Title

The Effects of Obstructive Sleep Apnea Risk on Post-Operative Recovery Following Rotator Cuff Repair

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The authors have no conflicts of interest to declare at this point.

Abstract

Background: Rotator cuff injuries are the most common tendon injury in the adult population affecting nearly 30% of adults over the age of 60 years (Khatri 2019). Obstructive Sleep Apnea (OSA) is a similarly common condition that is characterized by repeated episodes of respiratory pathway obstruction throughout a period of sleep (Senaratna 2017). OSA has been shown to worsen patient reported outcomes post-surgery (Cancienne 2019, Gali 2007, Legler 2018, Bamgbade 2017, Schreiner 2020).

Purpose: The purpose of this study was to determine whether patients at high risk for OSA experience worse outcomes after surgical treatment for rotator cuff repair via a retrospective cohort study.

***Methods*:** Included patients completed STOP-BANG surveys in which scores greater than 3 were considered high risk for OSA as per standard guidelines (Chung 2016). Five mixed model repeated measures ANCOVAs were performed for five different outcome measures: VAS pain scores, SANE scores, VR-12 mental and physical scores, and total ASES scores, measured pre-operatively, 3 months, 6 months, and 1 year post-operatively.

Results: There was a significant group by time interaction for the VR-12 mental scores ($F = 3.66$, $p = .0128$): scores consistently increased over time for patients at high risk of OSA, while patients at low risk of sleep apnea did not exhibit a significant difference post-operatively. There was a significant group effect, time effect ($F = 56.59$, $p < .0001$), group by time interaction, and effect of BMI on the VR-12 physical scores. Patients at high risk of OSA had on average lower scores by 3.35 points ($F = 7.27$, $p = .0076$). While scores increased on average over time for patients at low risk and high risk of OSA, patients at low risk showed a quicker and greater improvement overall (F = 4.36, p = .005), while patients with a higher BMI performed significantly worse (F = 6.76, p = .01).

Conclusions: Our findings suggest that RCR in patients at high-risk of OSA can expect similar improvements in PROs of shoulder function and shoulder pain; while in some cases, greater improvements in mental health at 1 year post-operatively, compared to their low-risk counterparts. However, in contrast to their low-risk counterparts, our results suggest that patients at high risk of OSA cannot expect similar improvements in physical health one-year post RCR. Hence, orthopedists should take into consideration that while high-risk OSA patients can anticipate achieving similar levels of recovery following RCR, their progress towards these results may be markedly slower for certain parameters of recovery.

Key Terms: obstructive sleep apnea, rotator cuff repair, postoperative patient reported scores, physical health, mental health, pain

Introduction

Rotator cuff injuries are the most common tendon injury in the adult population affecting nearly 30% of adults over the age of 60 years (Khatri 2019). Although many individuals may go years without symptoms following a rotator cuff injury, upwards of 35% of patients experiencing a rotator cuff tear will develop substantial pain and inability to perform basic daily tasks (Khatri 2019, Dang 2018). Treatment of rotator cuff injuries can be complex as several factors must be considered, such as: tear thickness, size, and morphology. However, it has been consistently shown in the literature that surgical intervention, specifically rotator cuff repairs (RCR), results in greater long-term patient outcomes (Dang) compared to conservative treatment.

Another common pathology among older adults is obstructive sleep apnea (OSA). OSA is a condition that is characterized by repeated episodes of respiratory pathway obstruction throughout a period of sleep (Senaratna 2017). These continuous bouts of upper airway obstruction causing patients to often experience extreme sleep fragmentation; resulting in irregular sleep patterns that leave the individual experiencing excessive day-time sleepiness, often combined with morning headaches (Senaratna 2017). Not dissimilar to those suffering from rotator cuff tears, OSA may also be present in adults without demonstrating any of the aforementioned glaring symptoms. The reported prevalence of OSA in higher-income countries such as the United States has increased over time, partly due to increases in tandem with other comorbidities such as obesity (Senaratna 2017) and longer life expectancy.

