

**RESEARCH ARTICLE**

# The Persistent Backlog of Knee and Shoulder Orthopedic Sport Surgery Case Volume Following the COVID-19 Pandemic

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**Abstract**

**Objectives:** As COVID-19 will not be the last pandemic, understanding our historical response allows us to predict and improve our current practices in preparation for the next pandemic. Following the removal of the elective surgery suspension at the onset of the COVID-19 pandemic, it is unclear whether sports medicine surgery volume has returned to pre-pandemic levels as well as whether the backlog from the original suspension was addressed. The purpose of this study to observe the monthly changes in volume and backlog of knee and shoulder sports surgery one year since the original suspension.

**Methods:** National all-payer data was utilized to identify patients undergoing knee and shoulder sports procedures from January 2017 to April 2021. Descriptive analysis was utilized to report the monthly changes in surgeries. A linear forecast analysis using historical data was utilized to determine the expected volume. This was compared to the observed case volume. The difference in expected and observed volume was utilized to calculate the estimated change in backlog.

**Results:** From March to May 2020, there was a persistent decrease in the observed shoulder and knee sports volume when compared to the expected volume. By June 2020, all knee and shoulder sports volume reached the expected volume. By April 2021, the estimated backlog for shoulder and knee procedures had increased by 49.8% (26,412 total cases) and 19.0% (26,412 total cases), respectively, with respect to the original calculated backlog from March to May 2020.

**Conclusion:** Within four months, the sudden decrease in volume for knee and shoulder sports procedures had returned to pre-pandemic levels; however, the original backlog in cases has continually increased one year following the suspension. Additionally, the backlog is significantly higher for knee when compared to shoulder surgeries.

**Level of evidence:** IV

**Keywords:** COVID-19, Knee surgery, Shoulder surgery, Sports medicine, Surgical volume

**Introduction**

On March 10th, 2020, the World Health Organization (WHO) declared SARS-CoV-2 (COVID-19) a worldwide pandemic.<sup>1</sup> To prepare for an influx of hospitalizations, the United States (US) Surgeon General and the American College of Surgeons recommended an indefinite delay of all elective surgical procedures.<sup>2</sup> These countermeasures had a major impact on orthopaedic

surgery, with numerous reports chronicling massive reductions in orthopaedic operations.<sup>3-7</sup> While all elective surgical procedures were profoundly affected, some of the greatest reductions were seen in arthroplasty and ligament reconstruction of the knee, with reductions of 64% and 44% respectively.<sup>4</sup>

Delays in access to sports medicine surgeries were

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associated with significantly worse patient reported outcomes and higher emotional distress.<sup>8</sup> Decreased surgical case volume also had major effects on medical education. Almost sixty percent of sports medicine surgical fellows reported doubts regarding readiness for practice following their training during the pandemic.<sup>9</sup> Furthermore, both physicians and healthcare institutions endured heavy financial burdens due to a decrease in surgical volume, with many organizations pushed to the verge of bankruptcy.<sup>10-12</sup> as the adverse effects of surgical delays and decreased case volume continued to accumulate, some studies attempted to estimate the time point at which we would see a return to pre-pandemic volumes. One study postulated that, worst-case-scenario, a minimum of 16 months would be needed to return to 90% of pre-pandemic case volume.<sup>13</sup> Additionally, they projected a cumulative backlog of more than 1 million surgical cases would remain for 2 years following the pandemic. However, much of the published research was conducted during the early pandemic, using estimations and projections with older data. Limited data is available to observe how we responded to the pandemic within one year since its onset.

Therefore, the aims of this study were to 1) observe the monthly changes in elective knee and shoulder sports procedure volume and 2) estimate the remaining backlog one year since the original suspension. We hypothesize that the monthly volume of elective knee and shoulder sports procedures would return to normal pre-pandemic rates earlier than projected estimates but that, one year later, the backlog of cases would still persist.

## Materials and Methods

### Database

The PearlDiver (Mariner dataset) Database (10435 Marble Creek Circle Colorado Springs, CO 80908) was utilized for this retrospective analysis. The Mariner dataset contains all-payer claims information from 2010 to 2021 of over 150 million patients. Patients in this dataset are identified using Current Procedure Terminology (CPT) and International Classification of Diseases (ICD) billing codes. All patient information was de-identified, and thus, this study is exempt from Institutional Review Board approval.

### Patient Selection

Patients who underwent elective knee and shoulder sports procedures using CPT codes were identified in our database. The knee procedures observed were anterior cruciate ligament (ACL) reconstructions, knee cartilage procedures, and meniscus surgeries. The shoulder procedures observed were shoulder instability procedures and rotator cuff surgeries. The CPT codes for each category can be found in [Appendix A]. The CPT codes used were aggregated from the Accreditation Council for Graduate Medical Education (ACGME) case log guidelines for orthopedic sports medicine cases.<sup>14</sup> We included patients who underwent these procedures from January 2017 to April 2021.

### Observed and Expected Volume

The monthly volume for each procedure category, knee sports procedures, and shoulder sports procedures were observed from January 2017 to April 2021. To observe the change in monthly pandemic volume performed, a linear forecasted analysis of the historical data from January

2017 to February 2020 was conducted to predict the expected volume and proportion from March 2020 to April 2021. We utilized three years of historic monthly data in order to account for seasonal variability and other potential monthly confounders<sup>15</sup> March 2020 was the beginning of the expected volume as that is the month that the World Health Organization announced COVID-19 to be a worldwide pandemic.<sup>1</sup> For the projection model, the expected volume with its 95% Confidence interval was recorded for each month. If the observed volume or proportion did not fall within the 95% confidence interval, it was determined that there was a statistically significant difference in the observed and expected volume for that month. Adjusted R<sup>2</sup>'s were used to evaluate the performance of the linear forecasting models.

