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ORIGINAL PAPER

Temporal changes in sleep quality and knee function following primary total knee arthroplasty: a prospective study

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Abstract

Purpose Several patient-reported outcome measures (PROMs) have been used to assess improvement in the quality of life following total knee arthroplasty (TKA). However, there is paucity of studies evaluating the sleep quality and knee function following TKA. The primary aim of our study was to evaluate the sleep quality and knee function in primary TKA patients using the Pittsburgh Sleep Quality Index (PSQI) and Knee Society Score (KSS), respectively. The secondary aim was to assess the correlation between the two outcome measures over the course of first post-operative year following TKA.

Methods One hundred sixty-eight patients (female-140/male-28) with mean age of 64.63 years (± 7.50) who underwent 168 primary unilateral TKA using a cemented posterior-stabilised implant without patella resurfacing between June 2018 and October 2018 were included in the study. Global PSQI and KSS were recorded pre-operatively and post-operatively weekly up to six weeks and at one year. Body mass index (BMI) and Charlson comorbidity index (CCI) were recorded during pre-operative assessment.

Results Mean(± SD) BMI and CCI were 28.45(± 4.64) and 2.48(± 0.93), respectively. Pre-operative global PSQI of 1.98(± 0.97) increased to 13.48(± 3.36) in the first post-operative week ($p < 0.001$) and remained high during all the six weeks following TKA ($p < 0.001$), whereas at the first post-operative year, it reduced to 2.10(± 1.15) ($p = 0.15$). Pre-operative KSS of 52.00(± 9.98) increased to 71.67(± 6.58) and 85.49(± 4.67) at 6 weeks and the first post-operative year respectively ($p < 0.001$). Pre-operative global PSQI had moderate correlation with pre-operative KSS ($r = 0.39$) ($p < 0.001$). Strong correlation was noted between pre-operative global PSQI and six week post-operative KSS ($r = 0.47$) ($p < 0.001$). Low correlation was noted between pre-operative global PSQI and KSS at the first post-operative year ($r = 0.10$, $p = 0.19$) following TKA. Multiple regression analysis revealed age, CCI, and pre-operative range of motion as independent predictors of global PSQI.

Conclusions Patients undergoing TKA experience changes in sleep quality but report an overall improvement in knee function during the first post-operative year. Sleep quality has moderate to strong correlation with knee function in the early post-operative period beyond which there is a low correlation with knee function thereby suggesting a transient phenomenon. Hence patients undergoing TKA can be appropriately counselled regarding the variation in sleep quality in the post-operative period and reassured accordingly.

Keywords Knee · Arthroplasty · Sleep · Function · Outcomes

Introduction

Total knee arthroplasty (TKA) is an elective orthopaedic procedure with good outcomes that is performed routinely across the world [1–4]. Several preoperative factors have been described in the literature that influence the peri-operative and post-operative outcomes following TKA [5–7]. Pre-operative parameters including age [8], gender [9], body mass index (BMI) [10], comorbidities [11], extent of knee joint deformity [12], and range of motion (ROM) [13]

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amongst others may potentially influence the early and late outcomes following TKA.

Sleep is a vital physiological event that has a restorative function for maintaining normal body physiology [14]. Sleep pattern and duration are often influenced by various external factors including surgical procedures [14, 15]. Surgical stress, sedatives, and post-operative pain are the main factors that may influence the post-operative sleep [16]. The post-surgery stress response involving endocrine-metabolic system and an inflammatory response may last for a few days or even weeks [17]. Furthermore, the magnitude of the surgical procedure is associated with the severity of sleep disturbances [18]. This directly affects the early rehabilitation or recovery of patients. Sleep and pain interact bi-directionally: pain disturbs the sleep architecture, and sleep deprivation has a hyperalgesic effect[19].

