The association between sleep quality, preoperative risk factors for chronic postoperative pain and postoperative pain intensity 12 months after knee and hip arthroplasty

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Published in:
British Journal of Pain

DOI (link to publication from Publisher):
10.1177/20494637211005803

Publication date:
2021

Document Version
Accepted author manuscript, peer reviewed version

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Journal:	*British Journal of Pain*
Manuscript ID	BJP-20-0093
Manuscript Type:	Original Manuscript
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Abstract

Background: Chronic postoperative pain following total joint replacement (TJR) is a substantial clinical problem and preoperative predictive risk factors such as high levels of anxiety and depression have been identified. Poor sleep seems to affect several cognitive factors, but it is currently unclear how sleep quality is associated with preoperative predictive risk factors for chronic postoperative pain. This exploratory cohort study investigated 1) the relationship between preoperative sleep quality, clinical pain intensity, pain catastrophizing, anxiety, and depression, and 2) their associations to chronic postoperative pain following TJR.

Methods: Preoperative Pittsburgh Sleep Quality Index (PSQI), Pain Catastrophizing Scale (PCS), and Hospital Anxiety and Depression Scale (HADS) were obtained from 74 knee and 89 hip osteoarthritis (OA) patients scheduled for TJR. Pain intensity at rest was assessed before and 12 months after TJR using a visual analog scale (VAS). Poor sleepers were identified preoperatively as patients with PSQI scores higher than 5.

Results: Poor sleepers demonstrated higher preoperative VAS (p=0.003), higher pain catastrophizing (p<0.001), higher anxiety (p<0.001) and depression (p<0.001) when compared to good sleepers. Preoperative VAS was correlated with preoperative factors PSQI (r=0.36, p<0.001), PCS (r=0.46, p<0.001), and depression (r=0.23, p=0.004), and postoperative VAS (r = 0.32, p < 0.001).

Conclusion: OA patients with poor preoperative sleep quality show higher preoperative pain intensities, higher scores of pain catastrophizing, and depression. High preoperative pain intensity, but not sleep quality, was associated with higher chronic postoperative pain intensity. Future studies are encouraged to further explore the associations between sleep and chronic postoperative pain.

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Introduction

Knee and hip osteoarthritis (OA) are highly prevalent musculoskeletal disorders that affect the elder population.[1] The treatment for end-stage-OA is total joint replacement (total knee or hip replacement: TKR and THR, respectively), however, it is well-established that an approximate 20% of patients following TKR and 10% of patients following THR will report chronic postoperative pain.[2]

Preoperative pain intensity[3] and cognitive factors such as high preoperative pain catastrophizing predicts the presence of chronic postoperative pain six and 24 months after TKR.[4–8] In a mixed musculoskeletal pain cohort, improvements in depression, anxiety, and pain catastrophizing predicted pain 12 months after being enrolled in a telecare rehabilitation program.[9] Additionally, insomniac knee OA patients exhibit stronger signs of central sensitization, and pain catastrophizing may attain a key role in moderating sleep efficiency and the development of pain sensitization.[10] A recent study demonstrated that preoperative sleep parameters such as Pittsburgh Sleep Quality Index (PSQI) and daily sleepiness were associated with acute postoperative pain after TKR and THR.[11] Sleep may therefore play an important role in body homeostasis and in mediating cognitive factors known to be involved with postoperative chronic pain, possibly through a bidirectional relationship with e.g. anxiety and depression.[12] Conclusively, these studies indicate that there might be an interplay between cognitive factors, sleep and postoperative pain. However, no evidence is currently available on how preoperative poor sleep is associated with preoperative risk factors pain catastrophizing, depression, anxiety, or chronic postoperative pain 12 months after TKR and THR.

The aims of the present study were to 1) assess the impact of preoperative sleep quality on preoperative clinical pain intensity, pain catastrophizing, anxiety, and depression and 2) explore the associations

between preoperative sleep quality, pain intensity, pain catastrophizing, depression, and anxiety to chronic postoperative pain intensity 12 months after total joint replacement in patients with OA.

Methods

Patients

A total of 185 knee OA patients (82 men and 103 women; mean age ± SD: 68.8 ± 8.92 years) and 189 hip OA patients (120 men and 69 women; mean age ± SD: 66.93 ± 13.75 years) scheduled for TKR and THR were enrolled. The patients took part in a large randomized controlled trial assessing the effect of acute and 7 days postoperative administration of the muscle relaxant chlorzoxazone on postoperative pain (12 months after TKR or THR). Chlorzoxazone is believed to enhance acute postoperative pain recovery[13], which may improve postoperative pain[14], but the study demonstrated no effect of chlorzoxazone on acute and chronic postoperative pain compared to placebo.[15] Therefore, these exploratory analyses were carried out. Patients were assessed for eligibility at a prescheduled hospital visit preceding admission for surgery between September 2015 and September 2016, and follow-up was conducted 12 months post-surgery (2017).