The observed and expected volume was also utilized to determine the estimated remaining backlog of cases. The initial backlog was identified as the difference in the number of cases observed and expected from March 2020 to May 2020. The percent change in volume was recorded in April 2021 to observe the estimated remaining backlog of cases.

## Results

### Pre-Pandemic: Volume

Between January 2017 to February 2020, the overall volume of total knee sports surgeries increased by 10.0%, including increases in ACL reconstructions by 17.7%, knee cartilage surgeries by 15.1%, and meniscus surgeries by 7.0%. During this same period, the overall volume of shoulder surgeries increased by 10.6%, including increases in glenohumeral instability procedures by 17.4%, and rotator cuff surgeries by 10.4% [Figures 1-7, Appendix A].

### Pandemic: Volume

The adjusted R<sup>2</sup> for the linear projection model using historical surgical volume for total sports knee surgery, total sports shoulder surgery, ACL reconstruction, knee cartilage surgery, meniscus surgery, glenohumeral instability surgery, and rotator cuff surgery volume from January 2017 to February 2020 was 0.826, 0.712, 0.695, 0.612, 0.891, 0.693, 0.828 respectively. Between March 2020 to May 2020 (first peak of COVID-19 cases and surgeon general Recommendation), there was a significant decrease for all surgeries from what was expected [Figures 1-7, Appendix A]. By June 2020, all knee and shoulder surgeries reached the expected number based on the linear regression model [Figures 1-7, Appendix A]. The observed volume never dropped below the expected volume for any surgical procedure observed [Tables 1, 2].

### Estimate Change in Backlog of Knee Sports Surgery

The estimated backlog of total sports knee volume from March to May 2020 was 17,497 cases. By April 2021, the estimated backlog had increased by 49.8% (26,412 total cases) with respect to the backlog from March to May 2020. The estimated backlog of ACL reconstruction from March to May 2020 was 2,267 cases. By April 2021, the estimated backlog had increased by 126.3% (5,131 total cases) with respect to the backlog from March to May 2020. The

estimated backlog of knee cartilage surgeries from March to May 2020 was 3,365 cases. By April 2021, the estimated

backlog had increased by 49.1% (5,017 total cases) with respect to the backlog from March to May 2020.