It has been suggested that along with pain, sleep disturbance is commonly reported by patients following TKA [20]. Sleep disturbance associated with TKA has been investigated by some authors [20–23]. Additionally, sleep disturbance may impact pain and potentially the functional outcomes following TKA [24]. This understanding has prompted several interventional strategies including self-guided meditation [24] and medications like gabapentin [25], zolpidem [26], and melatonin [27] with variable results. Patient satisfaction and perception of success following TKA have been demonstrated to be strongly associated with patient factors and complications than surgical or anaesthetic factors [28]. Furthermore, there is paucity of information in the current literature on the temporal changes in sleep disturbance and knee function following TKA.

The primary objective of our study was to evaluate the sleep quality and knee function in patients undergoing primary TKA using the Pittsburgh Sleep Quality Index (PSQI) and Knee Society Score (KSS), respectively. The secondary objective was to study the correlation between the two aforementioned outcome measures over the course of first post-operative year following TKA. We hypothesised (null hypothesis) that sleep quality has no effect on knee function following primary TKA during the first post-operative year.

Materials and methods

Study design and participants

A prospective cohort study on 175 primary TKA patients was conducted from June 2018 to October 2018. Inclusion criteria for this study were (i) elective primary unilateral TKA and (ii) patient consent to participate in the study and complete relevant outcome surveys. We excluded (i) revision TKA, (ii) complex primary TKA where pre-operative imaging demonstrated bone loss or the need for adjunctive implants or augments or adjunctive soft tissue procedures, (iii) unicondylar arthroplasty, (iv) patients with documented history of sleep disorders or those on medications for insomnia (benzodiazepines and antidepressants) or high dose opiates, (v) patients with conditions which could impact adherence to study protocol (psychiatric disorders/history of alcohol abuse), and (vi) previous surgical procedures on the knee (osteotomy/ligament reconstruction).

Sleep has been noted to be a complex physiological function with interplay of several factors over a period of time [14, 15]. Hence the above exclusion criteria were followed to minimise the potential sources of confounding and interaction emanating from patient factors.

Institutional review board approval was obtained, and all patients signed a written consent before participating in the study. All patients attended pre-operative assessment during which routine parameters including demographic details, body mass index (BMI), and Charlson comorbidity index (CCI) were recorded in the prospective arthroplasty database of the institution.

Surgical procedure and rehabilitation

All patients underwent TKA under spinal anaesthesia using routine midline incision and medial parapatellar approach performed by the senior author. All patients received infiltration of local anaesthetic between the popliteal artery and capsule of the knee (IPACK) [29]. During TKA a posterior-stabilised femoral component and tibial baseplate were implanted using cement without patella resurfacing. Wound closure and application of non-adherent wound dressing and circumferential bandage were performed in routine manner.

Post-operative monitoring and wound care

Post-operative pain relief included intravenous paracetamol 1 g six hourly, injection tramadol 50 mg eight hourly if required, and injection diclofenac 75 mg twice daily if required. Routine post-operative assessment included monitoring of vital parameters to detect early signs of thromboembolic events such as deep vein thrombosis or pulmonary embolism. Bowel and bladder function were monitored regularly during inpatient stay by the orthopaedic team. Regular wound review during inpatient hospital stay and outpatient visits of the patients was performed by the orthopaedic team. Monitoring of the wound in patient's home was undertaken by the rehab team as part of the routine clinical care offered by the hospital. This enabled early detection of wound complications and surgical site infections.

Rehabilitation and radiographic assessment

All patients received routine post-operative rehabilitation including full weight bearing mobilisation with supervised physiotherapy. Post-operative radiographs of the knee were performed at six weeks and one year post-operative time points on an outpatient basis. Subsequently, these were reviewed by the orthopaedic team as routine clinical activity to ensure satisfactory alignment and interfaces of cemented TKA components.

Patient-reported outcome measures

Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) [30] is a self-rated questionnaire that measures several different aspects of sleep, offering seven component scores and one composite score. The global PSQI score ranging from 0 to 21 is generated by summing up all the seven component scores, where 0 indicates no difficulty and 21 is severe difficulty in all areas. A global cut-off score of PSQI greater than 5 is used to distinguish poor sleepers from good sleepers [30].

