High incidence of acute self-reported sleep disturbances in patients following arthroscopic-assisted knee surgery

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ABSTRACT

Objectives To evaluate the self-reported incidence of sleep disturbances, defined as ≤ 7 hours of sleep per 24-hour period, in patients undergoing arthroscopic-assisted knee surgery.

Methods Patients who underwent arthroscopic knee surgery over the course of a 4-month period were prospectively included. Patients were excluded if a history of insomnia or other sleep altering medical history was reported. Self-reported sleep metrics included average number of hours of sleep per night, average number of awakenings during sleep per night, perceived quality of sleep, average pain level during sleep and number of hours of physical activity/therapy per week. Data were collected at weeks 1, 3, and 6 postoperatively. Joint circumference was measured on postoperative day 1 and served as an indicator of a knee effusion. Paired *t*-tests were used to compare preoperative to postoperative hours of sleep. Simple and multiple linear regression were used to evaluate relationships between surgical variables and postoperative sleep metrics.

Results There were 123 patients who underwent arthroscopic knee surgery during the prospective enrolment period; 83 patients were included in the final analysis. The overall incidence of preoperative sleep disturbances was 20% ($n=17$). The overall incidence of self-reported postoperative sleep disturbances was 99%, 96% and 90% at weeks 1, 3 and 6, respectively. The average number of hours slept was significantly reduced at 1, 3 and 6 weeks postoperatively compared with the preinjury state ($p<0.001$). Knee joint circumference had a significantly negative correlation with average number of hours of sleep in the first 6 weeks postoperatively ($R=-0.704$; $p=0.001$). Surgical variables including severity of surgery, weekly postoperative pain level and weekly hours of postoperative physical therapy were not significant independent predictors of acute postoperative sleep disturbances ($p>0.05$).

Conclusion Sleep disturbances were commonly reported in patients following arthroscopic knee surgery without correction of sleep metrics by 6 weeks postoperatively. The majority of sleep disturbances in this cohort correlated with an increased knee effusion. A multidisciplinary team approach is recommended to counsel patients regarding the potential for and problems with acute sleep disturbances following arthroscopic knee surgery.

Level of evidence: 3.

What are the new findings

- ▶ High incidence ($>90\%$) of acute self-reported sleep disturbances (8.0 hours compared with 5.9 hours, preoperative to postoperative, respectively) following arthroscopic knee surgery.
- ▶ Increased knee effusion was significantly correlated with postoperative sleep disturbances.
- ▶ Severity of surgery, pain level and hours of physical therapy were not significantly correlated with postoperative sleep disturbances.
- ▶ Most commonly reported causes of postoperative sleep disturbances following knee surgery were increased knee temperature/warmth from knee effusion (96%), wearing a brace to sleep (90%) and not sleeping in normal body position compared with presurgery (87%).

INTRODUCTION

Sleep disturbances are commonly reported following musculoskeletal injury/surgery and neurocognitive impairments (eg, concussions). Pain at night and sleep disturbances are often associated with joint osteoarthritis and shoulder pathology such as rotator cuff tears, and previous studies have demonstrated a corrective effect of sleep with recovery after a rotator cuff repair.^{1–3} Substantial evidence suggests that sufficient quantity and quality of sleep are necessary for maintaining normal bodily function, including restoration of damaged tissues and flushing toxins from the brain, while inadequate sleep can have serious long-term health consequences.^{4–8}

Not having sufficient sleep has been reported as a public health risk contributing to obesity, cardiovascular disease and mental health disorders.^{9–11} Research has shown that individuals who report short sleep durations (ie, ≤ 7 hours per night) have a 10%–30% increased risk of developing cardiovascular disease.^{9–12} Insufficient sleep may also trigger the release of various proteins that cause systemic inflammation and cause dysregulation of the immune system.^{13–14} These increased inflammatory markers may adversely prolong recovery following orthopaedic-related surgery and/or musculoskeletal injury.^{13–15}