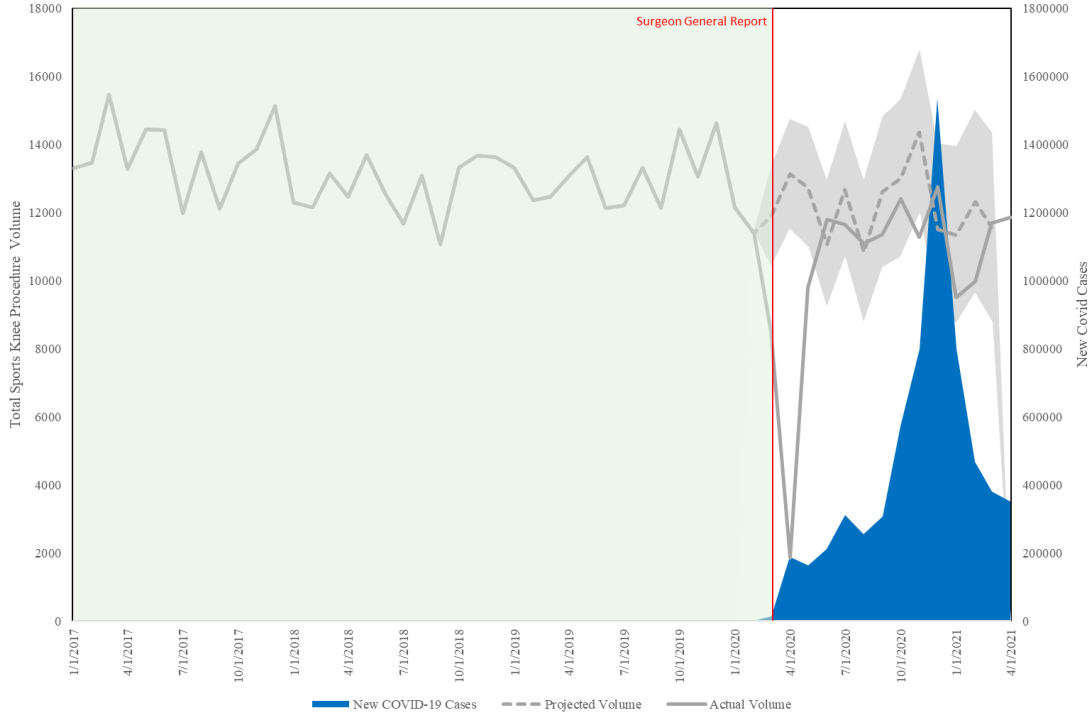


Figure 1. Total Sports Knee Surgery Volume from January 2018 to April 2021

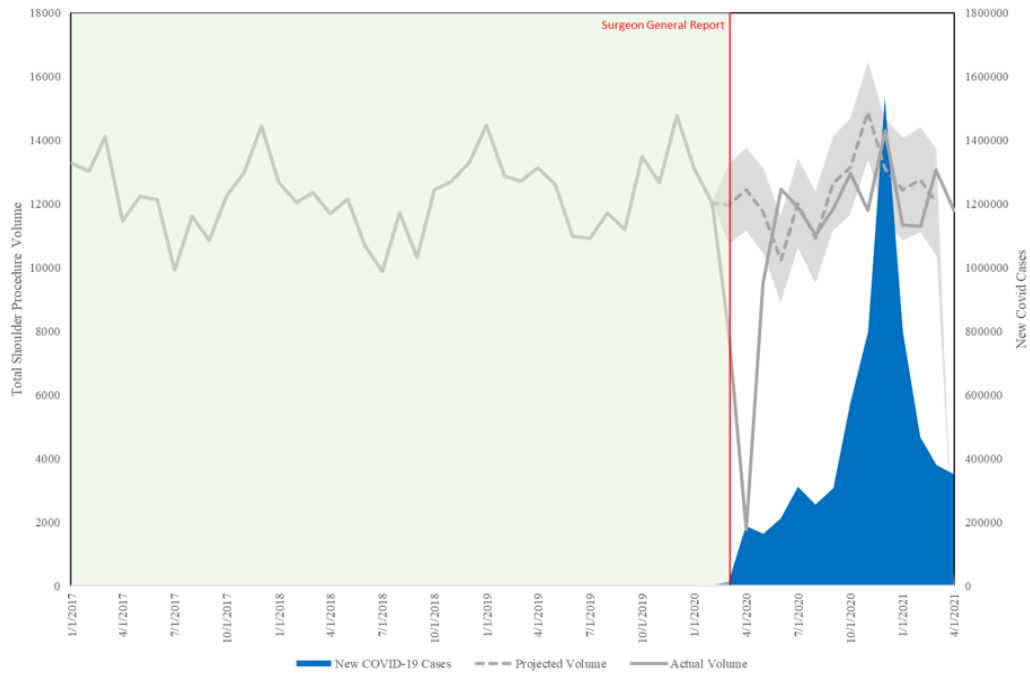


Figure 2. Total Sports Shoulder Surgery Volume from January 2018 to April 2021

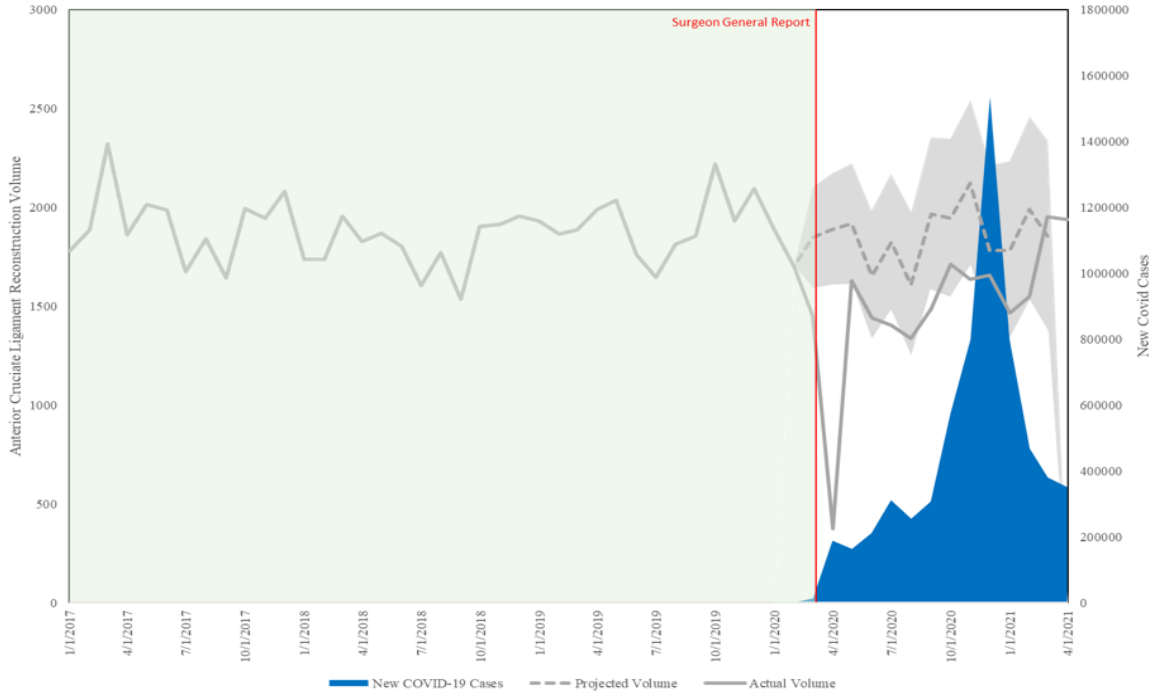


Figure 3. ACL Reconstruction Volume from January 2018 to April 2021