Due to the increasing prevalence of OSA rates in higher income countries, combined with the overall prevalence of rotator cuff injuries, the combination of the two in relation to post-operative healing and rehabilitation is likely intertwined as well as highly relevant to orthopedists treating rotator cuff injuries. Previous literature suggests that patients with OSA may experience deteriorated healing that is increased in total length based on patient reported outcomes (Gali 2007). Despite the overlap between these two populations, there remains a scarcity in the literature as to how OSA affects post-operative healing and rehabilitation following RCR. Thus, the purpose of this study was to elucidate the effect of OSA negatively affects parameters of mental, physical health, pain, and shoulder function in patients recovering from RCR.

Methods

Study Methodology

A retrospective chart review of patients who underwent RCR by five fellowship-trained orthopedic surgeons between 2014 and 2019 was performed. Patient medical history was screened for either a diagnosis of OSA, or patients deemed at high risk by STOP BANG questionnaire (Chung 2016).

Reporting Outcomes

All patients were asked to complete PROs preoperatively, at three months postoperatively, six months postoperatively, and one year post-operatively: American Shoulder Elbow Surgeons Score (ASES), Visual Analog Scale (VAS) for pain scores, Single Assessment Numeric Equivalent (SANE) scores, and Veterans Rand (VR)-12 mental and physical scores.

Statistical Analyses

Five mixed model repeated measures ANCOVAs were performed for five different outcome measures – also measured pre-operatively, three months, six months, and one year post-operatively. A STOP-BANG score of greater than 3 was considered high risk for OSA as per guidelines (Chung 2016, Legler 2018). Risk of OSA was the primary independent variable (high risk vs low risk). Five mixed model repeated measures ANCOVAs were performed for five different outcome measures: VAS pain scores, SANE scores, VR-12 mental and physical scores, and total ASES scores. For each of these models, a time effect (a preoperative measure, three months postop, six months postop, and one year postop) and group by time interaction were included with the group effect. Due to missing STOP-BANG and preoperative scores, 205 out of 320 subjects were included in these models. Several possible confounding factors were considered when developing these models: age, gender, BMI, smoking status, diagnosis of diabetes, and diagnosis of dyslipidemia. To determine which of these factors would be included in the models, t-tests and chi-square tests were performed to determine significant differences between the two risk groups. T-tests were performed on group means for continuous demographic values (age and BMI) and on group means of the outcome measures at each time point. Chi-square tests were performed for categorical demographic variables (gender, smoking status, diagnosis of diabetes, and diagnosis of dyslipidemia). The only demographic factor that was not included in these models was smoking status since there was no significant difference between the two groups. An alpha of .05 was chosen for significance, and a Tukey adjusted P value was used for post hoc comparisons for risk groups, time-points, and categorical confounding variables. T-tests were also performed to determine the significant mean differences between risk groups at every time-point for each score.

Results

Patients at high risk for OSA were significantly older than patients at low risk for OSA (61.89 (8.95) vs. 59.02 (11.51), t = 2.03, p = .0433). Patients at high risk for OSA also had significantly larger preoperative BMIs (30.546 (5.18) vs. 25.71 (4.49), t = 7.22, p < .0001) and one-year postoperative BMIs (30.68 (5.52) vs. 26.54 (4.7), t = 4.35, p < .0001) than their counterparts, patients at low risk for OSA. These results are depicted in Table 1. Patients at high risk for OSA were more likely to be male ($\chi2$ = 6.8575, p = .0088), be prediabetic or have type II diabetes ($\chi2$ = 13.9667, p = .003), and have high cholesterol ($\chi2$ = 8.2276, p = .0041). These results are depicted in Table 2.

