR)	-	6.5 (5.9-7.9)	-	
Missing	-	120	-	
Total exercise (minutes per week)				<.001 ¹
Mean (SD)	189.8 (244.2)	101.0 (166.0)	191.6 (245.1)	
Median (IQR)	100 (0-300.0)	0 (0-145)	100 (0-300)	
Missing	4607	111	4495	
Multi-ligament injury, n (%)	936 (5.0)	29 (7.6)	907 (4.9)	0.019 ²
Graft type, n (%)				<.001 ²
Allograft	4101 (21.8)	197 (51.4)	3904 (21.2)	
BPTB autograft	8005 (42.6)	77 (20.1)	7928 (43.1)	
Hamstring autograft	6227 (33.1)	102 (26.6)	6125 (33.3)	
Hybrid graft	464 (2.5)	7 (1.8)	457 (2.5)	

¹Kruskal-Wallis p-value²Chi-Square p-value

BMI=body mass index. BPTB=bone patellar tendon bone. IQR=interquartile range. SD=standard deviation.

minutes vs 191.6 minutes; $p<.001$). The average hemoglobin A1c (HbA1c) among those with diabetes was 7.1. The mean follow-up time for all patients was 5.1 years (standard deviation=3.9) with a range of 0 to 15.9 years. The numbers lost to follow up between the diabetic cohort and non-diabetic cohort were 37 (9.7%) and 5721 (31.1%) respectively.

Of the 383 patients with diabetes, 6 experienced revision surgery and 41 had an ipsilateral reoperation during study follow-up, and 7 were readmitted to the hospital within 90 days. Comparing to patients without diabetes in unadjusted bivariate descriptive analysis, patients with diabetes had a

lower rate of revision surgery (1.6% vs 3.6%; $p=0.037$) but a higher rate of hospital readmission (1.8% vs. 0.7%, $p = 0.016$) (Table 2). There was no significant difference in rates of ipsilateral reoperation (10.7% vs 8.0%; $p=0.051$) between those with diabetes compared to those without.

Following multivariable adjustment, there were no significant associations between diabetes status and risk of the adverse events following primary ACLR (Table 3).

This study leveraged longitudinal ACLR registry data from a large integrated delivery system with diverse membership (Davis et al. 2023; Koebnick, Langer-Gould, Gould,

Table 2. Crude frequency of adverse events following primary anterior cruciate ligament reconstruction by diabetes status.

	Crude Incidence, n (% ²)		
	Diabetes	No Diabetes	P-value ¹
Total N	383	18,414	
Revision	6 (1.6)	654 (3.6)	0.037
Ipsilateral reoperation	41 (10.7)	1468 (8.0)	0.051
90-day readmission	7 (1.8)	137 (0.7)	0.016

¹Chi-Square p-value²Crude incidence calculated as cumulative incidence at 15.9 years follow-up for revision and reoperation events and n/N*100 for readmission events.**Table 3. Adjusted¹ association between diabetes status and adverse events following primary anterior cruciate ligament reconstruction.**

Event	Adjusted Estimate ² (95% CI)	P-value
Revision during follow-up		
No diabetes	Ref	
Diabetes	0.63 (0.31-1.27)	0.198
Ipsilateral reoperation during follow-up		
No diabetes	Ref	
Diabetes	1.34 (0.99-1.80)	0.058
90-Day Hospital Readmission		
No diabetes	Ref	
Diabetes	1.83 (0.76-4.44)	0.180

¹Adjusted analysis includes age, gender, race, smoking status, body mass index (BMI), American Society of Anesthesiologist's (ASA) classification, comorbid conditions identified via Elixhauser algorithm, education level, income level, graft type, and pre-procedural exercise levels.²Hazard ratios reported for revision and reoperations; odds ratios reported for readmission.

et al. 2012) to examine adverse outcomes following ACLR among patients with and without diabetes. The most important finding of this study was an absence of an association between diabetes status and risk of adverse events following primary ACLR.

Among various surgical subspecialties, diabetes has been described as a risk factor for adverse events (Goode-nough, Liang, Nguyen, et al. 2015; Halkos, Puskas, Lattouf, et al. 2008; Little et al. 2002; Yong, Weinberg, Torkamani, et al. 2018). Yong and colleagues examined patients undergoing high-risk cardiac, general, and orthopedic surgery with at least one overnight hospital stay and compared patients with prediabetes, diabetes, and no diabetes six months after surgery. They concluded that the presence of diabetes

was associated with increased mortality, major complications, ICU admission, mechanical ventilation, and hospital length of stay, and that each percentage increase in hemoglobin A1C (HbA_{1C}) was associated with an increase in major complications, ICU admission, and hospital length of stay.