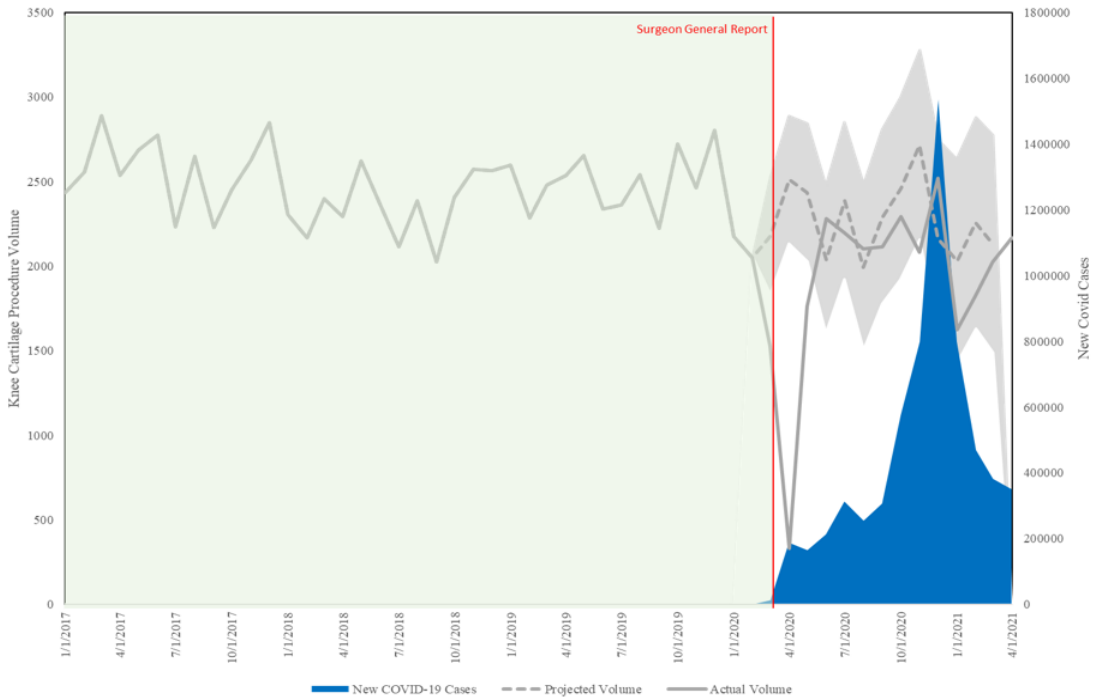


Figure 4. Knee Cartilage Surgery Volume from January 2018 to April 2021

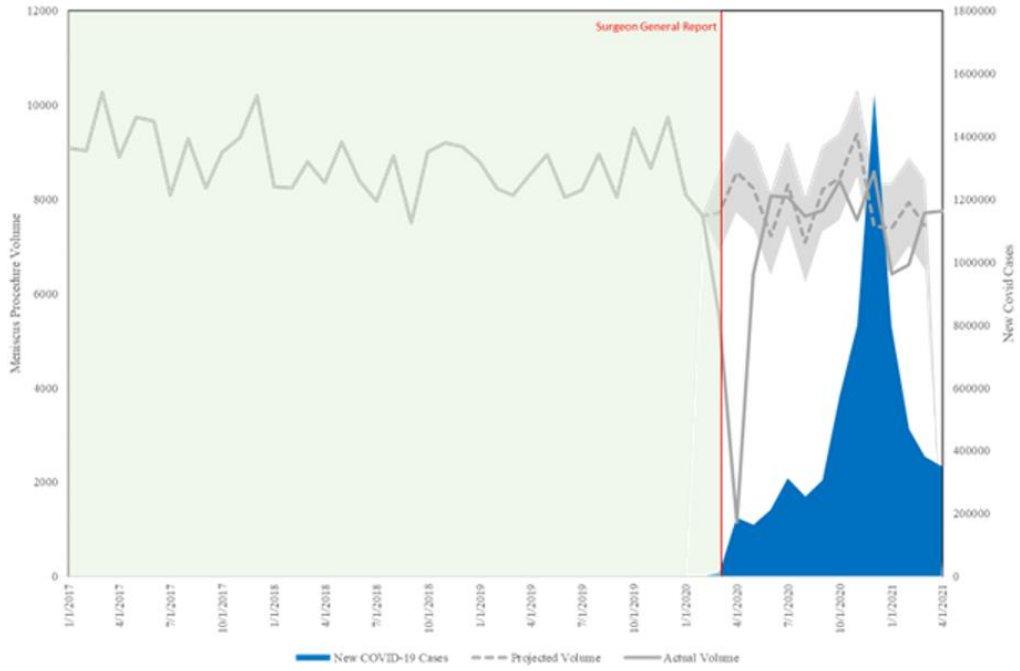


Figure 5. Meniscus Surgery Volume from January 2018 to April 2021

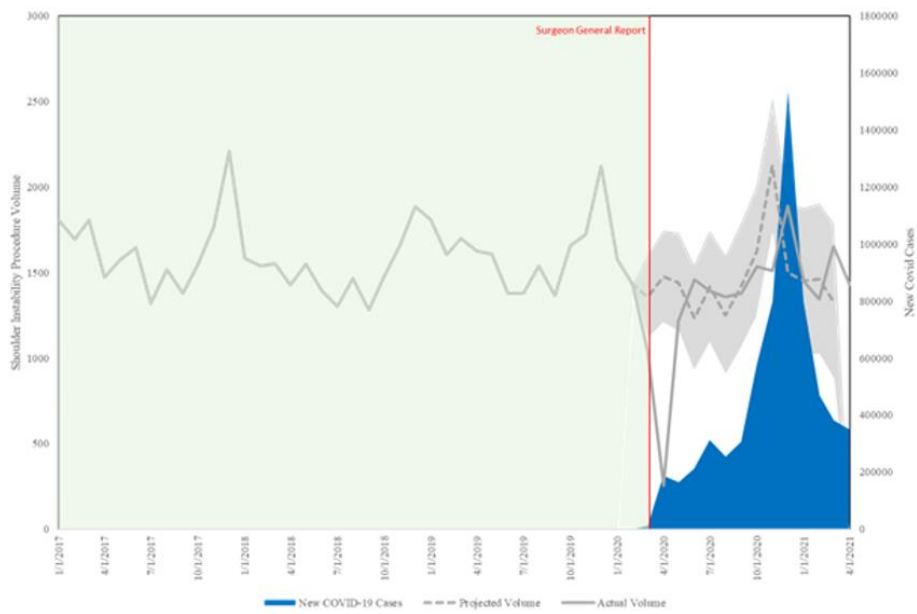


Figure 6. Glenohumeral Instability Surgery Volume from January 2018 to April 2021