As expected, most of the observed patient reported outcomes changed over time. Total ASES scores (F = 147.71, p < .0001) and SANE scores (F = 150.91, p < .0001) increased over time while VAS pain scores decreased over time (F = 86.3, p < .0001). ASES scores significantly increased three months post-op (14.15 (1.47), t = -9.6, p < .0001) and likewise increased between the three-month and six-month post-op time period (14.05 (1.78), t = -7.87, p < .0001). The only time-point where scores were significantly lower for patients at high risk for OSA was three months post-operatively (62.47 (19.28) vs. 70.58 (15.22), t = -2.7, p = .0079). There was also a significant difference in gender (F = 8.23, p = .0046), as female patients had on average, lower scores by 6.615 points (95% CI: -11.16 to -2.07). These results are depicted in Table and Figure 3. SANE scores significantly increased three months post-op (22.77 (1.99), t = -11.46, p < .0001) and from three months to six months post-op (15.92 (2.41), t = -6.6, p < .0001). These results are depicted in Table 6. VAS pain scores significantly decreased three months post-op (-20.64 (1.91), t = 10.79, p < .0001). Age at time of surgery had a significant effect where older patients performed significantly better (had significantly lower scores) (F = 7.47, p = .0068). The regression showed that for every year of age, VAS scores decreased by .39 points (95% CI: -.67

to -.11). There was also a significant difference in gender ($F = 6.19$, $p = .0137$) where female patients had on average higher scores by 7.04 (95% CI: 1.47 to 12.62) points. These results are depicted in Table 7 and Appendix Figure 1.

When assessing the VR-12 mental and physical health components, there was a significant group by time interaction for the VR-12 mental scores ($F = 3.67$, $p = .0127$). Since this was statistically significant but the time factor was not, post-hoc paired t-tests were performed to elucidate differences between OSA risk groups at the post-operative timepoints. One year after surgery, scores significantly increased for patients at high risk of OSA (3.82 (11.13), $t = -2.12$, $p = .041$), while patients at low risk of OSA experienced a significant decrease one year after surgery (-3.11 (6.66), $t = -2.72$, $p = .0103$). These results are depicted in Figure 4. There was a significant group effect, time effect ($F = 56.55$, $p < .0001$), group by time interaction, as well as an effect of preoperative BMI on the VR-12 physical scores. Patients at high risk of OSA had on average lower scores by 3.38 points ($F = 7.39$, $p = .0071$). While average scores increased over time for patients at both low risk and high risk of OSA groups, patients at low risk showed a quicker improvement ($F = 4.37$, $p = .0049$). Patients with a higher BMI performed significantly worse ($F = 6.37$, $p = .0123$), in fact, for every 1-point increase in BMI, VR-12 physical scores decreased by .3 points (95% CI: -.54 to -.07). VR-12 physical scores significantly increased from three months to six months post-op (5.77 (.81), $t = -7.14$, $p < .0001$) and from six months to one-year post-op (2.88 (.94), $t = -3.06$, $p = .0127$). Three-month scores (37.16 (7.57) vs. 40.28 (8.31), $t = -2.27$, $p = .0249$), six-month scores (42.26 (7.95) vs. 46.99 (9.41), $t = -2.62$, $p = .0102$), and one-year scores (44.7 (9.64) vs. 51.39 (8.11), $t = -3.17$, $p = .0023$), were all significantly lower for patients at high risk for OSA. These results are depicted in Table, Figure 5, and Appendix Figure 1.

Discussion

Our findings suggest that RCR in patients at high-risk of OSA can expect similar improvements in PROs of shoulder function and shoulder pain; while in some cases, greater improvements in mental health at 1 year post-operatively, compared to their low-risk counterparts. However, in contrast to their low-risk counterparts, our results suggest that patients at high risk of OSA cannot expect similar improvements in physical health one-year post RCR. In addition, patients at high-risk of OSA may not improve as rapidly in terms of shoulder function as their low-risk counterparts as evidenced by significantly lower ASES scores at the 3-months post-operative mark. On that note, this finding was not seen when comparing SANE and VAS scores between our study groups at any timepoint. We speculate it is indicative of an underlying difference in shoulder function and its downstream effects on acts of daily living rather than shoulder pain. Hence, orthopedists should take into consideration that while high-risk OSA patients can anticipate achieving similar levels of recovery following RCR, their progress towards these results may be markedly slower for certain parameters of recovery.

