JSES International 5 (2021) 454–458

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Impact of smoking on patient-reported outcome measures after arthroscopic rotator cuff repair: a 2-year comparative cohort study

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ARTICLE INFO

Keywords:
Smoking
Rotator cuff repair
Patient-reported outcome measures
Subjective outcomes
Shoulder arthroscopy
Shoulder

Level of evidence: Level III; Retrospective Case-Control Design; Prognosis Study

Background and Hypothesis: Smoking is a well-established risk factor for tendon healing. The purpose of this study was to evaluate the differences in patient-reported outcome measures between smokers and nonsmokers who have undergone arthroscopic rotator cuff repair. It was hypothesized that smokers would have worse self-reported outcomes at 1 and 2 years postoperatively.

Methods: A total of 560 consecutive patients who underwent arthroscopic rotator cuff repair were divided into 2 groups: group I (smokers) n = 25 and group II (nonsmokers) n = 535. All participants were administered preoperative and postoperative surveys consisting of the following outcome-measuring tools: (i) visual analog scale, (ii) Veterans Rand 12-Item Health Survey, (iii) American Shoulder and Elbow Surgeons shoulder score, (iv) standard preoperative form consisting of 4 questions regarding their expectations of recovery, (v) Single Assessment Numeric Evaluation shoulder score, and (vi) Simple Shoulder Test.

Results: At 1 and 2 years postoperative, nonsmokers reported statistically significant differences in Veterans Rand 12-Item Health Survey mental scores (56.2 vs. 51.9, $P = .0162$ and 56.3 vs. 49.5, $P = .0004$, respectively). American Shoulder and Elbow Surgeons Shoulder scores showed no differences until the 2-year mark, at which time nonsmokers reported higher scores than smokers (87.9 vs. 79.0, $P = .0212$). Single Assessment Numeric Evaluation scores also remained similar up until 2-year follow-up, at which time nonsmokers reported statistically significant improvement (80.0 vs. 68.5, $P = .0339$). Nonsmokers reported higher Simple Shoulder Test scores at baseline and at 2-year follow-up (43.3 vs. 37.0, $P = .0417$ and 83.7 vs. 68.1, $P = .0046$, respectively).

Conclusion: At 2 years postoperatively, nonsmokers had significantly higher patient-reported outcome measure scores than smokers. In elective surgery, smoking status should be considered as a risk factor for poorer patient-reported outcomes after arthroscopic rotator cuff repair. However, smokers continue to report a clinical benefit at 2 years postoperatively.

In 2018, it was estimated that 13.7% of US adults were current smokers and of that group, 76.4% smoked daily.[1] Smoking is a well-established risk factor for postoperative infection as well as various other pulmonary, neurologic, and wound complications.[13,14] Owing to the ability to select for optimal surgical candidates in the elective setting, this risk factor has become increasingly relevant in orthopedic surgery. Lee et al[17] showed that smoking decreases bone mineral density, increases risk for fracture or tendon injury, and is associated with delayed, nonunion, and wound healing complications.

One of the more studied areas of its impact in elective orthopedic surgery is that of rotator cuff repair (RCR). Rotator cuff tendons are relatively avascular which worsens with age. The known vasoconstrictive effect of nicotine further exacerbates this avascular insult. This effect was demonstrated in vitro in a rat model by Galatz et al[12] in 2006 in which tendon-bone healing was delayed in the nicotine group vs. saline control, and the authors attributed this to chronic inflammation and decreased cell proliferation.

While the histologic data are difficult to retrieve in vivo, several studies have since reported smoking's effect on objective outcomes. Baumgarten et al[3] were the first to note that smoking is an independent risk factor for rotator cuff tear. Carbone et al[5] later demonstrated that smoking positively correlated with the

This research study was reviewed by the committee on clinical investigations and approved by the institutional review board.

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https://doi.org/10.1016/j.jseint.2021.01.002

incidence of rotator cuff tear and that both lifetime smoking duration and daily cigarette habit positively correlate with rotator cuff tear size. Cuff et al[7] also reported a higher incidence of postoperative pain in the first week after RCR among smokers. A 2015 meta-analysis concluded that smoking is associated with statistically significant decreases in cuff healing, tendon quality, biomechanics, and other clinical outcome measures.[26] One additional systematic review concluded that smoking exacerbates both rotator cuff degeneration and development of symptoms in otherwise clinically unimpressive rotator cuff pathology.[4]

Several other risk factors for suboptimal RCR outcomes have been reported in the literature. These consist of age, gender, obesity, diabetes mellitus, tear size, tear acuity, worker's compensation status, and any concomitant biceps tendon or acromioclavicular joint procedures.[6,8-11,16,19,22-24,27] To date, however, the isolated effect that smoking has on self-reported outcomes has been limited.