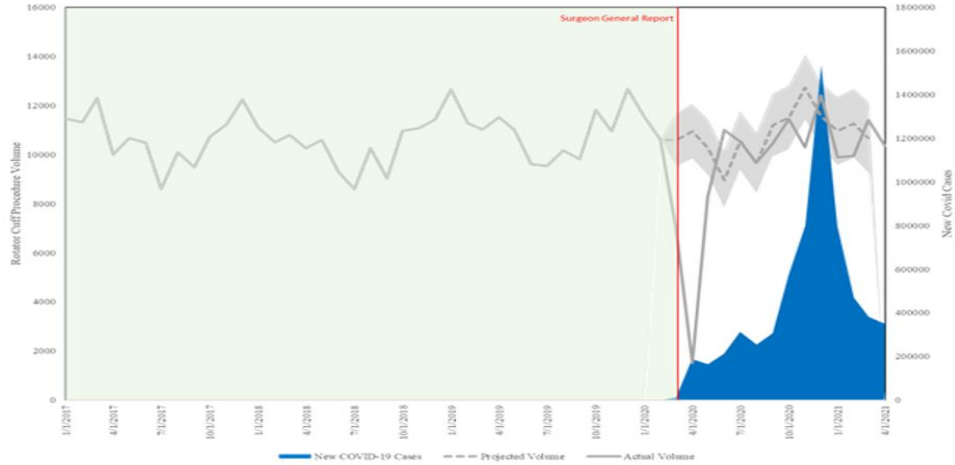


Figure 7. Rotator Cuff Surgery Volume from January 2018 to April 2021

Table 1. Monthly Total Sports Knee Surgery Volume from January 2017 to April 2021							
Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval	Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval
Jan-17	13309	-	-	Mar-19	12459	-	-
Feb-17	13476	-	-	Apr-19	13071	-	-
Mar-17	15475	-	-	May-19	13642	-	-
Apr-17	13287	-	-	Jun-19	12142	-	-
May-17	14450	-	-	Jul-19	12214	-	-
Jun-17	14427	-	-	Aug-19	13314	-	-
Jul-17	11993	-	-	Sep-19	12130	-	-
Aug-17	13776	-	-	Oct-19	14452	-	-
Sep-17	12105	-	-	Nov-19	13052	-	-
Oct-17	13447	-	-	Dec-19	14634	-	-
Nov-17	13876	-	-	Jan-20	12160	-	-
Dec-17	15134	-	-	Feb-20	11410	-	-
Jan-18	12312	-	-	Mar-20	8508	12636	11305-13968
Feb-18	12151	-	-	Apr-20	1854	11889	10399-13379
Mar-18	13153	-	-	May-20	9793	13127	11493-14761
Apr-18	12474	-	-	Jun-20	11798	12746	10979-14512
May-18	13704	-	-	Jul-20	11646	11068	9178-12958
Jun-18	12563	-	-	Aug-20	11083	12672	10666-14679
Jul-18	11682	-	-	Sep-20	11364	10840	8723-12957
Aug-18	13085	-	-	Oct-20	12402	12619	10397-14842
Sep-18	11069	-	-	Nov-20	11275	13015	10691-15338
Oct-18	13317	-	-	Dec-20	12765	14372	11951-16793
Nov-18	13688	-	-	Jan-21	9506	11519	9004-14033
Dec-18	13633	-	-	Feb-21	9990	11349	8743-13954
Jan-19	13323	-	-	Mar-21	11695	12324	9630-15018
Feb-19	12373	-	-	Apr-21	11860	11577	8797-14357

Table 2. Monthly Total Sports Shoulder Surgery Volume from January 2017 to April 2021							
Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval	Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval
Jan-17	13309			Mar-19	12459	-	-
Feb-17	13476			Apr-19	13071	-	-
Mar-17	15475			May-19	13642	-	-
Apr-17	13287			Jun-19	12142	-	-
May-17	14450			Jul-19	12214	-	-
Jun-17	14427			Aug-19	13314	-	-
Jul-17	11993			Sep-19	12130	-	-
Aug-17	13776			Oct-19	14452	-	-
Sep-17	12105			Nov-19	13052	-	-
Oct-17	13447			Dec-19	14634	-	-
Nov-17	13876			Jan-20	12160	-	-
Dec-17	15134			Feb-20	11410	-	-
Jan-18	12312	-	-	Mar-20	8508	12636	11305-13968
Feb-18	12151	-	-	Apr-20	1854	11889	10399-13379
Mar-18	13153	-	-	May-20	9793	13127	11493-14761
Apr-18	12474	-	-	Jun-20	11798	12746	10979-14512
May-18	13704	-	-	Jul-20	11646	11068	9178-12958
Jun-18	12563	-	-	Aug-20	11083	12672	10666-14679
Jul-18	11682	-	-	Sep-20	11364	10840	8723-12957
Aug-18	13085	-	-	Oct-20	12402	12619	10397-14,852
Sep-18	11069	-	-	Nov-20	11275	13015	10691-15,338
Oct-18	13317	-	-	Dec-20	12765	14372	11,951-16,793
Nov-18	13688	-	-	Jan-21	9506	11519	9,004-14,033
Dec-18	13633	-	-	Feb-21	9990	11349	8743-13,954
Jan-19	13323	-	-	Mar-21	11695	12324	9630-15,018
Feb-19	12373	-	-	Apr-21	11860	11577	8797-14,357

The estimated backlog of meniscus surgeries from March to May 2020 was 11,405 cases. By April 2021, the estimated backlog had increased by 22.7% (13,978 total

cases) with respect to the backlog from March to May 2020. [Tables 3-5].