Furthermore, our results also demonstrated that high-risk of OSA patients had significant improvements in mental health at 1 year post-operatively compared to pre-operatively, which was not observed in the low-risk OSA group. When taken together, the significant improvement in VR-12 mental scores may explain significantly lower ASES scores in the high-risk OSA group at 3 months post-operatively, despite showing no significant differences when compared pre-operatively or 6 & 12 months post-operatively to their low-risk counterparts. Hines 2022 demonstrated that VR-12 mental scores were associated with failure to progress early in recovery from RCR as demonstrated by ASES scores from patients who did not meet the substantial clinical benefit threshold (ASES score >86.7), who demonstrated lower VR-12 mental scores both pre-operatively and at 6 months, but not 12 months. However, while both groups showed significant improvement in VR-12 physical scores, only the low-risk OSA group demonstrated vastly greater improvements in physical health when compared to their high-risk counterparts, despite both groups demonstrating similar VR-12 physical scores pre-operatively. The discrepancy between the improvements seen in physical health between the low risk and high risk OSA groups managed to exceed the Minimum Clinically Important Difference (MCID) (Zhou 2018) at 12 months post RCR.

When compared to a similar cohort in McIntyre 2021 in terms of clinical characteristics that negatively impact VR-12 physical scores, that underwent RCR (BMI: 30.55 ± 5.18 vs. 30.40 ± 6.20 and Diabetes: 20.65% vs.18.60%, respectively), we found similar VR-12 physical scores at 12 months (44.7 vs. 47.3, respectively). Furthermore, an a-posteriori analysis found no significant changes in BMI across time for either group or between groups, which in our study was negatively associated with VR-12 physical scores. Thus, our findings indicate the RCR procedure is the probable intervention that led to this clinically relevant improvement in physical health and not to known confounders in this patient population.

We speculate that these improvements in VR-12 physical and mental health may be an indirect measure of improvement in sleep quality that has been previously shown in the literature to be poor in RCT patients (Barandiaran 2021, Longo 2021). One study utilizing cognitive behavioral therapy for insomnia (CBTi) to treat insomnia in active duty US Army personnel found that improving sleep quality and objective sleep parameters correlated with improved VR-12 mental and physical scores (Taylor 2018). We hypothesize that there may be an underlying compounded effect of OSA and shoulder-related sleep disturbance creating even poorer sleep quality in RCT patients in the high-risk OSA group at the pre-operative stage. This may explain our findings as the literature shows poor sleep quality due to shoulder-related sleep disturbance from a RCT improves significantly with RCR, where patients report better or sleep quality comparative to the normal population at 6 months post-operatively (Austin 2015, Cho 2015, Serbest 2016). Taken together, further research is needed to determine if improvements in sleep quality are achievable even in patients with undiagnosed or untreated OSA.

Limitations

Our results are limited due to its retrospective nature as complete outcome measures across all study timepoints was not available for consecutive patients. Other limitations include the construction of a cohort derived from multiple surgeons that included all rotator cuff tear patients with a variety of RCR methods, whether due to surgeon preference or indication at the time of surgery. However, with such a large cohort, this likely reflects the variance normally observed in a real-world setting and thus may be more generalizable cohort of patients undergoing RCR. Lastly, our use of the STOP BANG score as our measure for OSA prevalence is a limitation, while the questionnaire has a high reliability, it cannot diagnose OSA hence, it's likely a small subset of patients at high risk of OSA may not suffer from the disease.

Conclusion

Our findings suggest that RCR in patients at high-risk of OSA can expect similar improvements in PROs of shoulder function and shoulder pain; while in some cases, greater improvements in mental health at 1 year post-operatively, compared to their low-risk counterparts. However, in contrast to their low-risk counterparts, our results suggest that patients at high risk of OSA cannot expect similar improvements in physical health one-year post RCR. Hence, orthopedists should take into consideration that while high-risk OSA patients can anticipate achieving similar levels of recovery following RCR, their progress towards these results may be markedly slower for certain parameters of recovery.