Mallon et al[20] performed a retrospective evaluation on 224 patients and found a statistically significant improvement in both total University of California Los Angeles Shoulder Score and pain scores in nonsmokers vs. smokers. All of the patients underwent open RCR, provided limited outcome measures, and follow-up occurred only at 1 year postoperativey. One additional retrospective study examined the effect of smoking on American Shoulder and Elbow Surgeons (ASES) shoulder score, Western Ontario Rotator Cuff Index, and visual analog scale (VAS) after arthroscopic RCR and reported worse outcomes among smokers at the 1-year follow-up.[21]

The purpose of this study was to evaluate the difference in patient-reported outcome measures (PROMs) between smokers and nonsmokers who have undergone arthroscopic RCR. It was hypothesized that smokers would have worse self-reported outcomes at 1 and 2 years postoperatively.

Materials and methods

Approval by the institutional review board was obtained before the initiation of the study. This was a retrospective review of prospectively collected data study of 849 consecutive patients who underwent arthroscopic RCR from 2013 to 2016 by a total of 3 surgeons. In all 3 practices, patients are recommended to stop smoking 6 weeks before their RCR. Patients who followed this recommendation to stop smoking were given a cotinine test preoperatively to confirm that they did not have any nicotine in their blood. There is a verbal agreement between the patient and provider that once they have stopped smoking, they will not resume smoking until after their postoperative recovery for a minimum of 3 months during the healing period. An a priori power calculation was not performed owing to the limited number of smokers in our cohort. All patients who presented for rotator cuff surgery during the study period were voluntarily administered a preoperative survey consisting of the following outcome-measuring tools: (i) VAS used to measure overall pain level, (ii) the Veterans Rand 12-Item Health Survey (VR-12), a standard self-reported global health measure tool that is used to assess a patient's overall perspective of their health, (iii) the American Shoulder and Elbow Surgeons Shoulder Score (ASES) used to measure functional limitations and pain of the shoulder, (iv) standard preoperative form consisting of 4 questions regarding their expectations of recovery, (v) Single Assessment Numeric Evaluation shoulder score used to determine a patient self-assessment of their shoulder function, and (vi) Simple Shoulder Test used to assess functional disability of the shoulder based on 12-item score card.

The same outcome measures were reassessed at 3 months, 6 months, 1 year, and 2 years postoperatively. Interim surveys were sent at 2 weeks and 6 weeks assessing VAS pain and pain medication use. Patients without consistent and complete follow-up at all data collection points through the 2-year mark were excluded, leaving a total of 560 patients for long-term analysis. The patients were divided into 2 cohorts based on smoking status at the time of surgery: group I (smokers) n = 25 patients and group II (nonsmokers) n = 535 patients. The reason for the low number of current smokers is a result of the recommendation by the surgeons to stop smoking 6 weeks before surgery.

The scores for all functional assessment metrics were tallied for each cohort at each of the time points of data collection preoperatively and postoperatively. Demographic and clinical characteristics were compared between smokers and nonsmokers using the t-test for continuous variables and Chi-Square test for categorical variables. A linear mixed effects model was used to model the repeated measurements over time and assess differences between smokers and nonsmokers at each time point and in change from baseline to each time point. Models were adjusted for age, sex, and workers' compensation status. Statistical significance was set at $P < .05$.

The convenience sample of 25 smokers and 535 nonsmokers affords >80% power to detect a moderate effect size between groups of approximately 0.58 standard deviations.

Results

There were no significant differences in regard to sex, body mass index, diabetic status, or race/ethnicity between the 2 groups. Male patients made up 72% of the smokers vs. 55% of the nonsmokers. Patients in group 1 (smokers) were younger at treatment (52.9 vs. 57.1; $P = .001$) and had a higher proportion of worker's compensation claims (20.8% vs. 8.8%; $P = .0473$). (Table I) There were no

Table I
Population Characteristics: Smokers vs. Non-Smokers.