Knee Society Score

The Knee Society Score (KSS) [31] contains questions in two sections: knee joint (pain, range of motion, stability) and function (walking distance, ability to climb stairs). When calculating the score, deductions are taken for assistive devices and flexion contractures, misalignment, or extension lag. KSS has been widely used in the orthopaedic literature with the outcome being rated as excellent (80–100 points), good (70–79 points), fair (60–69 points), and poor (less than 60 points).

PSQI score and KSS were recorded one week pre-operatively, weekly up to the sixth post-operative week, and at one year mark following the TKA procedure. We evaluated the following primary outcome measures, (i) global PSQI at six weeks and one year following TKA and (ii) KSS at six weeks and one year following TKA, and the secondary outcome measures, (i) correlation of global PSQI and KSS during first post-operative year, (ii) clinical parameters of patients having global PSQI > 5 and < 5 at sixth post-operative week, and (iii) correlation of routine clinical factors with global PSQI at sixth post-operative week.

Statistical analysis

Statistical analysis was performed using SPSS, version 20, software (IBM, Armonk, NY). Descriptive statistics are presented as means and standard deviations for continuous variables such as mean patient-reported scores and counts and percentages for categorical variables. Means were compared between groups with independent *t*-tests for continuous variables, and categorical variables were compared using chi-square test. The Pearson correlation was performed to assess the relationship between global PSQI and the KSS. Correlation results were interpreted as no or very weak (-0.1 to 0.1), weak (-0.3 to -0.1 or 0.1 to 0.3), moderate (-0.5 to -0.3 or 0.3 to 0.5), and strong (-1.0 to -0.5 or 1.0 to 0.5) [32]. Multiple regression analysis was performed to assess the relationship between global PSQI (dependent variable) at the sixth post-operative week and routine clinical parameters (independent variables) such as age, gender, BMI, CCI, ROM (flexion), and knee deformity in sagittal and coronal plane. Statistical significance was set at $p < 0.05$.

Based on previous studies of global PSQI [30, 33] and KSS, an a priori power analysis revealed that a sample size of 32 and 26 respectively would be needed to achieve a power of 80% and a level of significance of 5%.

Results

Patient characteristics

Of the 175 patients recruited into the study, three patients were lost to follow-up between six weeks and one year post-operative period. Two patients withdrew from the study, and two patients had incomplete data. All these seven patients were excluded from the study analysis.

Hence, 168 patients (female-140/male-28) with a mean age of 64.63 years (± 7.50) who underwent 168 primary TKA between June 2018 and October 2018 were included in the analysis. Patient demographics and details of other clinical variables are presented in Table 1.

Post-operative complications and radiographs

There was no incidence of bowel or bladder dysfunction in the study patients. There were no patients with thromboembolic events or surgical site infections. All the patients in the study had satisfactory alignment and interfaces of cemented TKA components on review by three authors of the study as part of routine clinical activity.

Temporal changes: global PSQI

Mean($\pm$ SD) pre-operative global PSQI score of 1.98(± 0.97) increased to 13.48(± 3.36) in the first post-operative week ($p < 0.001$), and high global PSQI scores were noted during all the six weeks following TKA ($p < 0.001$), whereas at the first post-operative year, global PSQI score reduced to 2.10(± 1.15) ($p = 0.15$) (Fig. 1).

Table 1 Distribution of demographic and pre-operative parameters of the TKA patients

Parameter	Number of patients (n = 168)		
	n	%	Mean ± SD
Age (years)			64.63 ± 7.50
Gender			
- Male	28	23.80	
- Female	140	76.19	
Body mass index (kg/m^2)			26.44 ± 2.68
Charlson comorbidity index (CCI)			
- 0	1	0.93	2.48 ± 0.93
- 1	20	11.90	
- 2	70	41.66	
- 3	54	32.14	
- 4	20	11.90	
- 5	3	1.78	
Range of motion (ROM) in degrees			97.47 ± 16.11
Knee deformity (degrees)			
- Coronal plane[†]			− 10.77 ± 5.97
- Sagittal plane			3.30 ± 5.32
Laterality			
- Right	80	47.62	
- Left	88	52.38	

[†]Minus indicates varus alignment

Temporal changes: KSS

Mean(± SD) pre-operative KSS of 52.00(± 9.98) increased to 71.67(± 6.58) and 85.49(± 4.67) at the sixth week and the first post-operative year respectively ($p < 0.001$) (Fig. 2).