Table 1

	High Risk	Low Risk
Age*	61.89 (8.95)	59.02 (11.51)
Pre-Op BMI*	30.55 (5.18)	25.71 (4.49)
Post-Op BMI*	30.68 (5.52)	26.54 (4.7)
*=p<.05	mean (sd)	

Table 2

	High Risk	Low Risk
Gender*		
Female	24 (26.09%)	51 (43.59%)
Male	68 (73.91%)	66 (56.41%)
Smoking Status		
Current	6 (6.52%)	10 (8.55%)
Former	36 (39.13%)	44 (37.61%)
Never	50 (54.32%)	63 (53.85%)
Diabetes*		
Never	61 (66.3%)	99 (85.34%)
Prediabetic	12 (13.04%)	3 (2.59%)
Type I	0 (0%)	1 (.86%)
Type II	19 (20.65%)	13 (11.21%)
Dyslipidemia*		
Good	32 (34.78%)	64 (54.7%)
High	60 (65.22%)	53 (45.3%)
* = p < .05		

Table 3

	ASES	
	High Risk	Low Risk
Pre-Op	51.55 (19.39)	52.935 (18.42)
Month 3*	62.47 (19.28)	70.58 (15.22)
Month 6	80.21 (17.19)	83 (17.675)
Year 1	86.84 (15.96)	90.25 (14.55)
* = p < .05	mean (sd)	

ASES All Groups

Month 3-Pre-Op*	14.15 (1.47)
Month 6-Month 3*	14.05 (1.78)
Year 1-Month 6	5.26 (2.08)
* = p < .05	mean (SE)

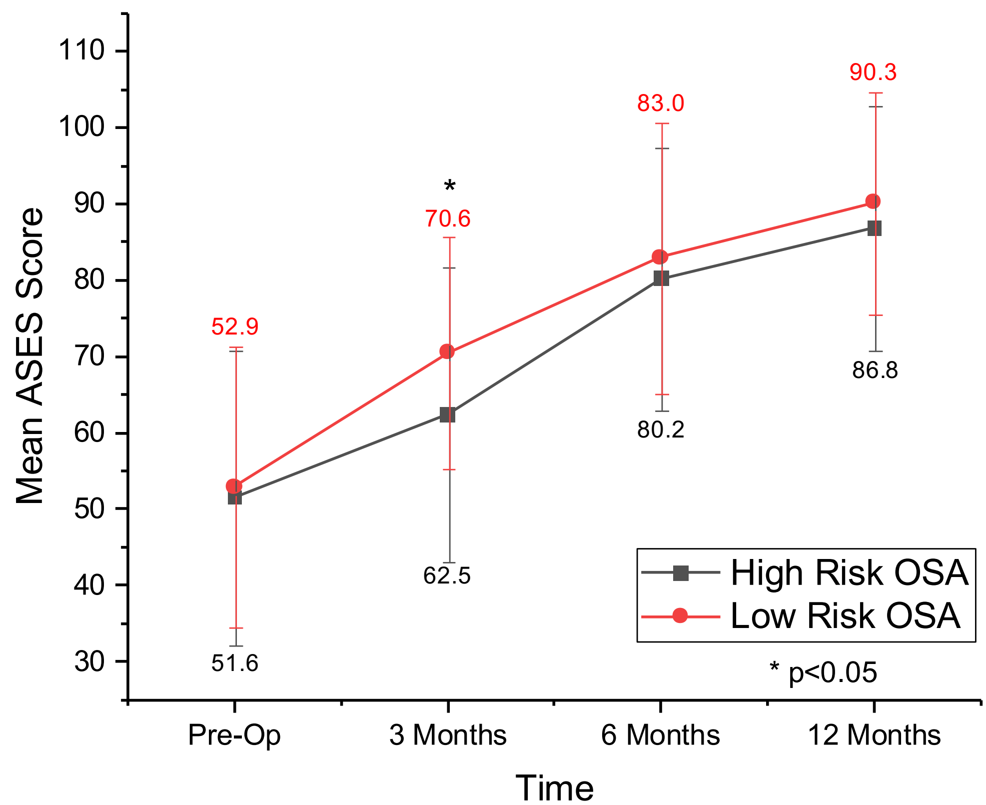


Figure 1. High-risk OSA patients report significantly worse ASES score at 3 months post-RCR

*=p<.05 Graph depicts the average total ASES scores at each time-point. As expected, mean ASES scores improved post-operatively compared to pre-operatively for both groups ($p < .0001$). 3-month scores were also significantly lower for patients at high risk for OSA (62.47 vs. 70.58, $p = .0079$), and average scores for female patients were lower overall (61.386 vs. 67.996, $p = .0046$).