While the previously mentioned study was limited to high-risk surgery, literature focusing specifically on ACLR, which has a lower risk for complications, have also identified diabetes to be a risk factor for adverse outcomes (Best et al. 2021; Bokshan, DeFroda, and Owens 2017; Brophy et al. 2015; Kawata, Sasabuchi, Taketomi, et al. 2018). Brophy and colleagues found diabetes to be associated with an 18-fold increased risk of infection following ACLR.

Brophy and colleagues performed a subsequent study comparing outcomes, including rates of subsequent surgeries, between the previously mentioned cohort (Brophy, Huston, Wright, et al. 2016). 21.7% of patients with diabetes underwent additional surgery on the ipsilateral knee compared to 15.4% of those without diabetes. Following application of the author's multivariable model, the difference was not significant, similar to our findings. The authors limited their clinical outcomes to subsequent surgeries whereas our outcomes differentiated between revision and reoperation.

A more recent study examined 30-day postoperative outcomes between 9,443 patients without diabetes versus 133 patients with diabetes (Manzi, Quan, Cantu, et al. 2022). The authors performed multivariable analysis to assess the association between diabetes status and risk of infection and readmission. They found presence of diabetes was associated with a higher risk of readmission, but no association between diabetes status and risk of infection was observed. Our study found no association between preoperative diabetes status and risk of readmission in multivariable analysis.

Our study found no increased risk of adverse outcomes in patients with diabetes compared to those without. This contrasts existing literature as mentioned previously in which diabetes was reported to be associated with adverse outcomes. McElvany et al performed a study utilizing the Kaiser Permanente Shoulder Arthroplasty Registry that examined outcomes following shoulder arthroplasty in patients with diabetes compared to those without. The authors found no increased risk of adverse outcomes in patients with diabetes (McElvany et al. 2018). The authors also stratified based on hemoglobin A1c (HbA1c) levels and found no association between HbA1c levels and adverse outcomes. The authors hypothesized that the integrated care structure of Kaiser Permanente benefits patients with diabetes and may create an environment that helps optimize this population to maximize outcomes following elective surgical procedures. It is possible that this is true for the diabetic population in our study receiving ACLR, as it is an elective procedure where patients can be medically optimized prior to surgery.

Another addition of the present study is the utilization of pre-procedural exercise levels. Kaiser Permanente members are asked about their exercise habits during intake for

routine care and the data are logged as minutes per week. We found that patients with diabetes exercised on average 90 minutes less per week than those without diabetes. This is in line with existing literature that demonstrates lower activity levels in patients with diabetes compared to patients without diabetes (Kriska, Rockette-Wagner, Edelstein, et al. 2021; Morrato et al. 2003). This could be a factor involved in our multivariable analysis finding patients with diabetes had a lower rate of revision surgery. It is possible that this less active population was also less active following surgery, decreasing the chance of reinjury and the necessity of revision. It is also important to note that the diabetic cohort was on average 10 years older than the non-diabetic cohort, with an average age of 38. This could also be a contributing factor in addition to decreased reported exercise levels, as older patients are at lower risk of revision (Maletis et al. 2018). This quantification of pre-procedural exercise levels is important as it provides insight into activity habits within this population to assist clinicians in management following ACLR.

The present study has several strengths. The size of our cohort allows for evaluation of rare occurrences. The use of the Kaiser Permanente ACLRR where data are prospectively collected and outcomes are manually validated increases internal validity. The cohort was derived from a demographically diverse population of over 4.8 million patients, and it has been demonstrated that the demographic characteristics of Kaiser Permanente members are comparable to the general population (Davis et al. 2023; Koebnick, Langer-Gould, Gould, et al. 2012). ACLR were performed by 134 surgeons at 14 healthcare centers, which further increases generalizability. The ACLRR longitudinally monitors patients within the healthcare network for outcomes. This allows for survival analysis which makes it possible to analyze patients that were lost to follow up and increases the ability of our study to accurately capture outcomes.

Limitations of our study include a high differential loss to follow up between the diabetic cohort (9.7%) vs the non-diabetic cohort (31.1%). Loss to follow up is due to mem-

bership termination, though patients are censored if they leave the organization and only contribute to the cohort as long as they are members. The difference in outcomes between the two groups may be understated due to differential loss to follow up. However, the mean follow up time was 6.8 years in the diabetic cohort and 5.1 in the non-diabetic cohort, thus those that maintained membership were tracked and evaluated for a substantial amount of time.

