Predicting Pain Reduction and Functional Improvement Following Joint Arthroplasty Utilizing Radiographic Severity of Osteoarthritis, Step Counts, and Preoperative Patient Factors

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INTRODUCTION:

Joint arthroplasty is a common procedure with favorable outcomes. However, some arthroplasty patients do not achieve pain reduction or functional improvement and would be better candidates for non-operative treatment. This study evaluated how preoperative step counts, radiographic osteoarthritis (OA), patient reported outcomes measures (PROMS), and demographics correlate with functional improvement and pain reduction following arthroplasty.

METHODS:

A prospective cohort study was conducted on 611 preoperative primary hip and knee (unicondylar and total) arthroplasty patients at a single academic medical center from 5/10/19-6/25/21. From 30 days preoperative until 90 days postoperative, daily step counts and pain levels (visual analog scale 0-10) were obtained using a mobile application. PROMIS Global Physical (PGPS) and Mental Scores (PGMS) were obtained preoperatively and at 12 weeks postoperatively. Anteroposterior (AP) (or posteroanterior if no AP) radiographs for all patients were graded on the Kellgren-Lawrence (KL) Classification System. Patients lacking recorded step data were excluded. Step entries were grouped by period into preoperative (30 days to 1 day before surgery), days 0-30, days 31-60 and days 61-90. Since some patients had missing step values, step counts were normalized by dividing patients' total step counts within each period by the number of days in that period that they recorded step values (steps/days-recorded=s/dr). To determine success in pain relief, average preoperative pain scores were subtracted from average pain scores from week 12 postoperatively. T-tests were performed to determine the difference in steps between males and females. A binary logistic regression was utilized to determine which preoperative and demographic factors were associated with pain reduction, accounting for KL grade, preoperative step counts, age, BMI, sex, preoperative pain, preoperative PGPS, preoperative PGMS, insurance type, employment status, tobacco usage, narcotics usage, and comorbidities (heart disease, respiratory condition, hypertension, and diabetes). This regression was also used to create a predictive model for pain relief. Relative effects from independent variables in the logistic regression were reported as odds ratios (OR). Statistical significance was set at $p<0.05$.

RESULTS:

Among the 507 eligible participants with step data, 59.5% were female, and the population had an average age of 63.7 yrs. and BMI of 29.0 kg/m^2 (Table 1). Prior to surgery, males walked an average of 4116.7 s/dr and females walked 2781.3 s/dr ($p<0.0001$). This difference was still significant 61-90 days post-surgery, when males walked on average 4434.1 s/dr and females walked 2893.0 s/dr ($p<0.0001$). For both groups, average step counts fell drastically in the 0-30 day period, but ultimately surpassed preoperative values (Figure 1; $p<0.0001$ for comparisons of males and females in each period).

KL grades 3 (OR:26.61, $p=0.043$) and 4 (OR:34.94, $p=0.036$) were significant predictors of pain relief relative to KL grade 1. Higher preoperative step counts (OR:1.0076, $p=0.041$) and preoperative pain levels (OR:4.41, $p=0.006$) were also significantly associated with higher odds of pain reduction. Finally, relative to commercial insurance, Medicare insurance was associated with lower odds of pain relief (OR:0.02, $p=0.043$). **Utilizing this binary logistic model with a classification cutoff of 0.85 to predict whether a patient's pain would improve with surgery, the model had a sensitivity (correct prediction of improvement) of 89.63% and a specificity (correct prediction of no improvement) of 92.86%. Overall, using preoperative factors, the model correctly classified 89.93% of patients on whether their pain would improve following surgery**.

DISCUSSION AND CONCLUSION:

Arthroplasty outcomes are heavily associated with preoperative factors. Males walked significantly more than females pre- and postoperatively, but both sexes improved on similar trajectories. Since many patients undergo arthroplasty for pain reduction, predicting which patients' pain will improve is critical. Binary logistic analysis indicated multiple significant, readily available preoperative factors which may affect pain reduction. This model accurately predicted postoperative pain relief in this patient population. Patients had higher odds of pain reduction if they had more severe OA (KL grades 3/4), took more preoperative steps, had greater preoperative pain and had commercial insurance. Although step counts are not yet widely available, increasingly ubiquitous smartphones and smart watches produce a great amount of step data that can be valuable, as shown in this study, in improving predictions of postoperative pain reduction in joint arthroplasty.

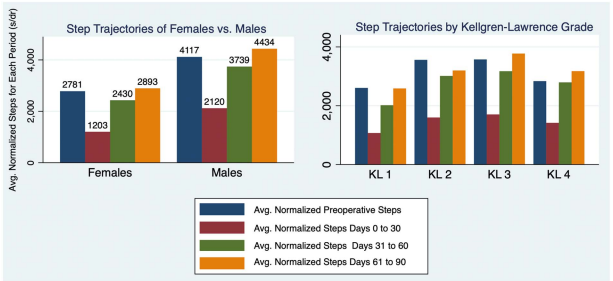

Figure 1: Bars represent average normalized step count (measured in s/dr = steps/day-recorded) for each subgroup in a given time period. T-test comparisons between Male and Female subjects' normalized step counts during each of the four periods yielded p<0.0001. One-way analyses of variance (ANOVA) for normalized steps in each period showed a significant difference by KL grade preoperatively (p= 0.016) but not for the 0-30 day (p= 0.153), 31-60 day (p=0.124), or the 61-90 day (p=0.156) periods.

KL Grade	1 (n= 32)	2 (n= 92)	3 (n= 212)	4 (n= 161)	p-value
Age (years)					
Mean (SD)	**61.72 (11.90)**	**61.54 (12.61)**	**64.42 (9.76)**	**65.17 (10.21)**	**0.04***
BMI (kg/m^2)					
Mean (SD)	**29.77 (5.56)**	**28.33 (4.39)**	**28.60 (5.06)**	**29.83 (5.92)**	**0.07**
Sex %					
Male	**32.26%**	**31.76%**	**43.30%**	**42.25%**	**0.23**
Female	**67.74%**	**68.24%**	**56.70%**	**57.75%**	
Normalized Preop Steps (s/dr)					
Mean (SD)	**2605.44 (1801.07)**	**3557.02 (2550.35)**	**3574.34 (2851.15)**	**2835.91 (2493.76)**	**0.02***

Table 1: KL = Kellgren-Lawrence, BMI = body mass index, s/dr = steps/day-recorded, SD = standard deviation. All p-values were calculated using a one-way ANOVAs with the exception of Sex for which a Pearson chi-squared analysis was performed. * Signifies statistically significant values