Figure 4

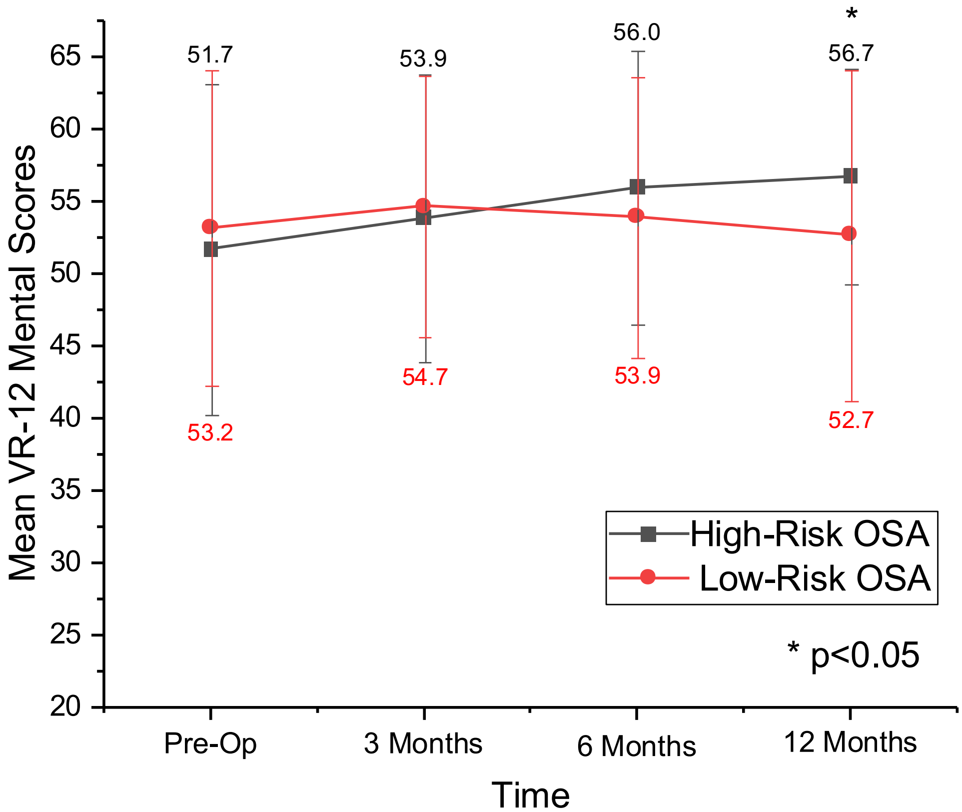


Figure 2. Mean VR-12 mental health scores significantly improved at 12 months post-RCR compared to pre-RCR

Graph depicts the average VR-12 mental scores at each time-point. There was a significant group by time interaction for the VR-12 mental scores (p = .0127).

Table 5

	V12 Physical	
	High Risk	Low Risk
Pre-Op	37.03 (8.39)	37.91 (8.53)
Month 3*	37.16 (7.57)	40.28 (8.31)
Month 6*	42.26 (7.95)	46.99 (9.41)
Year 1*	44.7 (9.64)	51.39 (8.11)
* = p < .05	mean (sd)	

V12 Physical All Groups	
Month 3-Pre-Op	.92 (.67)
Month 6-Month 3*	5.77 (.81)
Year 1-Month 6*	2.88 (.94)
* = p < .05	mean (SE)