Exclusion criteria involved use of gabapentinoids, glucocorticoids, opioids, anxiolytics, antiepileptics or antidepressants; alcohol abuse; other pain treatments outside of standard care; malignant conditions; pregnancy; BMI > 40 kg/m^2; suffering from other peripheral or central acting diseases; allergy towards chlorzoxazone; perioperative complications (e.g. fractures) and liver diseases. All patients signed an informed consent prior to inclusion. The study was approved by the Danish Medicines Agency, the local ethics committee (VN-20150024) and Danish Data Protection Agency, preregistered at

Clinicaltrials.gov (identifier number: NCT02405104) and conducted in accordance to the Declaration of Helsinki.

Sleep quality

Sleep quality was assessed preoperatively using the PSQI. The PSQI measures sleep quality and disturbances over 1 month intervals by 19 items including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, sleep medication usage, as well as daytime dysfunction and is assessed on a 0-21 point scale.[16] A PSQI measure > 5 indicates poor sleep, with reported sensitivity of ~90% when distinguishing good from poor sleepers.[16]

Pain Catastrophizing Scale

The Pain Catastrophizing Scale (PCS)[17] was administered preoperatively to assess pain catastrophizing. The PCS scores range from 0-52 across three subscales (rumination, magnification, and helplessness) based on 13 items (each scored from 0-4) reflecting the frequency of catastrophizing cognitions. The PCS is validated in chronic pain patients, pain-free subjects[18,19] and the Danish version in clinical and non-clinical cohorts.[20] The total PCS score was calculated and used for further analysis.

Anxiety and depression

The Hospital Anxiety and Depression Scale (HADS) is considered part of the (British) National Institute for Health and Care Excellence (NICE) recommendation for diagnosis of depression and anxiety[21], and was employed to determine the level of preoperative anxiety and depression. The scale

consists of 14 questions of which seven items assesses anxiety and seven items assesses depression.[22] Each item is evaluated by a score from 0-3 and summated to give a separate score for anxiety and depression. Cut-off values for anxiety and depression scores are 8 or above, which yield good specificity and sensitivity.[23]

Pain intensity measures

Clinical pain intensity was defined as pain after 20 minutes of rest and was rated on a visual analogue scale (VAS; 0-10 cm; referred to as pain from hereon). Both pre- and 12 months postoperative clinical pain intensity were obtained.

Statistics

First, the potential effect of chlorzoxazone on the study parameters was tested in a multivariate analysis of co-variance (MANCOVA), with fixed factor randomization (chlorzoxazone or placebo).

Patients (TKR and THR pooled) were grouped based on sleep quality into good or poor sleepers defined as PSQI>5. Independent samples t-tests were conducted between the two subgroups to explore whether the two groups differed. Chi-square tests on proportions were used to test differences in proportions of gender and surgery type between good and poor sleepers. Associations between preoperative pain intensity, sleep quality, cognitive factors, and chronic postoperative pain were tested using Pearson's product-moment correlation analysis. A p-value below 0.05 was set to determine statistical significance. Bonferroni correction was applied to correct for multiple comparisons (0.05/5 = 0.01). All statistical analyses were performed in Statistical Package for Social Sciences (SPSS; version 26, IBM). Data are reported as mean ± standard error of the mean (SEM) unless otherwise stated.

Results

A total of 163 patients had all preoperative and postoperative data available and were included for further analysis (CONSORT diagram, Fig. 1). The excluded patient group displayed a significantly higher proportion of females (62.8%) compared with included patients (37.2%, $p = 0.03$) but otherwise no significant differences were found for age ($t_{372} = 1.68$, $p = 0.09$), PCS ($t_{328} = 0.89$, $p = 0.4$), PSQI ($t_{230} = -0.54$, $p = 0.6$), anxiety ($t_{295} = 0.31$, $p = 0.76$), or depression ($t_{291} = 0.3$, $p = 0.3$). Demographics for the included patients can be seen in Table 1. The MANCOVA demonstrated that randomization (chlorzoxazone or placebo) did not impact preoperative pain ($F_{1,161} = 1.74$, $p = 0.19$), postoperative pain ($F_{1,161} = 0.87$, $p = 0.35$), PCS ($F_{1,161} = 0.14$, $p = 0.71$), PSQI ($F_{1,161} = 0.39$, $p = 0.53$), anxiety ($F_{1,161} = 0.41$, $p = 0.52$), or depression ($F_{1,161} = 2.15$, $p = 0.14$).

[Insert Figure 1.]

[Insert Table 1.]

The impact of sleep quality on psychological factors

The good sleepers were older than the poor sleepers ($t(151) = -0.25$, $p = 0.02$). In addition, a higher proportion of females were found in the poor sleepers' group (poor sleepers = 50m/44f; good sleepers = 41m/18f) ($\chi^2 = 3.9$, $p = 0.046$). No difference was observed for proportion of surgery type in the subgroups ($\chi^2 = 3.2$, $p = 0.07$).