Correlation of global PSQI and KSS

Pre-operative global PSQI score had moderate correlation pre-operative KSS of patients ($r = 0.39$) ($p < 0.001$). Strong correlation was noted between the pre-operative global PSQI score and the six week post-operative KSS ($r = 0.47$) ($p < 0.001$). However, low correlation was noted between preoperative global PSQI score and KSS at the first post-operative year ($r = 0.10$, $p = 0.19$) following TKA. Similar correlation findings were noted between the post-operative global PSQI score at six weeks and post-operative KSS at the six weeks and at one year following TKA (Table 2).

Comparison of patients reporting good and poor sleep quality at sixth post-operative week

At the sixth post-operative week, 144 TKA patients and 24 TKA patients reported a global PSQI score of below 5 (good sleep quality) and above 5 (poor sleep quality),

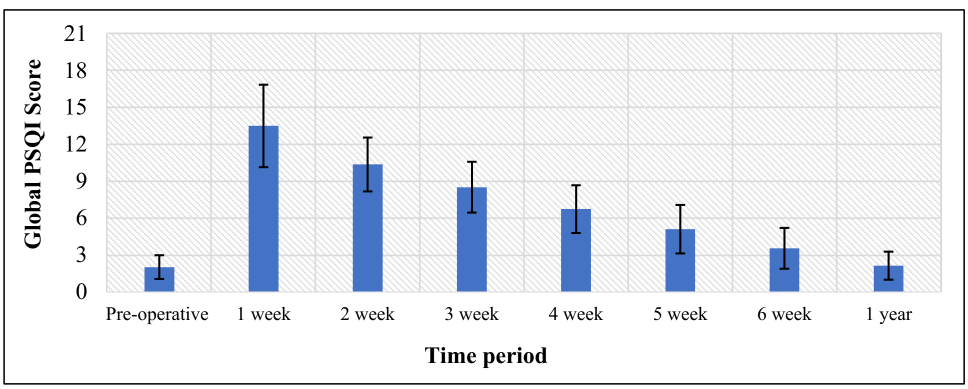

Fig. 1 Temporal changes in global PSQI score in the first post-operative year following primary TKA

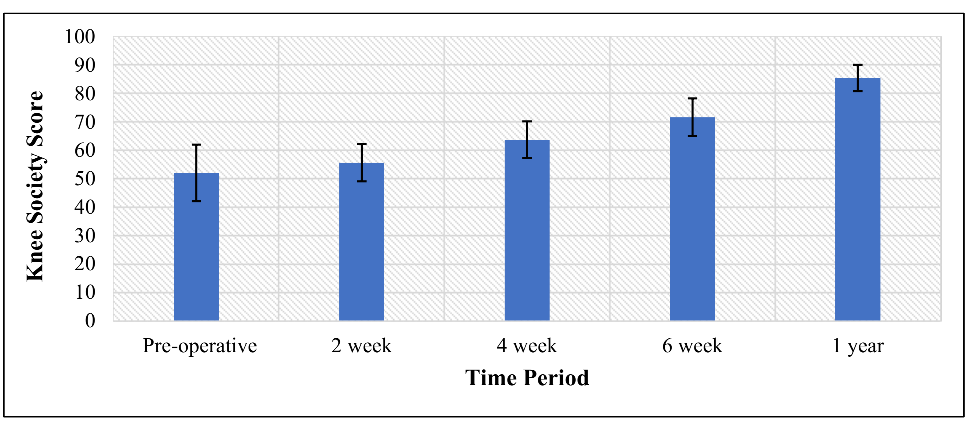

Fig. 2 Temporal changes in KSS in the first post-operative year following primary TKA

Table 2 Correlation of global PSQI score and KSS ($^{*}=p<0.05$)

Time point: Global PSQI	Time point: KSS	r	p-value
Pre-operative	Pre-operative	0.39	$<0.001^{*}$
	6 weeks	0.59	$<0.001^{*}$
	1 year	0.10	0.19
6 weeks	6 weeks	0.47	$<0.001^{*}$
	1 year	0.13	0.09

respectively. Patients reporting poor sleep quality (global PSQI > 5) were compared to patients reporting good sleep quality (global PSQI < 5) at sixth post-operative week following TKA (Table 3).