Previous data have shown that sleep disturbances are reported in patients following hip and knee

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joint arthroplasty.^{16 17} A recent study has reported a dramatic increase in sleep disorders of 111% following hip arthroscopy.¹⁸ However, there are limited studies investigating the incidence of sleep disturbances following arthroscopic knee surgery such as anterior cruciate ligament (ACL) reconstruction. Therefore, the purpose of this study was to evaluate the self-reported incidence of sleep disturbances, defined as ≤ 7 hours of sleep per 24-hour period, in patients undergoing arthroscopic-assisted knee surgery. The hypothesis was that patients would report significantly decreased hours of sleep from preoperative to postoperative states.

METHODS

This study was approved following review from an institutional review board (*institution and protocol number blinded for review*). All patients who underwent arthroscopic knee surgery by a single board-certified orthopaedic surgeon (*initials blinded for review*) from September 2019 to December 2019 were prospectively enrolled. Demographics and surgical procedural data were collected on all patients including age, sex, body mass index (BMI), chronicity, time from injury to surgery, previous history of knee surgery, medical history (including osteoarthritis), social habits (smoking, tobacco and alcohol use), current medications, surgical procedure, tourniquet time and postoperative weight bearing status. All patients had general anaesthesia and prescription of the same narcotic (Oxycodone, 5 mg #40 quantity, as needed; patients were also provided a self-disposal narcotic neutralisation bag) for postoperative analgesia. All patients started physical therapy on postoperative day 1. During the first postoperative physical therapy session, knee circumference was measured at the level of the joint line in all patients and a side-to-side difference was recorded. This served as an objective baseline indicator of knee joint effusion.

Based on the extent of the surgical procedure, patients were divided *posthoc* into three groups for subanalysis: 'mild', 'moderate' and 'severe' knee surgery (table 1). This grouping was developed according to size of approach, anticipated postoperative pain and weight bearing status following the procedure. The rationale for this subdivision was to attempt to control for postoperative pain and disability associated with different surgical procedures (eg, meniscectomy vs ACL reconstruction) which may affect postoperative sleep metrics. Patients were excluded if they reported a current or prior history of insomnia or other sleep altering medical history (antidepressant medication, sleep apnoea), were less than 18 years of age, had a current history of osteoarthritis or underwent predominantly open knee surgical procedures (fracture open reduction internal fixation, tibial/femoral osteotomy, osteoarticular allograft transplant, meniscal allograft transplant, multiligament knee reconstruction). Complications that occurred in the first 6 weeks postoperatively were recorded.

Sleep metrics

Self-reported sleep metrics were collected from all included patients during the first 6 weeks following surgery. Preoperatively, patients were questioned regarding their baseline sleeping metrics, including the average number of hours of sleep per night and average number of awakenings during sleep per night. Patients were asked to keep a sleep diary of their sleeping habits and specific metrics during their postoperative recovery. Self-reported sleep metrics included the average number of hours of sleep per night, average number of awakenings during sleep per night because of their knee, perceived quality of sleep, average knee pain level at night during sleep and number of hours of physical therapy per week. In addition, data were collected on postoperative sleeping habits including the use of a knee brace, ice or ice machine, pillow underneath knee and body position (traditionally/preoperatively and during postoperative state). In conjunction with these sleep metrics, patients were surveyed to report their perceived causes of sleep disturbances and also their self-reported remedies that improved their perceived sleep disturbances. Surveys were completed at three different time-points: weeks 1, 3 and 6 postoperatively. Missing data were reconciled via email of survey correspondents. Sleeping was classified as either 'disturbed': sleeping ≤ 7 hours per 24-hour period or 'non-disturbed': sleeping > 7 hours per 24-hour period.¹²