The poor sleepers reported significantly increased preoperative pain intensity ($t(151) = 3.06$, $p = 0.003$; Fig. 2A), higher pain catastrophizing thoughts ($t(149.16) = 4.96$, $p < 0.001$; Fig. 2B), higher anxiety

scores ($t(150.88) = 5.32, < 0.001$; Fig. 2C), and higher depression scores ($t(150.51) = 4.5$, $p < 0.001$; Fig. 2D) compared with the good sleepers. No difference was found comparing postoperative pain intensity between good and poor sleepers ($t(151) = 0.17$, $p = 0.86$).

[Insert Figure 2.]

Associations between preoperative sleep, preoperative pain intensity, and preoperative cognitive factors

Preoperative PSQI was positively correlated with preoperative pain ($r = 0.36$, $p < 0.001$). In addition, preoperative pain intensity was positively correlated to preoperative PCS ($r = 0.46$, $p < 0.001$), preoperative depression ($r = 0.23$, $p = 0.004$), but not preoperative anxiety levels ($r = 0.16$, $p = 0.12$, Bonferroni-corrected).

Association between preoperative sleep quality, pain intensity, cognitive factors, and postoperative chronic pain

Chronic postoperative pain intensity was positively correlated with preoperative pain intensity ($r = 0.32$, $p < 0.001$) and trended towards significance for preoperative PCS ($r = 0.15$, $p = 0.057$). There was no significant correlation between preoperative sleep quality and chronic postoperative pain ($r = 0.05$, $p = 0.52$).

Discussion

The current study is the first larger scale study to assess the impact of poor sleep quality on preoperative and chronic postoperative pain after total joint replacement. The results show that poor sleepers demonstrate higher preoperative pain intensity, higher levels of pain catastrophizing thoughts, and higher levels of anxiety and depression. Finally, higher preoperative pain intensity, but not preoperative sleep quality, was associated with higher chronic postoperative pain intensity.

Sleep quality, its impact on preoperative pain, and relation to chronic postoperative pain

Up to 50% of chronic pain patients report poor sleep[24], and an earlier study reported that preoperative sleep quality mediated the relationship between 1 month postoperative pain and functional limitation 3 months after surgery.[25] A recent systematic review and meta-analysis identified sleep difficulties as a strong preoperative predictor of poor postoperative pain control, however, this was only based on two studies.[26] Additionally, Mamie et al.[27] showed preoperative chronic sleep difficulties increased the risk of severe postoperative pain following intraperitoneal or orthopedic surgery. Poor preoperative sleep has also been shown to be associated with poor physical recovery after cardiac surgery.[28] A recent study reported that preoperative PSQI and daily sleepiness were associated with acute postoperative pain, up to 3 months after TKR and THR.[11] These findings indicate there may be an association between having poor preoperative sleep and reporting chronic postoperative pain however the mechanisms are unclear. In healthy participants, partial and total sleep deprivation have shown to affect both peripheral[29,30] and central facilitatory and inhibitory pain mechanisms.[31,32] These pain mechanisms are also altered in chronic pain patients suffering from e.g. fibromyalgia or knee OA[33–36] and may predict the analgesic response to standard pain treatment in OA[37,38] and reports of chronic postoperative pain following TKR[39–44] and THR.[45,46] Together with the current findings, these studies indicate that OA patients reporting poor sleep also suffer from higher preoperative pain which is predictive of

chronic postoperative pain.[3] Roehrs and Roth[47] demonstrated, in a cohort of 18 knee and hip OA patients scheduled for TJR, that extending sleep by approx. 1 hour yielded an improvement in acute postoperative pain and opiate use, indicating that improving sleep might yield better postoperative outcomes for patients and more research in this field is encouraged in the future. It is important to note that an earlier study demonstrated that knee OA patients scheduled for revision surgery were younger than those undergoing primary surgery, and also reported higher chronic pain intensity.[48] Since the current study found a difference in age between those patients who sleep poorly compared to those who sleep well, the possible effect of age on postoperative pain should be considered, despite the availability of contrasting evidence on the association between age and postoperative pain after various surgical procedures.[49] Furthermore, a larger proportion of women was found in the poor sleep group, and since women in general report higher preoperative pain intensity[50], and more frequently develop chronic postoperative pain[51,52], this should be acknowledged and controlled in future studies.

Sleep quality and its relation to anxiety, depression, and pain catastrophizing

Sleep abnormalities have been associated with high-risk of depression[53,54], anxiety[12], and pain catastrophizing[55]. For instance, depression was shown to be independently associated with sleep problems in rheumatoid arthritis patients[56], however, the direction in which insomnia, depression, and even chronic pain interact remains elusive.[57] In temporomandibular disorder patients, sleep disturbance was shown to exert a mediating role on pain catastrophizing.[58] In support, indirect evidence for the role of sleep on pain catastrophizing was shown in another study, where cognitive behavioral therapy for insomnia in knee OA patients reduced pain catastrophizing.[59]

Together with the current findings of higher levels of pain catastrophizing in knee OA patients who report poor sleep prior to TJR, these studies support early interventions aimed at managing depression, anxiety, and pain catastrophizing, since, especially the latter, is known to predict chronic postoperative pain.[4,5] A recent multi-site randomized clinical trial was performed to lower catastrophizing thoughts in TKR patients but showed no effect on the incidence of chronic postoperative pain.[60] Therefore, future studies may explore the possibility of managing this triad of cognitive impairment through for instance sleep therapy or cognitive behavioral therapy, to evaluate its effect on chronic postoperative pain.