Population characteristics	All patients	Smokers	Nonsmokers	*P* value
Average age at treatment	57 (20 to 82)	53 (41 to 71)	58 (2 to 82)	.0098
Average body mass index	27.9 (18.2 to 59.1)	28.1 (24.1 to 38.9)	27.9 (18.2 to 59.1)	.6399
Workman's compensation case				.0473
No	56 (90.7%)	19 (79.2 %)	487 (91.2%)	
Yes	52 (9.3%)	5 (20.8%)	47 (8.8%)	
Missing	2	1	1	
Diabetic				.8638
No	541 (96.6%)	24 (96.0%)	517 (96.6%)	
Yes	19 (3.4%)	1 (4.0%)	18 (3.4%)	
Ethnicity				.6353
Hispanic	18 (3.3%)	0 (0.0%)	18 (3.4%)	
Non-Hispanic Black	12 (2.2%)	1 (4.3%)	11 (2.1%)	
Non-Hispanic White	424 (77.8%)	17 (73.9%)	407 (78.0 %)	
Other	91 (16.7%)	5 (21.7%)	86 (16.5%)	
Missing	15	2	13	

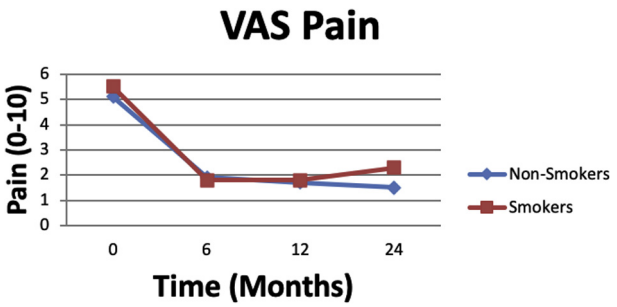

Figure 1 VAS pain scores: smokers vs. nonsmokers. *VAS*, visual analog scale.

differences in symptom duration before surgery ($P = .168$), tear acuity ($P = .573$), or tear size (0.322) between the 2 groups. More than ninety percent of the operations were primary procedures, and there was no significant difference between groups ($P = .751$).

Adjusting for age, sex, and worker's compensation status, there were no significant differences between baseline ($P = .267$), 6-month ($P = .631$), and 1-year ($P = .328$) VAS pain (Fig. 1). There was a significant difference, however, between baseline and 2-year ($P = .039$) VAS pain (Fig. 1). There were no significant differences for VR-12 physical scores (baseline $P = .207$, 6 months $P = .810$, 1 year $P = .364$, and 2 year $P = .102$) (Fig. 2A) between the 2 groups. At 1 and 2 years postoperatively, nonsmokers reported statistically significant differences in VR-12 mental scores compared with smokers (54.95 vs. 50.94, $P = .016$ and 55.07 vs. 48.75, $P = .0004$, respectively) (Fig. 2B). There was no significant difference in ASES shoulder function scores at baseline ($P = .484$), 6 month ($P = .567$), or 1 year ($P = .330$) postoperatively between the 2 groups. However, at the 2-year follow-up, nonsmokers reported statistically significant differences vs. smokers (24.2 vs. 21.6, $P = .021$) (Fig. 3A). Similarly, ASES Shoulder Index scores showed no differences until the 2-year mark, at which time nonsmokers reported higher scores than smokers (87.9 vs. 79.0, $P = .0270$) (Fig. 3B). Single Assessment Numeric Evaluation scores also remained similar up until the 2-year follow-up, after which time nonsmokers reported statistically significant differences vs. smokers (83.35 vs. 75.18, $P = .017$) (Fig. 4). Nonsmokers reported higher Simple Shoulder Test scores than smokers at baseline and at the 2-year follow-up (35.58 vs. 24.43, $P = .0417$ and 75.95 vs. 60.98, $P = .0046$, respectively), but there were no differences between the 2 groups in the interim 6-month ($P = .493$) and 1-year marks ($P = .608$) (Fig. 5).

Both smokers and nonsmokers reported statistically significant improvements from baseline PROMs at 6, 12, and 24 months postoperatively (Fig. 6). At 12 months postoperatively, PROM scores plateaued for smokers. At 24 months postoperatively, PROM scores for smokers showed regression from the year prior. However, there was no significant difference in change from baseline between smokers and nonsmokers at any time point.