Statistical analysis

To assess for normal distribution, histograms of outcome variables were generated prior to statistical analysis which demonstrated symmetrical bell curve distribution of sample data. Additionally, descriptive statistics determined no substantial skewness (0.2–0.7) of mean values for outcome variables. To address the primary hypothesis, paired-sample *t* tests were performed to compare hours of sleep from preinjury to postoperatively at weeks 1, 3 and 6. Ordinary least squares regression was used to test the association between the presence of a postoperative knee effusion and number of hours of sleep per week in the acute phase (< 6 weeks) following knee arthroscopy. Multiple linear regression modelling was performed to estimate the unadjusted and adjusted effect of postoperative knee effusion on predicting sleep metrics. In the multiple linear regression model, age, sex, BMI, surgery severity, tourniquet time, injury chronicity, postoperative weight bearing status, postoperative pain level, hours of physical therapy per week and previous history of knee surgery were entered as possible confounders. A sample size calculation was made to determine the required sample size necessary to detect a Pearson correlation magnitude of 0.3, which is conventionally considered a "medium" strength correlation. Based on the assumption of 2-tailed testing and an alpha level of 0.05, 82 patients were sufficient to detect an effect size of $|r| = 0.3$ with 80% statistical power. Residual diagnostics were performed to

Table 1 Severity of knee surgical procedures for subgroup analysis

Severity of surgery	Sample size (%)	Weight bearing status	Knee surgical procedures
Mild	19 (23%)	WBAT	Meniscectomy, chondroplasty, loose body removal
Moderate	41 (49%)	WBAT	ACLR (with or without meniscal repair), bone grafting of previous ligament reconstruction tunnels
		NWB	Isolated meniscus repair, ACLR with meniscal radial or root repair
Severe	23 (28%)	NWB	Ligament repair (eg, MPFL, MCL), tendon repair (eg, quadriceps/patellar), isolated PCL reconstruction

ACLR, anterior cruciate ligament reconstruction; MCL, medial collateral ligament; MPFL, medial patellofemoral ligament; NWB, non-weight bearing; PCL, posterior cruciate ligament; WBAT, weight bearing as tolerated.

Figure 1 Flow chart of prospective enrolment of consecutive patients who underwent arthroscopic knee surgery during study period.

assess whether model assumptions were satisfactorily met. For the subanalysis on severity of surgery classification, a composite score was calculated to determine the overall mean number of hours of sleep postoperatively. A one-way analysis of variance was performed on mean number of hours of sleep postoperatively according to severity of surgical procedures ('mild', 'moderate', 'severe'). All data were analysed using SPSS V.25 (Chicago, Illinois, USA).

RESULTS

During the open enrolment period, 123 consecutive patients underwent arthroscopic knee surgery. Twenty-three patients were excluded at time of enrolment and 17 patients were lost to follow-up (83% retention rate) during the 6-week data collection period; 83 patients (38 male, 45 female) were included in the final analysis (figure 1). The average age was 41.0 ± 14.4 years (range, 18–66 years). Fifty-five patients had chronic injuries (>12 weeks from time of injury to surgery) and 28 patients had acute injuries (≤ 12 weeks). The average overall tourniquet time was 40.6 ± 28.0 min (range, 7–120 min) and 55 patients were non-weight bearing in the first 6 weeks following surgery while the remaining 28 were permitted to weight bear as tolerated. The average time to discontinuation of pain medicine was 8.0 ± 2.2 days (range, 1–17 days). There were no reported surgical complications in the first 6 weeks postoperatively; however, one patient (1.2%) developed and was treated for atelectasis with mobilisation and incentive spirometry during the early postoperative period and resolved without sequelae. Patient demographics and clinical characteristics are presented in table 2.