Table 3. Monthly ACL Reconstruction Volume from January 2017 to April 2021							
Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval	Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval
Jan-17	1779	-	-	Mar-19	1886	-	-
Feb-17	1886	-	-	Apr-19	1990	-	-
Mar-17	2321	-	-	May-19	2036	-	-

Table 3. Continued							
Apr-17	1864	-	-	Jun-19	1761	-	-
May-17	2016	-	-	Jul-19	1648	-	-
Jun-17	1988	-	-	Aug-19	1813	-	-
Jul-17	1674	-	-	Sep-19	1856	-	-
Aug-17	1841	-	-	Oct-19	2219	-	-
Sep-17	1643	-	-	Nov-19	1933	-	-
Oct-17	1996	-	-	Dec-19	2094	-	-
Nov-17	1945	-	-	Jan-20	1887	-	-
Dec-17	2083	-	-	Feb-20	1702	-	-
Jan-18	1,739	-	-	Mar-20	1451	1984	1754-2,215
Feb-18	1739	-	-	Apr-20	374	1847	1590-2,105
Mar-18	1956	-	-	May-20	1629	1890	1607-2,172
Apr-18	1828	-	-	Jun-20	1443	1917	1611-2,222
May-18	1869	-	-	Jul-20	1404	1655	1328-1,981
Jun-18	1805	-	-	Aug-20	1338	1824	1477-2,171
Jul-18	1605	-	-	Sep-20	1486	1608	1242-1,975
Aug-18	1773	-	-	Oct-20	1712	1968	1583-2,352
Sep-18	1535	-	-	Nov-20	1636	1945	1543-2,346
Oct-18	1906	-	-	Dec-20	1658	2123	1704-2,542
Nov-18	1916	-	-	Jan-21	1466	1781	1346-2,216
Dec-18	1955	-	-	Feb-21	1551	1783	1332-2,234
Jan-19	1,931	-	-	Mar-21	1954	1992	1526-2,458
Feb-19	1866	-	-	Apr-21	1939	1855	1374-2,336

Table 4. Monthly Knee Cartilage Volume from January 2017 to April 2021							
Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval	Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval
Jan-17	2436	-	-	Mar-19	2480	-	-
Feb-17	2558	-	-	Apr-19	2537	-	-
Mar-17	2890	-	-	May-19	2653	-	-
Apr-17	2537	-	-	Jun-19	2340	-	-
May-17	2689	-	-	Jul-19	2363	-	-
Jun-17	2775	-	-	Aug-19	2543	-	-
Jul-17	2233	-	-	Sep-19	2226	-	-
Aug-17	2651	-	-	Oct-19	2725	-	-
Sep-17	2228	-	-	Nov-19	2462	-	-
Oct-17	2453	-	-	Dec-19	2805	-	-
Nov-17	2627	-	-	Jan-20	2176	-	-
Dec-17	2850	-	-	Feb-20	2051	-	-
Jan-18	2,304	-	-	Mar-20	1529	2301	1993-2,609



Table 4. Continued

Feb-18	2,169	-	-	Apr-20	332	2178	1833-2,522
Mar-18	2,400	-	-	May-20	1763	2510	2132-2,888
Apr-18	2,292	-	-	Jun-20	2283	2436	2028-2,845
May-18	2,622	-	-	Jul-20	2196	2038	1601-2,475
Jun-18	2,363	-	-	Aug-20	2105	2385	1921-2,849
Jul-18	2117	-	-	Sep-20	2114	1993	1503-2,483
Aug-18	2385	-	-	Oct-20	2294	2290	1776-2,805
Sep-18	2028	-	-	Nov-20	2083	2458	1920-2,995
Oct-18	2409	-	-	Dec-20	2522	2717	2157-3,277
Nov-18	2573	-	-	Jan-21	1626	2162	1581-2,744
Dec-18	2566	-	-	Feb-21	1828	2028	1425-2,631
Jan-19	2597	-	-	Mar-21	2025	2255	1632-2,878
Feb-19	2285	-	-	Apr-21	2166	2132	1489-2,775

Table 5. Monthly Meniscus Surgery Volume from January 2017 to April 2021

Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval	Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval
Jan-17	9094	-	-	Mar-19	8093	-	-
Feb-17	9032	-	-	Apr-19	8544	-	-
Mar-17	10264	-	-	May-19	8953	-	-
Apr-17	8886	-	-	Jun-19	8041	-	-
May-17	9745	-	-	Jul-19	8203	-	-
Jun-17	9664	-	-	Aug-19	8958	-	-
Jul-17	8086	-	-	Sep-19	8048	-	-
Aug-17	9284	-	-	Oct-19	9508	-	-
Sep-17	8234	-	-	Nov-19	8657	-	-
Oct-17	8998	-	-	Dec-19	9735	-	-
Nov-17	9304	-	-	Jan-20	8097	-	-
Dec-17	10201	-	-	Feb-20	7657	-	-
Jan-18	8269	-	-	Mar-20	5528	8197	7339-9,055
Feb-18	8243	-	-	Apr-20	1148	7711	6845-8,576
Mar-18	8797	-	-	May-20	6401	8574	7702-9,446
Apr-18	8354	-	-	Jun-20	8072	8241	7361-9,120
May-18	9213	-	-	Jul-20	8046	7223	6337-8,109
Jun-18	8395	-	-	Aug-20	7640	8312	7419-9,206
Jul-18	7960	-	-	Sep-20	7764	7089	6188-7,989
Aug-18	8927	-	-	Oct-20	8396	8212	7304-9,120
Sep-18	7506	-	-	Nov-20	7556	8465	7550-9,380
Oct-18	9002	-	-	Dec-20	8585	9385	8462-10,307
Nov-18	9199	-	-	Jan-21	6414	7428	6499-8,358

Dec-18	9112	-	-	Feb-21	6611	7393	6456-8,330
Jan-19	8795	-	-	Mar-21	7716	7933	6989-8,878
Feb-19	8222	-	-	Apr-21	7755	7447	6495-8,399

**Estimate Change in Backlog of Shoulder Sports Surgery**

The estimated backlog of total sports shoulder volume from March to May 2020 was 17,743 cases. By April 2021, the estimated backlog had increased by 19.0% (26,412 total cases) with respect to the backlog from March to May 2020. The estimated backlog of glenohumeral instability surgeries

from March to May 2020 was 1,808 cases. By April 2021, the estimated backlog had decreased by 7.5% (13,978 total cases) with respect to the backlog from March to May 2020. The estimated backlog of rotator cuff surgeries from March to May 2020 was 15,824 cases. By April 2021, the estimated backlog had increased by 12.1% (17,746 total cases) with respect to the backlog from March to May 2020 [Tables 6, 7].

Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval	Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval
Jan-17	1807	-	-	Mar-19	1698	-	-
Feb-17	1696	-	-	Apr-19	1626	-	-
Mar-17	1807	-	-	May-19	1608	-	-
Apr-17	1474	-	-	Jun-19	1379	-	-
May-17	1573	-	-	Jul-19	1377	-	-
Jun-17	1645	-	-	Aug-19	1537	-	-
Jul-17	1321	-	-	Sep-19	1366	-	-
Aug-17	1519	-	-	Oct-19	1658	-	-
Sep-17	1377	-	-	Nov-19	1721	-	-
Oct-17	1545	-	-	Dec-19	2121	-	-
Nov-17	1767	-	-	Jan-20	1575	-	-
Dec-17	2208	-	-	Feb-20	1432	-	-
Jan-18	1,585	-	-	Mar-20	1040	1488	1270-1,707
Feb-18	1,539	-	-	Apr-20	255	1356	1112-1,601
Mar-18	1,553	-	-	May-20	1217	1476	1208-1,744
Apr-18	1,428	-	-	Jun-20	1457	1442	1152-1,732
May-18	1,548	-	-	Jul-20	1392	1234	923-1,544
Jun-18	1,391	-	-	Aug-20	1357	1416	1087-1,746
Jul-18	1,301	-	-	Sep-20	1378	1250	903-1,598
Aug-18	1,464	-	-	Oct-20	1535	1424	1059-1,789
Sep-18	1,282	-	-	Nov-20	1510	1624	1242-2,006
Oct-18	1,472	-	-	Dec-20	1891	2126	1729-2,524
Nov-18	1,655	-	-	Jan-21	1448	1500	1087-1,913
Dec-18	1,887	-	-	Feb-21	1344	1450	1023-1,878
Jan-19	1808	-	-	Mar-21	1653	1463	1021-1,905
Feb-19	1603	-	-	Apr-21	1430	1331	875-1,787

Table 7. Monthly Rotator Cuff Surgery Volume from January 2017 to April 2021

Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval	Category	Actual: Volume	Expected: Volume	Expected: 95% Confidence Interval
Jan-17	11471	-	-	Mar-19	11024	-	-
Feb-17	11326	-	-	Apr-19	11517	-	-
Mar-17	12309	-	-	May-19	11011	-	-
Apr-17	10000	-	-	Jun-19	9615	-	-
May-17	10671	-	-	Jul-19	9543	-	-
Jun-17	10482	-	-	Aug-19	10176	-	-
Jul-17	8596	-	-	Sep-19	9827	-	-
Aug-17	10091	-	-	Oct-19	11826	-	-
Sep-17	9480	-	-	Nov-19	10953	-	-
Oct-17	10722	-	-	Dec-19	12666	-	-
Nov-17	11229	-	-	Jan-20	11547.00	-	-
Dec-17	12248	-	-	Feb-20	10607	-	-
Jan-18	11098	-	-	Mar-20	7057	11164	10106-12,221
Feb-18	10503	-	-	Apr-20	1515	10581	9490-11,672
Mar-18	10806	-	-	May-20	8291	10942	9819-12,065
Apr-18	10262	-	-	Jun-20	11006	10289	9134-11,444
May-18	10604	-	-	Jul-20	10514	8969	7783-10,155
Jun-18	9295	-	-	Aug-20	9664	10557	9340-11,773
Jul-18	8590	-	-	Sep-20	10467	9639	8392-10,885
Aug-18	10258	-	-	Oct-20	11443	11201	9925-12,477
Sep-18	9037	-	-	Nov-20	10299	11500	10195-12,805
Oct-18	10966	-	-	Dec-20	12412	12735	11401-14,069
Nov-18	11074	-	-	Jan-21	9896	11556	10195-12,918
Dec-18	11426	-	-	Feb-21	9952	10965	9575-12,355
Jan-19	12662	-	-	Mar-21	11414	11262	9844-12,680
Feb-19	11275	-	-	Apr-21	10363	10679	9235-12,124

## Discussion

This study found that knee and shoulder sport surgery volume had returned to the expected pre-pandemic projected volume by June 2020. However, it also showed a persistent and increasing estimated backlog of sport knee and shoulder cases one year since the onset of the suspension of elective surgeries, with a higher increase in the backlog for total sport knee cases (50%) when compared to total sport shoulder cases (19%).

From March to May 2020, during the suspension of elective surgeries, total volume of knee and shoulder sport surgeries

had dropped by more than 80%. This percentage decrease within this period aligns with other studies from various surgical specialties.<sup>16-18</sup> the elective nature of many sports medicine injuries permitted the postponement and cancellation of operative interventions for the benefit of patient and provider safety. Although not emergent, the demand for elective sports surgeries exists, translating to a consistently increasing backlog during the suspension. Our study corroborated this original backlog, but more interestingly showed that the backlog has continued to grow despite removal of elective surgery restrictions.