Patients reporting poor sleep quality were noted to have higher BMI ($p=0.003$), longer duration of length of stay ($p=0.04$), and poor KSS ($p<0.001$) compared to patients reporting good sleep quality.

Multiple regression analysis

Amongst the routine clinical parameters that formed the independent predictors, age ($\beta=-0.894$, $p=0.027$) and ROM ($\beta=-0.535$, $p=0.010$) had significant negative correlation, whereas CCI ($\beta=0.617$, $p=0.058$) had positive correlation with global PSQI at the sixth post-operative week (Table 4).

Other parameters such as gender, BMI, sagittal deformity, and coronal deformity had no significant correlation with global PSQI at the sixth post-operative week following TKA (Table 4).

Discussion

Normal sleep cycle comprises two stages: rapid eye movement (REM) and non-rapid eye movement (NREM) phase. REM phase comprises 25% of total sleep of normal night, and if it is suppressed for one or more nights, rebound REM sleep occurs the following nights, which resembles REM sleep but with an increased intensity and duration [14]. Rebound REM phase sleep has been linked with delirium,

Table 3 Patient groups based on global PSQI at sixth post-operative week following TKA ($^{*}=p<0.05$), χ^2—chi-square test

	Total TKA Patients (n = 168)		
	Global PSQI > 5 ($n=24$)	Global PSQI < 5 ($n=144$)	
Parameter	Mean ± SD	Mean ± SD	p-value
Pre-operative			
- Age	65.08 ± 7.98	64.51 ± 7.45	0.74
- Gender (M:F ratio)$^{\chi}$	5:19	35:109	0.04^{*}
- BMI	27.94 ± 2.47	26.19 ± 2.64	0.003^{*}
- Range of motion (flexion)	97.50 ± 12.60	97.54 ± 17.22	0.99
- Sagittal deformity	3.13 ± 5.67	3.17 ± 5.37	0.99
- Coronal deformity	−12.29 ± 6.75	−10.46 ± 6.08	0.23
- CCI	2.63 ± 0.46	2.46 ± 0.92	0.46
Postoperative			
- LOS	5.79 ± 2.23	4.78 ± 1.67	0.04^{*}
- KSS (sixth week)	65.63 ± 4.33	72.67 ± 6.36	$<0.001^{*}$

Table 4 Multiple regression analysis for the relationship between global PSQI (sixth week) as dependent variable and routine clinical parameters as independent variables ($^{*}=p<0.05$) ($R^2=0.545$)

Parameter	β	SE	95% CI Lower	95% CI Upper	t	p-value
Age	−0.894	0.020	−0.093	−0.006	−2.428	0.027^{*}
Gender	−0.018	0.269	−0.589	0.550	−0.073	0.943
BMI	−0.122	0.036	−0.098	0.055	−0.603	0.555
CCI	0.617	0.132	−0.010	0.548	2.045	0.058^{*}
ROM	−0.535	0.006	−0.032	−0.005	−2.945	0.010^{*}
Sagittal deformity	−0.279	0.015	−0.053	0.009	−1.492	0.155
Coronal deformity	−0.052	0.012	−0.029	0.022	−0.285	0.779

mental confusion, obstructive sleep apnoea syndrome, stroke, myocardial infarction, and haemodynamic instability and wound breakdown [34]. Sleep duration, frequency, and periodicity of sleep disruption are the most important determinants for the restorative capability of sleep [35].