The average self-reported number of hours of sleep per night preoperatively was 8.0 ± 0.9 hours (range, 5–10), with 20% (n=17) of patients reporting ≤ 7 hours of regular sleep preoperatively. The incidence of self-reported sleep disturbances was

Table 2 Demographics and clinical characteristics for all included patients (n=83)

Demographic/clinical characteristic	Value
Age (years)*	41.0 ± 14.4
Sex	
Male	38/46%
Female	45/54%
Body mass index (kg/m^2)*	26.6 ± 5.8
Tourniquet time (min)*	40.6 ± 28.0
Previous history of knee surgery	43/52%
Current tobacco smoker	1/1%
Current alcohol user	36/43%
Postoperative complications (within first 6 weeks)	1/1%
Knee joint effusion, postoperative day 1 (cm)*	3.2 ± 1.9

Values reported as n/%.

*Data reported as mean $\pm$ SD.

99%, 96% and 90% at postoperative weeks 1, 3 and 6, respectively. There were significant reductions in the average number of self-reported hours of sleep from preinjury to postoperative (5.6 ± 1.3 , 6.0 ± 1.3 and 6.2 ± 1.2 hours for postoperative weeks 1, 3 and 6, respectively; $p < 0.001$). There was a significant negative correlation between knee joint circumference and the number of hours of sleep postoperatively ($R = -0.704$; $p = 0.001$) (figure 2). There were no significant correlations identified between postoperative sleep and postoperative nighttime pain ($R = -0.121$; $p = 0.276$) or hours of physical therapy ($R = -0.024$; $p = 0.829$). No significant differences were found between severity of surgical procedures and mean number of hours of sleep postoperatively (6.3 ± 0.6 , 5.8 ± 0.9 and 5.9 ± 1.1 hours for 'mild', 'moderate' and 'severe' surgical procedures, respectively; $p = 0.147$). Multivariable regression analysis revealed that other surgical variables were not significant independent predictors of postoperative sleep (table 3). Descriptive data of postoperative sleep metrics are reported in table 4.

The most common patient-reported causes of sleep disturbances were: knee 'warmth' (n=80, 96%) at night, wearing a knee brace to sleep (n=75, 90%) and not sleeping in a normal body position compared with presurgery (n=72, 87%). The most common patient-reported therapeutic factors for improving

Figure 2 Scatterplot of unadjusted linear regression relationship between postoperative knee effusion and postoperative sleep duration. There was a significant negative correlation between the postoperative day 1 knee joint circumference and average number of hours of sleep per week during the acute phase (6 weeks) following arthroscopic knee surgery ($R = -0.704$; $p = 0.001$).

Table 3 Multivariable linear regression model for surgical variables and postoperative hours of sleep

	Beta*	95% CI	SE	t value	P value†
(Intercept)	7.579	6.404 to 8.754	0.590	12.85	0.001
Knee effusion	−0.373	−0.467 to −0.280	0.047	−7.96	0.001
Age	−0.004	−0.017 to 0.008	0.006	−0.66	0.509
Sex	−0.213	−0.549 to 0.124	0.169	−1.26	0.212
Body mass index	0.010	−0.018 to 0.038	0.014	0.72	0.474
Chronicity of injury	−0.050	−0.438 to 0.338	0.195	−0.25	0.798
Severity of surgery	−0.261	−0.660 to 0.139	0.201	−1.30	0.198
Tourniquet time	−0.003	−0.011 to 0.005	0.004	−0.82	0.412
Weight bearing status	−0.061	−0.569 to 0.447	0.255	−0.24	0.811
Previous history of knee surgery	0.299	−0.084 to 0.683	0.192	1.55	0.124

Statistically significant variables are provided in bold.

*Beta values are the expected change in sleep given a 1-unit decrease in that covariate, holding all other variables constant.

†Statistical significance considered $p < 0.05$.

postoperative sleep metrics were: placing a pillow underneath the knee during sleep ($n=82$, 99%), removal of knee brace during sleep ($n=79$, 95%) and performing ice, compression and elevation (ICE) during sleep ($n=69$, 83%).