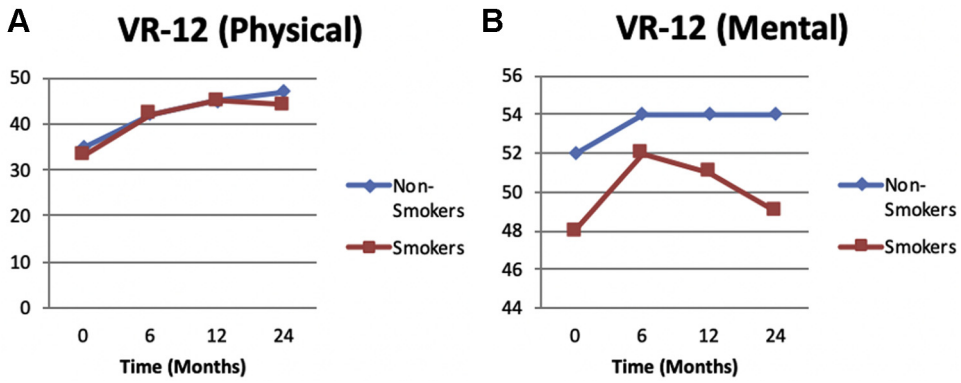

Figure 2 VR-12 outcome scores smokers vs. nonsmokers. (**A**) VR-12 physical scores: smokers vs. nonsmokers, (**B**) VR-12 mental scores: smokers vs. nonsmokers. *VR-12*, Veterans Rand 12-Item Health Survey.

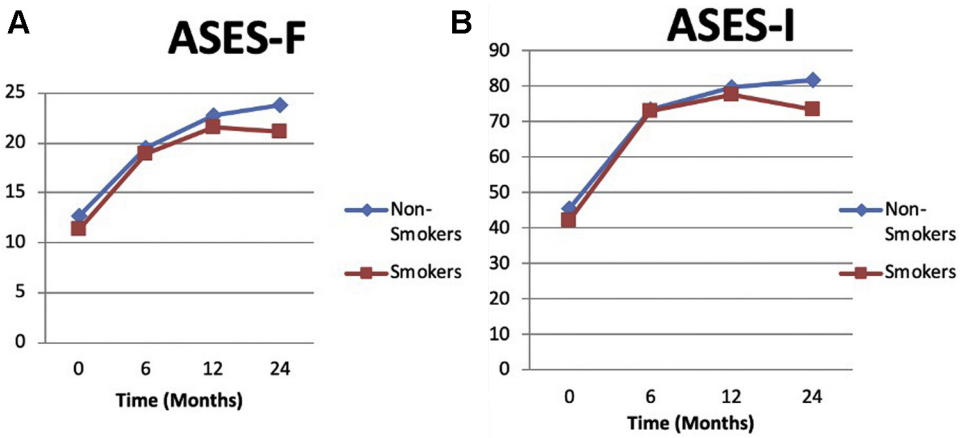

Figure 3 ASES outcome scores smokers vs. non-smokers. (**A**) ASES function scores: smokers vs non-smokers. (**B**) ASES Index Scores: smokers vs non-smokers. *ASES*, American Shoulder and Elbow Surgeons.

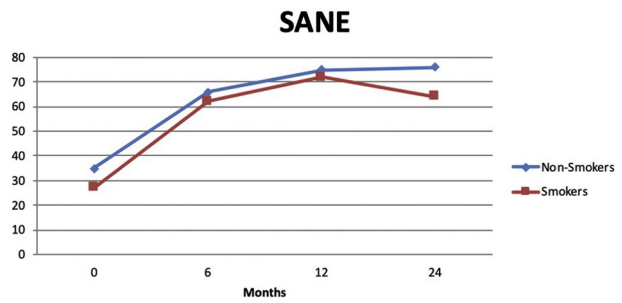

Figure 4 SANE scores: smokers vs non-smokers. *SANE*, Single Assessment Numeric Evaluation.

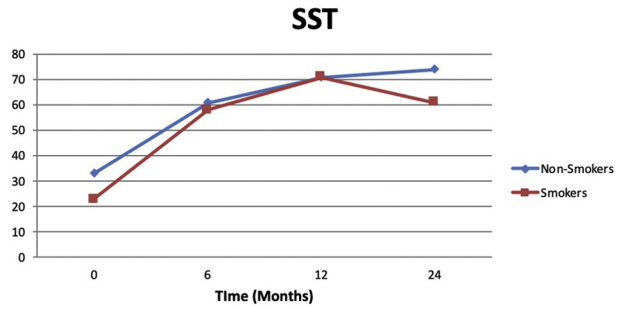

Figure 5 SST scores: smokers vs non-smokers. *SST*, Simple Shoulder Test.