It is also possible that some proportion of ACLR patients may have gone outside of Kaiser Permanente for follow-up care, although this is expected to be minimal as outside care would not be covered by the healthcare plan. The present study is observational, only associations are reported, not causality. While we attempted to address confounding in our statistical analysis, residual confounding due to unmeasured factors is possible. Additionally, it is possible that a proportion of patients within the ACLRR may have undiagnosed diabetes and could be falsely sorted into the non-diabetic cohort, which would likely bias towards the null hypothesis.

CONCLUSION

In this retrospective cohort study comparing outcomes following ACLR between diabetic and non-diabetic patients, there was found to be no association between diabetes status and risk of revision, ipsilateral reoperation or 90-day hospital readmission following ACLR. These findings may be used during discussions between clinicians and patients regarding risks and benefits of ACL reconstruction to aid in shared decision making.

FUNDING

No funding was received for this study.

Submitted: May 21, 2024 EST, Accepted: September 30, 2024 EST



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-NC-ND-4.0). View this license's legal deed at <https://creativecommons.org/licenses/by-nc-nd/4.0> and legal code at <https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode> for more information.

REFERENCES

- Ahldén, M., K. Samuelsson, N. Sernert, M. Forssblad, J. Karlsson, and J. Kartus. 2012. "The Swedish National Anterior Cruciate Ligament Register: A Report on Baseline Variables and Outcomes of Surgery for Almost 18,000 Patients." *Am J Sports Med* 40 (10): 2230–35. <https://doi.org/10.1177/0363546512457348>.
- Best, M. J., A. B. Harris, M. Marrache, S. D. Martin, J. P. H. Rue, and J. H. Wilckens. 2021. "Risk Factors for Readmission Following Anterior Cruciate Ligament Reconstruction." *J Knee Surg*, October. <https://doi.org/10.1055/s-0041-1736200>.
- Bokshan, S. L., S. F. DeFroda, and B. D. Owens. 2017. "Risk Factors for Hospital Admission After Anterior Cruciate Ligament Reconstruction." *Arthroscopy* 33 (7): 1405–11. <https://doi.org/10.1016/j.arthro.2017.02.002>.
- Brophy, R. H., L. J. Huston, R. W. Wright, et al. 2016. "Outcomes of ACL Reconstruction in Patients with Diabetes." *Med Sci Sports Exerc* 48 (6): 969–73. <https://doi.org/10.1249/MSS.0000000000000876>.
- Brophy, R. H., R. W. Wright, L. J. Huston, S. K. Nwosu, MOON Knee Group MOON Knee Group, and K. P. Spindler. 2015. "Factors Associated with Infection Following Anterior Cruciate Ligament Reconstruction." *J Bone Joint Surg Am* 97 (6): 450–54. <https://doi.org/10.2106/JBJS.N.00694>.
- Davis, A.C., J.L. Voelkel, C.L. Remmers, J.L. Adams, and E.A. McGlynn. 2023. "Comparing Kaiser Permanente Members to the General Population: Implications for Generalizability of Research." *Perm J* 27 (2): 87–98. <https://doi.org/10.7812/TPP/22.172>.
- Elixhauser, A., C. Steiner, D.R. Harris, and R.M. Coffey. 1998. "Comorbidity Measures for Use with Administrative Data." *Med Care* 36 (1): 8–27. <https://doi.org/10.1097/00005650-199801000-00004>.
- Goodenough, C. J., M. K. Liang, M. T. Nguyen, et al. 2015. "Preoperative Glycosylated Hemoglobin and Postoperative Glucose Together Predict Major Complications after Abdominal Surgery." *J Am Coll Surg* 221 (4): 854–861.e1. <https://doi.org/10.1016/j.jamcollsurg.2015.07.013>.
- Greenhalgh, D.G. 2003. "Wound Healing and Diabetes Mellitus." *Clin Plast Surg* 30 (1): 37–45. <https://doi.org/10.1016/j.jamcollsurg.2015.07.013>.
- Halkos, M. E., J. D. Puskas, O. M. Lattouf, et al. 2008. "Elevated Preoperative Hemoglobin A1c Level Is Predictive of Adverse Events after Coronary Artery Bypass Surgery." *J Thorac Cardiovasc Surg* 136 (3): 631–40. <https://doi.org/10.1016/j.jtcvs.2008.02.091>.