DISCUSSION

The main finding of this study was that patients reported acute sleep disturbances following arthroscopic knee surgery without correction of baseline sleep patterns by 6 weeks postoperatively. A significant negative correlation was identified between the

postoperative sleep hours and a postoperative knee effusion. Additionally, pain level and hours of physical therapy were not significantly associated with sleep metrics per patient-reported data. The primary self-reported causes of acute sleep disturbances were knee 'warmth' (swelling), wearing a knee brace and not sleeping in a normal body position. The most frequent self-reported therapeutic factors for improving sleep were placing a pillow underneath the knee, removal of knee brace and using the ICE principal (ice, compression, elevation).

The overall incidence of self-reported preoperative sleep disturbances (≤ 7 hours) was 20% which increased to 99%, 96% and 90% at postoperative weeks 1, 3 and 6, respectively, following arthroscopic knee surgery. The average number of hours slept was significantly reduced at 1, 3 and 6 weeks postoperatively compared with the preoperative state. Previous studies report similar sleep metrics following knee and hip arthroplasty, with corrections of sleep to preoperative baseline at 10 months postoperatively.^{16 17} Additionally, a recent study reported a 111% increase in sleep disorders following hip arthroscopy.¹⁸ In contrast, Hudson *et al*¹⁹ reported that ambulatory surgery and anaesthesia had minimal effect on sleep parameters 1–3 days after orthopaedic surgery. However, their study purpose was to measure changes in perioperative sleep parameters, specifically evaluating presence of sleep apnoea; thus, these results are not directly comparable to the present study. Also, in the current study, nighttime pain was not associated with any sleep metrics in the first 6 weeks following arthroscopic knee surgery. This finding was supported by a randomised controlled trial that failed to improve postoperative sleep following lower extremity surgery with the use of prescription medication (Gabapentin) for pain control.²⁰ Considering the high incidence of acute sleep disturbances demonstrated in this study of consecutive adult patients undergoing arthroscopic knee surgery, it is recommended that further research should focus on developing sleep intervention therapy for this specific patient-population.^{15 21–24}

Table 4 Sleep metrics following knee surgery reported at preoperative and postoperative time points

Sleep-related metric	Preoperative value	Week 1 value	Week 3 value	Week 6 value
Nightly sleep duration (hours)*	8.0±0.9	5.6±1.3	6.0±1.3	6.2±1.2
Nightly awakenings				
0	66/80%	0/0%	0/0%	4/5%
1	7/8%	14/17%	27/33%	39/47%
2	7/8%	11/13%	16/19%	14/17%
3	2/2%	16/19%	10/12%	11/13%
4+	1/1%	42/51%	30/36%	15/18%
Sleep quality				
1=very poor		17/20%	12/14%	6/7%
2=poor		34/41%	27/33%	14/17%
3=average		21/25%	24/29%	28/34%
4=good		10/12%	16/19%	27/33%
5=excellent	NR	1/1%	4/5%	8/10%
Nighttime pain level				
0=none		14/17%	33/40%	54/65%
1=mild		49/59%	41/49%	26/31%
2=moderate		18/22%	9/11%	3/4%
3=severe	NR	2/22%	0/0%	0/0%
Weekly hours of physical therapy*	NR	9.0±6.2	8.5±5.2	9.2±5.0
Sleep disturbance	17/20%	82/99%	81/96%	75/90%

Values reported as n/%.

*Data reported as mean±SD.

NR, not reported.

A significant negative correlation was identified between postoperative sleep hours and a postoperative knee effusion, as patients with increased knee swelling had decreased self-reported hours of sleep per night. This was also supported by our finding of self-reported knee 'warmth' as a contributing factor that negatively affected sleep. A potential theory to describe why patients report sleep disturbances following orthopaedic surgery relates to an increase in joint inflammation. C reactive protein, interleukin 6 and tumour necrosis factor are three commonly measured inflammatory markers that are increased in patients with sleep disorders.^{14 25 26} Similarly, studies have reported increased levels of the same inflammatory markers following orthopaedic surgery and high elevations of these markers may negatively impact musculoskeletal healing.^{13 27} Thus, in theory, the larger the healing response associated with the surgery and recovery, the greater the potential sleep disturbance. However, additional research is needed to further evaluate the role of sleep disturbances on the impact of elevated inflammatory markers and musculoskeletal tissue healing.