Our study demonstrated some of the routine clinical factors that may contribute towards high global PSQI (sleep disturbance) and low KSS (knee function) post-operatively in TKA patients. In our study, majority of the patients (144/168) regained their baseline global PSQI (<5) by the sixth post-operative week. Twenty-four patients (14.28%) continued to report poor sleep quality at this stage along with low KSS score. However, the temporal changes suggest that further improvements continue during the first post-operative year beyond the sixth week (Figs. 1 and 2). Additionally, there was significant correlation noted between global PSQI and KSS initially which decreased significantly beyond the sixth post-operative week (Table 2). This indicated towards a transient phenomenon of sleep disturbance reported by the patients which was limited to the early post-operative period (6 weeks in the current study). Hence, sleep disturbance may be associated with poor knee function for a limited period notably in the early post-operative period following TKA in patients.

Sleep disturbance has been observed in majority of the patients undergoing surgical procedures such as TKA in the early post-operative period. However, we noted that amongst the patients who reported poor sleep quality at the sixth post-operative week, the length of hospital stay (LOS) was significantly higher (5.79 days vs. 4.78 days, $p=0.04$) (Table 3). This is probably due to a combination of reasons and an indirect metric of the time taken by this subgroup to achieve their post-operative knee rehabilitation parameters. Similar findings have been noted by other investigators [36, 37].

Sleep deprivation is a common problem in the post-operative period as it can lead to hyperalgesia and cognitive problems [15]. Krenk et al. [21] evaluated 10 patients that underwent fast-track knee arthroplasty using polysomnography. They noted that the sleep architecture on the first post-operative night was more disturbed compared to the preoperative period and normalised on the fourth post-operative night. Furthermore, they found no association between opiate use, pain scores, and inflammatory response with sleep disturbance. Er et al. [38] evaluated sleep quality in 42 patients undergoing TKA using PSQI and 100-mm visual analogue scale (VAS). They concluded that improvement in sleep quality was not related to pain relief. In contrast, Wang et al. [39] reported that pain and anxiety were risk factors associated with post-operative sleep disturbance. Hence, there is a lack of consensus on the potential risk factors contributing towards sleep disturbance in the TKA patients. We performed multiple regression analysis to evaluate the influence of routine clinical parameters (independent factors) such as age, gender, BMI, CCI, and extent of knee deformity on sleep quality (global PSQI) at the sixth post-operative week (Table 4). Amongst the independent factors, age ($\beta=-0.894$, $p=0.027$) and ROM ($\beta=-0.535$, $p=0.010$) had significant negative correlation, whereas CCI ($\beta=0.617$, $p=0.058$) had positive correlation with global PSQI at the sixth post-operative week (Table 4).

The current study has some limitations. First, objective measurements of sleep apnoea (polysomnography) and sleep duration (actinography) which would enable external validity and better interpretation of results were not performed. However, it must be noted that whilst they are specialist sleep assessments, they are resource intensive measurements which may not be widely available. Second, separate scores evaluating central or peripheral aspect of pain were not undertaken. However, the PSQI evaluation includes a component question regarding pain. Third, objective assessment of patient anxiety was not undertaken. Notwithstanding these limitations, the temporal changes in global PSQI and KSS over a longer duration of time were the primary focus of the study which was demonstrated.

Conclusions

Patients undergoing primary TKA experience changes in sleep quality but report an overall improvement in knee function during the first post-operative year. Sleep quality (assessed using global PSQI score) has moderate to strong correlation with knee function in the early post-operative period (up to 6 weeks) beyond which there is a low correlation with knee function, thereby suggesting a transient phenomenon. Age, ROM, and CCI were independent predictors of sleep quality. Hence patients undergoing TKA can be appropriately counselled regarding the variation in sleep quality in the post-operative period and reassured accordingly.

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Author contribution All the authors contributed towards the literature search, critical review, data analysis, and manuscript preparation.

Data availability Presented in the manuscript.

Declarations

Ethics approval Institutional review board (IRB) approval was obtained prior to this study, and all patients signed a written consent before participating in the study. A copy of the IRB document is provided along with the manuscript during submission via the journal editorial manager.

Consent to participate Written informed consent was obtained in all patients and signed copy was retained for records.

Consent for publication All the authors provide full consent to publish the study findings in your journal (International Orthopaedics).

Competing interests The authors declare no competing interests.

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