- Hettrich, C. M., W. R. Dunn, E. K. Reinke, MOON Group, and K. P. Spindler. 2013. "The Rate of Subsequent Surgery and Predictors after Anterior Cruciate Ligament Reconstruction: Two- and 6-Year Follow-up Results from a Multicenter Cohort." *Am J Sports Med* 41 (7): 1534–40. <https://doi.org/10.1177/0363546513490277>.
- Kawata, M., Y. Sasabuchi, S. Taketomi, et al. 2018. "Atopic Dermatitis Is a Novel Demographic Risk Factor for Surgical Site Infection after Anterior Cruciate Ligament Reconstruction." *Knee Surg Sports Traumatol Arthrosc* 26 (12): 3699–3705. <https://doi.org/10.1007/s00167-018-4958-7>.
- Koebnick, C., A. M. Langer-Gould, M. K. Gould, et al. 2012. "Sociodemographic Characteristics of Members of a Large, Integrated Health Care System: Comparison with US Census Bureau Data." *Perm J* 16 (3): 37–41. <https://doi.org/10.7812/TPP/12-031>.
- Kriska, A. M., B. Rockette-Wagner, S. L. Edelstein, et al. 2021. "The Impact of Physical Activity on the Prevention of Type 2 Diabetes: Evidence and Lessons Learned From the Diabetes Prevention Program, a Long-Standing Clinical Trial Incorporating Subjective and Objective Activity Measures." *Diabetes Care* 44 (1): 43–49. <https://doi.org/10.2337/dc20-1129>.
- Little, S. A., W. R. Jarnagin, R. P. DeMatteo, L. H. Blumgart, and Y. Fong. 2002. "Diabetes Is Associated with Increased Perioperative Mortality but Equivalent Long-Term Outcome after Hepatic Resection for Colorectal Cancer." *J Gastrointest Surg* 6 (1): 88–94. [https://doi.org/10.1016/s1091-255x\(01\)00019-1](https://doi.org/10.1016/s1091-255x(01)00019-1).
- Maletis, G. B., T. T. Funahashi, M. C. S. Inacio, and L. W. Paxton. 2022. "Optimizing Anterior Cruciate Ligament Reconstruction: Individualizing the Decision-Making Process Using Data from the Kaiser Permanente ACLR Registry: 2018 OREF Award Paper." *J Orthop Res* 40 (1): 29–42. <https://doi.org/10.1002/jor.25020>.
- Mall, N. A., P. N. Chalmers, M. Moric, et al. 2014. "Incidence and Trends of Anterior Cruciate Ligament Reconstruction in the United States." *Am J Sports Med* 42 (10): 2363–70. <https://doi.org/10.1177/0363546514542796>.
- Manzi, J. E., T. Quan, N. Cantu, et al. 2022. "The Association between Diabetes Status and Postoperative Complications for Patients Receiving ACL Reconstruction." *Eur J Orthop Surg Traumatol*, June. <https://doi.org/10.1007/s00590-022-03316-w>.
- McElvany, M. D., P. H. Chan, H. A. Prentice, M. T. Dillon, and R. A. Navarro. 2018. "The Association of Diabetes and Perioperative Glycemic Control with Shoulder Arthroplasty Outcomes." *Journal of Shoulder and Elbow Surgery* 27 (4): e119. <https://doi.org/10.1016/j.jse.2018.02.002>.
- Paxton, E.W., M.C. Inacio, and M.L. Kiley. 2012. "The Kaiser Permanente Implant Registries: Effect on Patient Safety, Quality Improvement, Cost Effectiveness, and Research Opportunities." *Perm J* 16 (2): 36–44. <https://doi.org/10.7812/TPP/12-008>.
- Quan, H., V. Sundararajan, P. Halfon, et al. 2005. "Coding Algorithms for Defining Comorbidities in ICD-9- CM and ICD-10 Administrative Data." *Med Care* 43 (11): 1130–39. <https://doi.org/10.1097/01.mlr.0000182534.19832.83>.

Sun, H., P. Saeedi, S. Karuranga, et al. 2022. "IDF Diabetes Atlas: Global, Regional and Country-Level Diabetes Prevalence Estimates for 2021 and Projections for 2045." *Diabetes Res Clin Pract* 183:109119. <https://doi.org/10.1016/j.diabres.2021.109119>.

Yong, P. H., L. Weinberg, N. Torkamani, et al. 2018. "The Presence of Diabetes and Higher HbA1c Are Independently Associated With Adverse Outcomes After Surgery." *Diabetes Care* 41 (6): 1172–79. <https://doi.org/10.2337/dc17-2304>.