Cognitive factors and their relation to chronic postoperative pain

A systematic review and meta-analysis showed that preoperative anxiety and pain catastrophizing hold predictive value for chronic postoperative pain 3-12 months after various surgeries.[61] Another study reported that patients enrolled for abdominal surgery who underwent a preoperative pain management intervention for understanding and managing chronic postoperative pain, exhibited lower preoperative anxiety and pain attitude, and importantly, reported lower acute pain intensity up to 24 hours after surgery.[62] In knee OA, preoperative anxiety and depression was shown to be associated with chronic postoperative pain 6[63] and 12 months after TKR.[64] Furthermore, in TKR patients, pain intensity and pain-related distress may be associated with anxiety, depression, and pain catastrophizing[65], pain self-efficacy, and fear of movement.[66] In addition, preoperative pain catastrophizing has been demonstrated to predict chronic postoperative pain six[4] and 24 months[5] after TKR, albeit controversial evidence exist.[67] In this respect, poor sleep before TKR was shown to mediate the relationship between 1 and 3 months postoperative functional limitations.[25] Furthermore, depression has been shown to predict higher postoperative pain whereas catastrophizing was shown to be a unique predictor of higher

postoperative night time pain.[68] In populations suffering from sleep-related disorders such as sleep apnea, the prevalence of depression and anxiety is more pronounced when compared to a non-apnea group.[69] The current study adds to this growing body of evidence by showing that hip and knee OA patients reporting poor sleep, exhibit higher preoperative anxiety, depression, and pain catastrophizing levels. These factors may play a direct or an indirect role in chronic postoperative pain, and further research similar to the study by Riddle et al.[60] is needed, to further our understanding of preoperative interventions on cognitive factors associated with postoperative pain.

Limitations

The current study is limited by missing data for ~56% of the patients and a larger proportion of females were found in the excluded and poor sleepers' groups. Females are known to report higher anxiety[70], higher preoperative pain intensity[50], and more frequently develop chronic postoperative pain[51,52] and therefore the results of the current study should be interpreted with care.

Conclusion

The current study is the first large-scale study to investigate the effect of preoperative quality of sleep on preoperative risk factors for chronic postoperative pain after TRJ. The results showed that, OA patients with poor preoperative sleep have higher preoperative pain intensities and higher levels of pain catastrophizing, anxiety, and depression compared to patients that sleep well. Preoperative pain intensity, but not sleep quality, was associated with chronic postoperative pain 12 months after total knee and hip arthroplasty. Since preoperative sleep quality affected preoperative pain, which predicted chronic postoperative pain, future studies are encouraged to investigate if improving sleep prior to surgery may reduce preoperative pain intensity to decrease the risk of chronic postoperative pain.

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by The Aalborg University Talent Management Programme (j.no. 771126), The Shionogi Science Program and the TaNeDS Europe grant. None of the funders had any role in the study other than to provide funding. KKP received a grant from the Danish Ministry of Higher Education and Science in collaboration with Cortex Technology Aps to develop the cuff algometer. Center for Neuroplasticity and Pain (CNAP) is supported by the Danish National Research Foundation (DNRF121).

Data availability: Upon request

References

1. Vos T, Abajobir AA, Abate KH, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017; 390: 1211–1259.
2. Beswick AD, Wylde V, Gooberman-Hill R, et al. What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of Prospective studies in unselected patients. *BMJ Open* 2012; 2: 1–12.
3. Lewis GN, Rice DA, McNair PJ, et al. Predictors of persistent pain after total knee arthroplasty: A systematic review and meta-analysis. *Br J Anaesth* 2015; 114: 551–561.
4. Riddle DL, Wade JB, Jiranek WA, et al. Preoperative pain catastrophizing predicts pain outcome after knee arthroplasty. *Clin Orthop Relat Res* 2010; 468: 798–806.
5. Forsythe ME, Dunbar MJ, Hennigar AW, et al. Prospective relation between catastrophizing and

residual pain following knee arthroplasty: Two-year follow-up. *Pain Res Manag* 2008; 13: 335–341.