Discussion

The goal of this study was to evaluate the effect of smoking on subjective clinical outcomes. Smokers were, on average, younger at time of surgery and had a higher proportion of worker's compensation claims. A similar trend was noted in the study by Naimark et al[21] in which smokers had RCR surgery at a younger age compared with nonsmokers. This could be rationalized by an earlier-onset avascular insult brought about by nicotine's known vasoconstrictive effects.[3-5,7,12,17,26] While there are no basic science data to back the higher proportion of worker's compensation, there may be a complex psychosocial relationship between substance dependency and work status. Studies in the past decade have already demonstrated a link between self-perceived physical health, mental health, and subsequent functional outcomes.[2,18,25,28,29] Thus, when treating these patients, it is important to recognize that both smoking and psychosocial status play a determining role in their postoperative outcome.

Overall, the results of this present study are reflective of the known objective effects of smoking on rotator cuff healing.[3-7,9,10,12,17,19,20,24,27] Interestingly, there were many trends showing smokers had lower outcome scores vs. nonsmokers at baseline, but only preoperative Simple Shoulder Test demonstrated significant differences. This finding differed from a similar study by Landfair et al[15] in which smokers had significantly less favorable baseline ASES scores and pain scores. However, at 2 years postoperatively, the present study's findings were similar to that of Landfair et al,[15] which reported that smokers had significantly lower PROMs. Similar to a study performed by Mallon et al,[20] the nonsmokers in this study outperformed smokers in all PROMs at 6, 12, and 24 months postoperatively.

Although nonsmokers show significantly improved outcomes, these data do indicate that smokers still receive a subjective clinical benefit from RCR. At nearly all time points, smokers reported statistically significant improvements in PROMs from baseline values despite regression after the 1-year mark. Furthermore, when comparing changes from baseline at each time point between smokers and nonsmokers, there were no statistically significant differences. In other words, despite being less in magnitude, smokers showed a similar trajectory in outcomes to nonsmokers with statistically significant improvements from baseline PROMs at 6, 12, and 24 months postoperatively.

There are several limitations to this study including the 2-year follow-up compliance with complete data at all time points. Of the 849 patients initially enrolled, only 560 (66%) demonstrated complete data at all time points. While our sample size afforded adequate power to detect moderate effect sizes of approximately 0.6 standard deviations, we were underpowered to find smaller differences. Furthermore, there was no postoperative cotinine test administered to patients which does not allow for confirmation that nonsmokers remained nonsmokers for the entire duration of their postoperative recovery period. Despite these limitations, statistical significance was demonstrated for the desired outcomes and follow-up time frames.

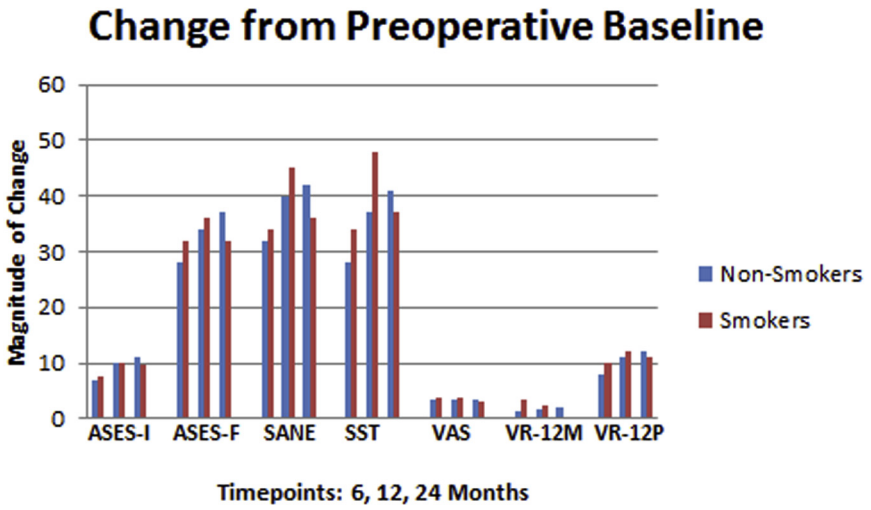

Figure 6 PROMs change from baseline to 6-, 12-,and 24-months postoperatively: smokers vs. non-smokers. *PROMs*, patient-reported outcome measures.

Conclusion

At 2 years postoperatively, nonsmokers had significantly higher PROM scores and showed greater improvement than smokers. In elective surgery, smoking status should be considered as a risk factor for poorer patient-reported outcomes after arthroscopic RCR. However, smokers continue to report a clinical benefit at 2 years postoperatively.

Disclaimers:

Funding: No funding was disclosed by the author(s).
Conflicts of interest: The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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