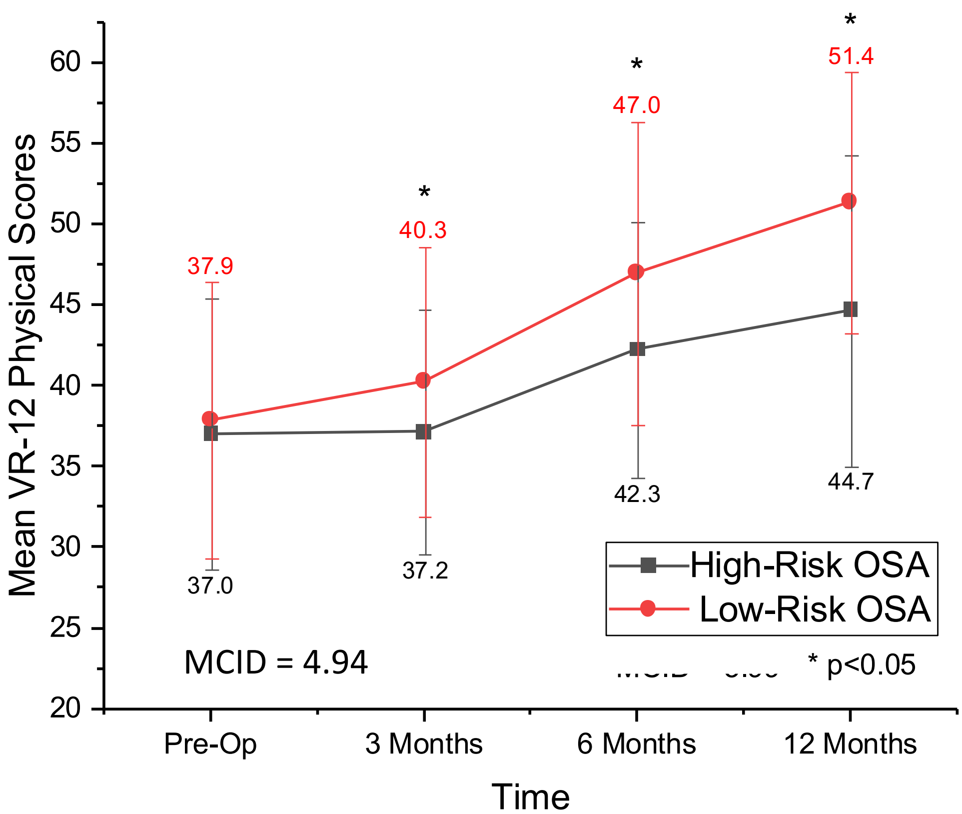


Figure 5. Mean VR-12 physical health scores significantly improved for high-risk OSA patients across 12 months post-RCR as well as compared to low-risk OSA patients.

Mean VR-12 physical scores for patients at high and low risk of OSA pre and post RCR depicts a significant group effect, time effect, as well as a group by time interaction effect ($p = .0071$, $p < .0001$, and $p = .0049$, respectively). More specifically, low-risk OSA patients saw a 35.6% improvement in VR-12 physical scores at 12 months compared to pre-operatively, while the high-risk group experienced a 20% improvement during the same time span. In fact, the difference between VR-12 physical scores at 12 months post RCR exceeded the Minimum Clinically Important Difference (MCID). Data represented as means ± SD, * denotes p-value <.05

Table 6

SANE All Groups

Month 3-Pre-Op*	22.77 (1.99)
Month 6-Month 3*	15.92 (2.41)
Year 1-Month 6	6.29 (2.82)

* = p < .05 mean (SE)

SANE scores increased over time (p < .0001).