6. Somers TJ, Keefe FJ, Pells JJ, et al. Pain catastrophizing and pain-related fear in osteoarthritis patients: relationships to pain and disability. *J Pain Symptom Manage* 2009; 37: 863–72.
7. Birch S, Stilling M, Mechlenburg I, et al. Association between pain catastrophizing, physical function and pain at first visit in the outpatient knee clinic. *Knee* 2019; 8–13.
8. Odole A, Ekediegwu E, Ekechukwu END, et al. Correlates and predictors of pain intensity and physical function among individuals with chronic knee osteoarthritis in Nigeria. *Musculoskelet Sci Pract* 2019; 39: 150–156.
9. Scott EL, Kroenke K, Wu J, et al. Beneficial effects of improvement in depression, pain catastrophizing, and anxiety on pain outcomes: A 12-month longitudinal analysis. *J Pain* 2016; 17: 215–222.
10. Campbell CM, Buenaver LF, Finan P, et al. Sleep, Pain Catastrophizing, and Central Sensitization in Knee Osteoarthritis Patients with and Without Insomnia. *Arthritis Care Res* 2015; 67: 1387–1396.
11. Luo ZY, Li LL, Wang D, et al. Preoperative sleep quality affects postoperative pain and function after total joint arthroplasty: a prospective cohort study. *J Orthop Surg Res* 2019; 14: 378.
12. Alvaro PK, Honors BP, Roberts RM, et al. REVIEW OF SLEEP DISTURBANCES , ANXIETY AND DEPRESSION A Systematic Review Assessing Bidirectionality between Sleep Disturbances , Anxiety , and Depression.
13. van Tulder MW, Touray T, Furlan AD, et al. Muscle relaxants for non-specific low-back pain. *Cochrane Database Syst Rev*. Epub ahead of print 22 April 2003. DOI: 10.1002/14651858.CD004252.

14. Kehlet H, Jensen TS, Woolf CJ, et al. Persistent postsurgical pain: risk factors and prevention. *Lancet (London, England)* 2006; 367: 1618–25.

15. Skrejborg P, Petersen KK, Beck J, et al. Investigating the Effect of Perioperative Chlorzoxazone on Acute Postoperative Pain After Total Hip and Knee Replacement Surgery. *Clin J Pain* 2020; 36: 352–358.

16. Buysse DJ, Reynolds CF, Monk TH, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res* 1989; 28: 193–213.

17. Sullivan MJL, Bishop SR, Pivik J. The Pain Catastrophizing Scale: Development and Validation. *Psychol Assess* 1995; 7: 524–532.

18. Osman A, Barrios FX, Gutierrez PM, et al. The pain catastrophizing scale: Further psychometric evaluation with adult samples. *J Behav Med* 2000; 23: 351–365.

19. Edwards RR, Calahan C, Mensing G, et al. Pain, catastrophizing, and depression in the rheumatic diseases. *Nat Rev Rheumatol* 2011; 7: 216–224.

20. Kjøgx H, Zachariae R, Pfeiffer-Jensen M, et al. Pain frequency moderates the relationship between pain catastrophizing and pain. *Front Psychol* 2014; 5: 1–11.

21. Kendrick T, Pilling S. Common mental health disorders - Identification and pathways to care: NICE clinical guideline. *Br J Gen Pract* 2012; 62: 47–49.

22. Snaith RP. The hospital anxiety and depression scale. Health and Quality of Life Outcomes. *Health Qual Life Outcomes* 2003; 10: 1–11.

23. Bjelland I, Dahl AA, Haug TT, et al. The validity of the Hospital Anxiety and Depression Scale. *J Psychosom Res* 2002; 52: 69–77.

24. Smith MT, Haythornthwaite JA. How do sleep disturbance and chronic pain inter-relate? Insights from the longitudinal and cognitive-behavioral clinical trials literature. *Sleep Med Rev*

2004; 8: 119–132.

25. Cremeans-Smith JK, Millington K, Sledjeski E, et al. Sleep disruptions mediate the relationship between early postoperative pain and later functioning following total knee replacement surgery. *J Behav Med* 2006; 29: 215–222.

26. Yang MMH, Hartley RL, Leung AA, et al. Preoperative predictors of poor acute postoperative pain control : a systematic review and meta-analysis. 2019; 1–11.

27. Mamie C, Bernstein M, Morabia A, et al. Are there reliable predictors of postoperative pain? *Acta Anaesthesiol Scand* 2004; 48: 234–242.

28. Poole L, Kidd T, Leigh E, et al. Preoperative sleep complaints are associated with poor physical recovery in the months following cardiac surgery. *Ann Behav Med* 2014; 47: 347–357.

29. Staffe AT, Bech MW, Clemmensen SLK, et al. Total sleep deprivation increases pain sensitivity, impairs conditioned pain modulation and facilitates temporal summation of pain in healthy participants. *PLoS One* 2019; 14: e0225849.

30. Schuh-Hofer S, Wodarski R, Pfau DB, et al. One night of total sleep deprivation promotes a state of generalized hyperalgesia: A surrogate pain model to study the relationship of insomnia and pain. *Pain* 2013; 154: 1613–1621.

31. Eichhorn N, Treede RD, Schuh-Hofer S. The Role of Sex in Sleep Deprivation Related Changes of Nociception and Conditioned Pain Modulation. *Neuroscience* 2018; 387: 191–200.