Interestingly, we found the percentage increase in backlog was two times greater for knee surgeries (50%) when compared to shoulder surgeries (19%). The difference may be associated with patient demand based on pain. Symptomatic knee pain can subside with rest and limited physical activity, a prevalent concept during the peak of the pandemic. However, this does not eliminate shoulder pain. Thus, there may have been more patients presenting with shoulder pain, contributing to the lower percent backlog. Additionally, more knee sports procedures are performed than shoulder.<sup>6</sup> Since more knee procedures are performed, the suspension in cases would therefore have a greater effect on the backlog of knee surgeries and thus require more time to address the backlog.

Specific to knee sport surgeries, the estimated percentage increase in backlog was highest for ACL reconstruction (126%), followed by knee cartilage surgeries (49.1%) and meniscus surgeries (22.7%). This may be associated with the patient population undergoing these procedures. There has been an increasing utilization of ACL reconstructions in non-sport patients, specifically older patients with increased comorbidities.<sup>19</sup> These patients are at a higher risk of complications, and thus are worse surgical candidates, especially during the COVID-19 pandemic. Additionally, although more than 95% of arthroscopic procedures are performed in outpatient setting, a higher percentage (up to 13.1%) of ACL reconstructions required inpatient hospitalization, when compared to other knee scope procedures.<sup>20-22</sup> Outpatient surgery, specifically those performed in ambulatory surgical centers provided advantages during the pandemic of results showing lower transmission rates of COVID-19 as well as freeing hospital beds and resources for patients with COVID-19.<sup>22,23</sup> Therefore, there was high incentive to perform more outpatient sports procedures.

For shoulder sports surgery, the estimated percentage backlog decreased by 7.5% for glenohumeral instability surgery; whereas, it increased by 21.1% in rotator cuff surgeries. Similar to knee arthroscopy, this can be explained by the different patient populations. Patients who undergo glenohumeral instability are often younger patients, frequently in high school or college. With lower comorbidities.<sup>24</sup> Among the MOON Shoulder Instability Study, the mean age of patients undergoing surgery for glenohumeral instability was 24.<sup>25</sup> However, patients who undergo rotator cuff surgery have been found to be older, with an average age of 60.<sup>26</sup> Additionally, the prevalence of patient medical comorbidities, such as hypertension, peripheral vascular disease, chronic pulmonary disease, congestive heart failure and diabetes, in patients undergoing rotator cuff surgery has increased.<sup>27</sup> As patients who undergo glenohumeral instability surgery are younger with lower comorbidities, they are better surgical candidates, especially during the COVID-19 pandemic. Additionally, rotator cuff repair has been the most frequent shoulder surgery in the United States with the number of procedures steadily increasing.<sup>27,28</sup> In 2018, it was reported that 20,000 shoulder stabilization surgery were performed; whereas,

75,000 rotator cuff surgeries were performed.<sup>29,30</sup> The higher incidence and demand of rotator cuff surgeries with respect to glenohumeral instability may contribute to the higher surgical backlog of rotator cuff surgeries with healthcare systems unable to keep up with the demand.

This is the first study to observe the change in volume and backlog of sports surgery cases following the onset of the COVID-19 pandemic. Besides showing a high and increasing backlog of all shoulder and knee sports cases since the onset of the pandemic, it also showed a disparity in this backlog with respect to anatomic location. This information is important for sports surgeons and surgical centers who cater to a higher percentage of knee sports surgeries. High volume facilities performing greater proportion of knee cases may have a worse financial burden when compared to those who perform more shoulder sports surgery. Additionally, understanding the change in backlog of shoulder and knee surgeries from the COVID-19 pandemic helps predict the duration and extent of recovery required following surgical suspensions in the United States. The COVID-19 pandemic will most likely not be the last pandemic. Understanding our historical response allows us to predict and improve our future response.

This study should be viewed in the context of its limitations. First, our database is currently limited to data from April 2021, one year since the onset of the pandemic. Future works can expand upon our dates to see if there has been any change in the estimated backlog. Second, the linear forecast model utilized was not able to account for certain factors that may influence the demand of elective surgeries, such as pandemic changes in employment, insurance, financial and emotional stress. Third, this is a retrospective analysis and thus cannot show direct causation but only association. For example, patient specific factors such as pain or function scores are not available which may help assess the reason behind shoulder cases progressing to operative treatment more rapidly than knee. Fourth, our database contains records of 150 million patients and thus is quite generalizable. However, it does not include data from all national institutions. Thus, the calculated backlog is only an estimate.

### Conclusion

Within four months, the sudden decrease in volume for knee and shoulder sports procedures had returned to pre-pandemic levels; however, the original backlog in cases has continually increased one year following the suspension. Additionally, the backlog is significantly higher for knee when compared to shoulder surgeries. COVID-19 has a persistent effect in knee and shoulder sports surgery one year since the original suspension.

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Appendix A. Current Procedure Terminology Billing Code	
Category	Current Procedure Terminology Billing Code
Anterior Cruciate Ligament Reconstruction	CPT-29888
Knee Cartilage Procedures	CPT-27412, CPT-27415, CPT-29877, CPT-29885, CPT-29886, CPT-29887, CPT-29879, CPT-29866, CPT-29867
Meniscus Surgeries	CPT-27403, CPT-29868, CPT-29880, CPT-29881, CPT-29882, CPT-29883
Glenohumeral Instability Shoulder Procedures	CPT-23450, CPT-23455, CPT-23460, CPT-23462, CPT-23465, CPT-23466, CPT-29806, CPT-29807
Rotator Cuff Surgeries	CPT-23120, CPT-23130, CPT-23410, CPT-23412, CPT-23415, CPT-23420, CPT-23430, CPT-23440, CPT-29828, CPT-29826, CPT-29827, CPT-29823