Table 7

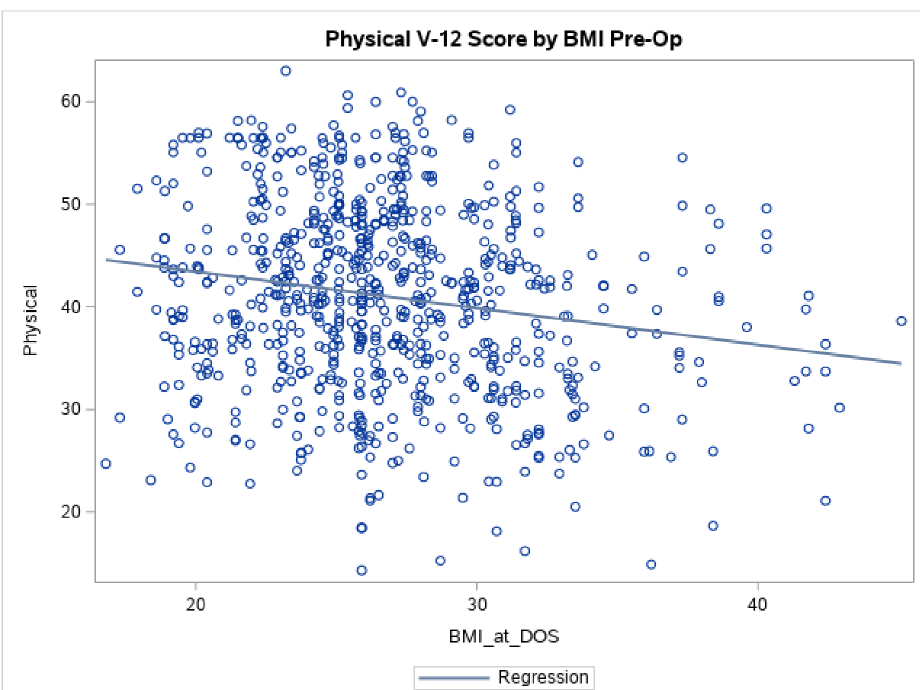
VAS All Groups

Month 3-Pre-Op*	-20.64 (1.91)
Month 6-Month 3	-5.86 (2.32)
Year 1-Month 6	-6.05 (2.71)

* = p < .05 mean (SE)

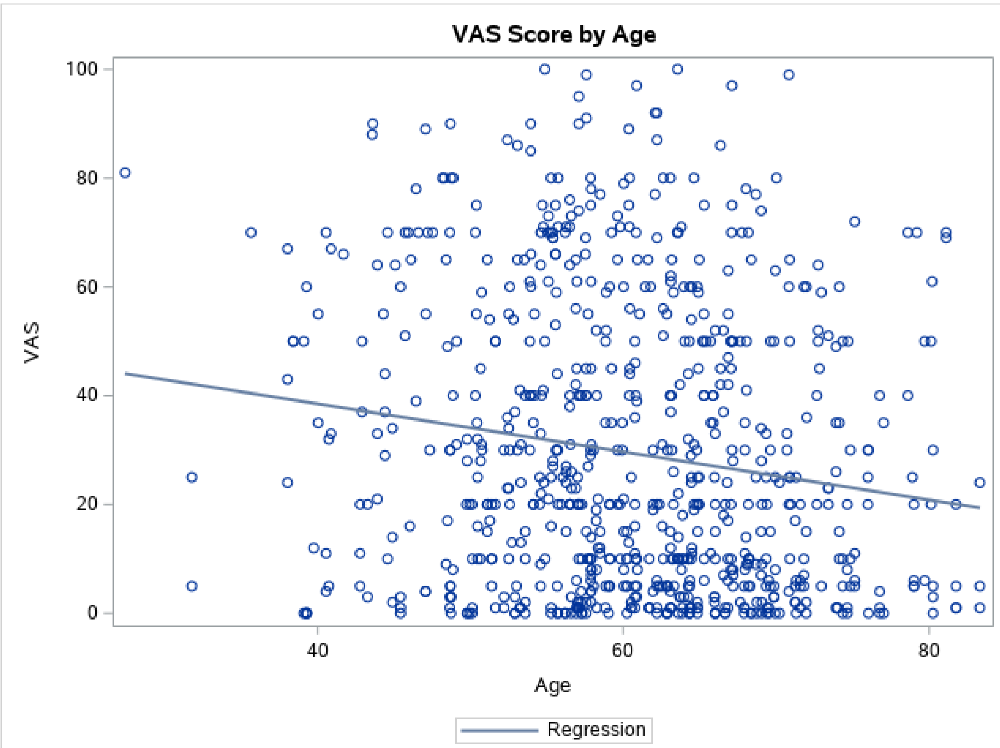
VAS pain scores decreased over time (p < .0001). Older patients had significantly lower scores (p = .0068), while female patients had significantly higher scores (30.86 vs. 23.82, p = .0137).

Appendix Figure 1.



Effect of BMI (higher BMI was associated with lower scores, p = .0123) on the VR-12 physical scores.

Appendix Figure 2.



Effect of age (older age was associated with lower scores before surgery, p = .0068) on the VAS pain scores.

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