32. Staffe AT, Bech MW, Clemmensen SLK, et al. Total sleep deprivation increases pain sensitivity, impairs conditioned pain modulation and facilitates temporal summation of pain in healthy participants. *PLoS One* 2019; 14: e0225849.

33. Sivertsen B, Lallukka T, Petrie KJ, et al. Sleep and pain sensitivity in adults. *Pain* 2015; 156: 1433–1439.

34. Petersen KK, Graven-Nielsen T, Simonsen O, et al. Preoperative pain mechanisms assessed by cuff algometry are associated with chronic postoperative pain relief after total knee replacement. *Pain*; 157. Epub ahead of print 2016. DOI: 10.1097/j.pain.0000000000000531.

35. Arendt-Nielsen L, Nie H, Laursen MB, et al. Sensitization in patients with painful knee osteoarthritis. *Pain* 2010; 149: 573–581.

36. Staud R, Cannon RC, Mauderli AP, et al. Temporal summation of pain from mechanical stimulation of muscle tissue in normal controls and subjects with fibromyalgia syndrome. *Pain* 2003; 102: 87–95.

37. Petersen KK, Olesen AE, Simonsen O, et al. Mechanistic pain profiling as a tool to predict the efficacy of 3-week nonsteroidal anti-inflammatory drugs plus paracetamol in patients with painful knee osteoarthritis. *Pain* 2019; 160: 486–492.

38. Petersen KK, Simonsen O, Olesen AE, et al. Pain inhibitory mechanisms and response to weak analgesics in patients with knee osteoarthritis. *Eur J Pain* 2019; 1904–1912.

39. Petersen KK, Arendt-Nielsen L, Simonsen O, et al. Presurgical assessment of temporal summation of pain predicts the development of chronic postoperative pain 12 months after total knee replacement. *Pain* 2015; 156: 55–61.

40. Petersen KK, Graven-Nielsen T, Simonsen O, et al. Preoperative pain mechanisms assessed by cuff algometry are associated with chronic postoperative pain relief after total knee replacement. *Pain* 2016; 157: 1400–1406.

41. Petersen KK, Simonsen O, Laursen MB, et al. The Role of Preoperative Radiological Severity, Sensory Testing, and Temporal Summation on Chronic Postoperative Pain following Total Knee Arthroplasty. *Clin J Pain*. Epub ahead of print 2018. DOI: 10.1097/AJP.0000000000000528.

42. Kurien T, Arendt-Nielsen L, Petersen KK, et al. Preoperative Neuropathic Pain-like Symptoms

and Central Pain Mechanisms in Knee Osteoarthritis Predicts Poor Outcome 6 Months After Total Knee Replacement Surgery. *J Pain* 2018; 19: 1329–1341.

43. Vaegter HB, Handberg G, Emmeluth C, et al. Preoperative Hypoalgesia after Cold Pressor Test and Aerobic Exercise is Associated with Pain Relief 6 Months after Total Knee Replacement. *Clin J Pain* 2017; 33: 475–484.
44. Wylde V, Palmer S, Learmonth ID, et al. The association between pre-operative pain sensitisation and chronic pain after knee replacement: An exploratory study. *Osteoarthr Cartil* 2013; 21: 1253–1256.
45. Izumi M, Petersen KK, Laursen MB, et al. Facilitated temporal summation of pain correlates with clinical pain intensity after hip arthroplasty. *Pain* 2017; 158: 323–332.
46. Wylde V, Sayers A, Lenguerrand E, et al. Preoperative widespread pain sensitization and chronic pain after hip and knee replacement: A cohort analysis. *Pain* 2015; 156: 47–54.
47. Roehrs TA, Roth T. Increasing presurgery sleep reduces postsurgery pain and analgesic use following joint replacement: a feasibility study. *Sleep Med* 2017; 33: 109–113.
48. Petersen KK, Simonsen O, Laursen MB, et al. Chronic postoperative pain after primary and revision total knee arthroplasty. *Clin J Pain* 2015; 31: 1–6.
49. Gagliese L, Weizblit N, Ellis W, et al. The measurement of postoperative pain : A comparison of intensity scales in younger and older surgical patients. 2005; 117: 412–420.
50. Keefe FJ, Lefebvre JC, Egert JR, et al. The relationship of gender to pain, pain behavior, and disability in osteoarthritis patients: The role of catastrophizing. *Pain* 2000; 87: 325–334.
51. Rosseland LA, Stubhaug A. Gender is a confounding factor in pain trials: Women report more pain than men after arthroscopic surgery. *Pain* 2004; 112: 248–253.
52. Pereira MP, Pogatzki-Zahn E. Gender aspects in postoperative pain. *Curr Opin Anaesthesiol*

2015; 28: 546–558.