There was no significant correlation found between postoperative sleep and number of hours performing postoperative physical therapy. There are many environmental and behavioural factors that may influence sleep, including screen time (eg, TV, phone, computer), psychological stress and anxiety and caffeine use—all of which were not controlled for in the current study.^{28–30} However, the current study attempted to account for physical inactivity which is also a commonly reported influential factor affecting number of hours of sleep per night.⁷ Previous studies have demonstrated that the quantity of sleep the quality of sleep are important, a combined term referred to in the sleep literature as 'sleeping efficiency'.³¹ Future studies ought to examine sleeping efficiency and evaluate potential associations with physical activity levels in patients following orthopaedic knee surgery.²³

In 2021, a reported 6.6 million individuals will undergo orthopaedic surgery in the USA alone.³² Considering the current 90% incidence of self-reported sleep disturbances in the current study, there is a potential for 5.9 million people per year to experience negative sleep metrics as a result of orthopaedic surgery in the USA alone. Although this scenario is hypothetical, it can offer encouragement to scientists, clinicians as well as members of industry to increase research efforts in reducing postoperative sleep disturbances following orthopaedic-related surgery. Results from the current study suggest improving strategies focused on reducing knee swelling, including preoperative and intraoperative care, as well as postoperative management.

Although there is limited clinical evidence to indicate that sleep disturbances affect overall recovery or functional impairment following orthopaedic surgery, insufficient sleep is a major reported health concern with associations to obesity, diabetes, cardiovascular disease and mental health.^{4 10 11 33–35} Because of these detrimental consequences, allied healthcare professionals involved in the care of orthopaedic surgical patients should take the initiative to improve this metric in healthcare systems. Based on the available evidence and results of the current study, a multidisciplinary team approach is recommended to help educate and counsel patients regarding the potential for acute sleep disturbances following arthroscopic knee surgery (such as ACL reconstruction). The team member at the centre of this team approach is the orthopaedic surgeon. Perioperative team members include nurses, physician assistants and anaesthesiologists, while postoperative team members include physical therapists, athletic trainers and sport psychologists.

This study is not without limitations. First, due to the nature of studying uncontrolled sleep settings, there was an inability to control for potential confounding variables that may have also

affected sleep such as environmental and behavioural factors. Second, data are indicated based on patient-reported sleep metrics which are subjective and lack clinical validation. Future studies should consider implementing wearable technology devices (eg, smart watch, actigraphy) for a more accurate and objective assessment of sleep quantity and quality postoperatively.³⁶ Third, daytime sleeping/napping was unable to be controlled for which may have influence over nighttime sleep data. Finally, long-term sleep corrections or associations of sleep disturbances with surgical outcomes were not able to be assessed due to the study design. Future studies should examine the long-term consequences of sleep disturbances following arthroscopic surgery and evaluate therapeutic agents that may improve sleeping metrics.

CONCLUSION

Sleep disturbances were commonly reported in patients following arthroscopic knee surgery without correction of sleep metrics by 6 weeks postoperatively. The majority of sleep disturbances in this cohort correlated with an increased knee effusion. A multi-disciplinary team approach is recommended to counsel patients regarding the potential for and problems with acute sleep disturbances following arthroscopic knee surgery.

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Contributors NND: primary writing contribution, data collection, data analysis, idea generation, formatting, patient consent. RD: primary writing contribution, data collection, idea generation. LE: significant writing contribution, data collector, data analysis. CML: significant writing contribution, data collector, data analysis. JM: writing contribution, data collector, data analysis. RL: critical edits, manuscript writing and idea generation.

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