53. Rao U, Hammen CL, Poland RE. Risk Markers for Depression in Adolescents : Sleep and HPA Measures. 2009; 1936–1945.

54. Goesling J, Clauw DJ, Hassett AL. Pain and Depression : An Integrative Review of Neurobiological and Psychological Factors. Epub ahead of print 2013. DOI: 10.1007/s11920-013-0421-0.

55. Goodin BR, Fillingim RB, Machala S, et al. Subjective Sleep Quality and Ethnicity Are Interactively Related to Standard and Situation-Specific Measures of. 2011; 913–922.

56. Nicassio PM, Wallston KA. Longitudinal Relationships Among Pain , Sleep Problems , and Depression in Rheumatoid Arthritis. 1992; 101: 514–520.

57. Finan PH, Smith MT. The comorbidity of insomnia , chronic pain , and depression : Dopamine as a putative mechanism. *Sleep Med Rev* 2013; 17: 173–183.

58. Buenaver LF, Quartana PJ, Grace EG, et al. Evidence for indirect effects of pain catastrophizing on clinical pain among myofascial temporomandibular disorder participants : The mediating role of sleep disturbance. *Pain* 2012; 153: 1159–1166.

59. Lerman SF, Finan PH, Smith MT, et al. Psychological interventions that target sleep reduce pain catastrophizing in knee osteoarthritis. 158.

60. Riddle DL, Keefe FJ, Ang DC, et al. Pain Coping Skills Training for Patients Who Catastrophize About Pain Prior to Knee Arthroplasty. *J Bone Jt Surg* 2019; 101: 218–227.

61. Theunissen M, Peters ML, Bruce J, et al. Preoperative anxiety and catastrophizing: A systematic review and meta-analysis of the association with chronic postsurgical pain. *Clin J Pain* 2012; 28: 819–841.

62. Lin LY, Wang RH. Abdominal surgery, pain and anxiety: Preoperative nursing intervention. *J*

Adv Nurs 2005; 51: 252–260.

63. Noiseux NO, Callaghan JJ, Clark CR, et al. Preoperative predictors of pain following total knee arthroplasty. *J Arthroplasty* 2014; 29: 1383–1387.

64. Brander VA, David Stulberg S, Adams AD, et al. Predicting Total Knee Replacement Pain: A Prospective, Observational Study. *Clin Orthop Relat Res* 2003; 27–36.

65. Hadlandsmyth K, Sabic E, Zimmerman MB, et al. Relationships among pain intensity, pain-related distress, and psychological distress in pre-surgical total knee arthroplasty patients: a secondary analysis. *Psychol Health Med* 2017; 22: 552–563.

66. Sinikallio SH, Helminen E-E, Valjakka AL, et al. Multiple Psychological Factors Are Associated With Poorer Functioning in a Sample of Community-Dwelling Knee Osteoarthritis Patients. *JCR J Clin Rheumatol* 2014; 20: 261–267.

67. Høvik LH, Winther SB, Foss OA, et al. Preoperative pain catastrophizing and postoperative pain after total knee arthroplasty: A prospective cohort study with one year follow-up. *BMC Musculoskelet Disord* 2016; 17: 1–7.

68. Edwards RR, Haythornthwaite JA, Smith MT, et al. Catastrophizing and depressive symptoms as prospective predictors of outcomes following total knee replacement. *Pain Res Manag* 2009; 14: 307–311.

69. Sharafkhaneh A, Giray N, Richardson P, et al. Association of psychiatric disorders and sleep apnea in a large cohort. *Sleep* 2005; 28: 1405–1411.

70. Wood TJ, Thornley P, Petruccelli D, et al. Preoperative Predictors of Pain Catastrophizing, Anxiety, and Depression in Patients Undergoing Total Joint Arthroplasty. *J Arthroplasty* 2016; 31: 2750–2756.

Figures

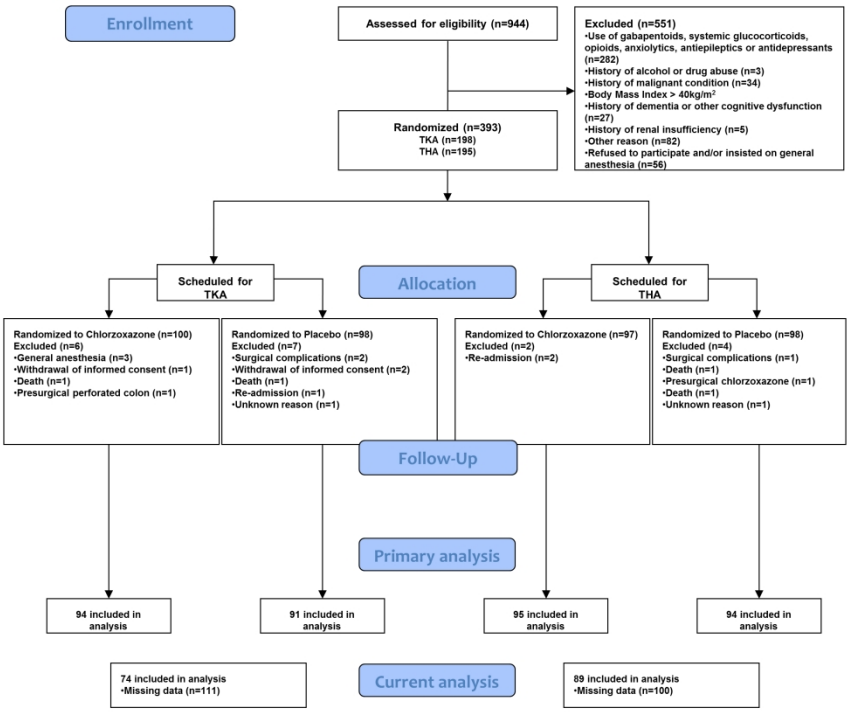
Figure 1. CONSORT diagramme. Flow of patients throughout the trial and the secondary analysis conducted in the current study. *TKA: Total knee arthroplasty, THA: Total hip arthroplasty*

Figure 2. Differences between OA patients suffering from poor sleep versus good sleep. Poor sleepers reported significantly higher pain (A), pain catastrophizing thoughts (B), anxiety (C), and depression (D). *PCS: Pain Catastrophizing Scale; Anxiety/Depression: Hospital Anxiety and Depression Scale*

Tables

Table 1. Demographics and descriptives of the patient cohort. Mean ± SD. *PCS: Pain Catastrophizing Scale, PSQI: Pittsburgh Sleep Quality Index, HADS: Hospital Anxiety and Depression Scale.*

	(N = 163)
Age	66.71 ± 13.63 (SD) years
Gender	99 m; 64 f
Surgical procedure (TKR/THR)	74 / 89
Preoperative pain intensity (0-10)	3.55 ± 2.3
PCS (0-52)	17.79 ± 12.25
PSQI (0-21)	7.91 ± 4.61
HADS (Anxiety; 0-21)	3.96 ± 3.36
HADS (Depression; 0-21)	2.31 ± 2.64



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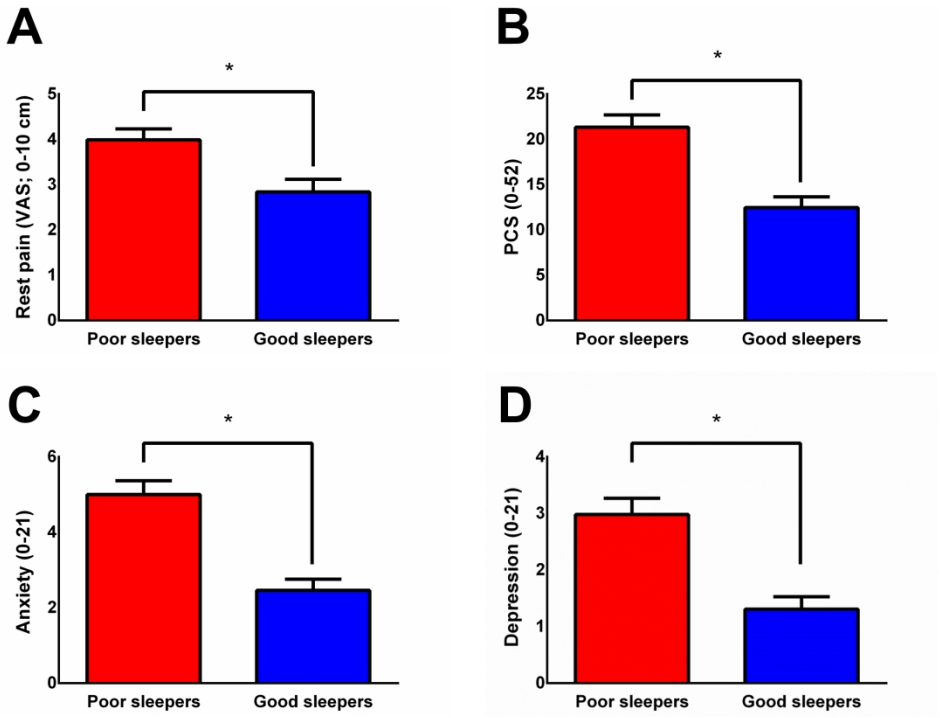
254x190mm (300 x 300 DPI)



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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	N/A – secondary analysis to primary trial
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	1
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3-4
	2b	Specific objectives or hypotheses	3-4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	4
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4-6
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	4
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	N/A
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	N/A
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	N/A
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	N/A

Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	N/A
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	N/A
	11b	If relevant, description of the similarity of interventions	
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	6
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	7
	13b	For each group, losses and exclusions after randomisation, together with reasons	7
Recruitment	14a	Dates defining the periods of recruitment and follow-up	4
	14b	Why the trial ended or was stopped	N/A
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	7
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	N/A
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	N/A
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	4
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	N/A
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	12
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	12
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	8-12
Other information			
Registration	23	Registration number and name of trial registry	1 & 5
Protocol	24	Where the full trial protocol can be accessed, if available	5
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	13

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.