Received: 30 March 2023 | Revised: 24 May 2023 | Accepted: 14 June 2023

DOI: 10.1111/jsr.13982

SHORT REPORT

The effect of sleep restriction therapy for insomnia on REM sleep fragmentation: A secondary analysis of a randomised controlled trial

Leonie Franziska Maurer[1,2] | Rachel Sharman[1] | Colin Alexander Espie[1,3] | Simon David Kyle[1]

[1]Sir Jules Thorn Sleep and Circadian Neuroscience Institute, Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, UK

[2]mementor DE GmbH, Leipzig, Germany

[3]Big Health Ltd, London, UK

Correspondence
Simon David Kyle, Sir Jules Thorn Sleep and Circadian Neuroscience Institute, Nuffield Department of Clinical Neurosciences, University of Oxford, Dorothy Crowfoot Hodgkin Building, South Parks Road, Oxford OX1 3QU, UK.
Email: simon.kyle@ndcn.ox.ac.uk

Funding information
Dr Mortimer and Theresa Sackler Foundation; National Institute for Health and Care Research (NIHR) Oxford Biomedical Research Centre (BRC); NIHR Oxford Health BRC; NIHR-Health Technology Assessment Programme, Grant/Award Number: HTA Project: 16/84/01

Summary

Rapid eye movement sleep fragmentation is hypothesised to be a reliable feature of insomnia, which may contribute to emotion dysregulation. Sleep restriction therapy, an effective intervention for insomnia, has the potential to reduce rapid eye movement sleep fragmentation through its manipulation of basic sleep–wake processes. We performed secondary data analysis of a randomised controlled trial to examine whether sleep restriction therapy reduces rapid eye movement sleep fragmentation in comparison to a matched control arm. Participants ($n = 56$; 39 female, mean age = 40.78 ± 9.08 years) were randomly allocated to 4 weeks of sleep restriction therapy or 4 weeks of time in bed regularisation. Ambulatory polysomnographic recordings were performed at baseline, week 1 and week 4. Arousals during rapid eye movement and non-rapid eye movement sleep were scored blind to group allocation. The following rapid eye movement sleep fragmentation index was the primary outcome: index 1 = (rapid eye movement arousals + rapid eye movement awakenings + non-rapid eye movement intrusions)/rapid eye movement duration in hours. Secondary outcomes were two further indices of rapid eye movement sleep fragmentation: index 2 = (rapid eye movement arousals + rapid eye movement awakenings)/rapid eye movement duration in hours; and index 3 = rapid eye movement arousals/rapid eye movement duration in hours. A non-rapid eye movement fragmentation index was also calculated (non-rapid eye movement arousals/non-rapid eye movement duration in hours). Linear-mixed models were fitted to assess between-group differences. There was no significant group difference for the primary rapid eye movement fragmentation index at week 1 ($p = 0.097$, $d = -0.31$) or week 4 ($p = 0.741$, $d = -0.06$). There was some indication that secondary indices of rapid eye movement fragmentation decreased more in the sleep restriction therapy group relative to control at week 1 (index 2: $p = 0.023$, $d = -0.46$; index 3: $p = 0.051$, $d = -0.39$), but not at week 4 ($d \leq 0.13$). No group effects were found for arousals during non-rapid eye movement sleep. We did not find clear evidence that sleep restriction therapy modifies rapid eye movement sleep fragmentation. Small-to-medium effect sizes in the

hypothesised direction, across several indices of rapid eye movement fragmentation during early treatment, demand further investigation in future studies.

KEYWORDS
insomnia, randomised controlled trial, rapid eye movement sleep, sleep restriction therapy

1 | INTRODUCTION

Rapid eye movement (REM) sleep is the most physiologically aroused brain state during sleep, and is characterised by muscle atonia, desynchronised electroencephalographic (EEG) activity, rapid eye movements, and dream mentation (Maquet et al., 1996). Another feature of REM sleep is the inhibition of the locus coeruleus (LC), a nucleus in the pons that releases norepinephrine during wakefulness and non-REM (NREM) sleep to promote long-term potentiation (Aston-Jones & Bloom, 1981). The silencing of the LC before NREM sleep spindles and during REM sleep is hypothesised to enable synaptic plasticity and aid memory consolidation (Swift et al., 2018). Incomplete LC silencing during REM sleep has been associated with EEG arousals and shifts to N1/N2 sleep stages and wakefulness (Aston-Jones et al., 2007).

Individuals with insomnia relative to controls experience more micro-arousals and awakenings during REM sleep (Feige et al., 2008; although see Feige et al., 2018 and Kao et al., 2021 for conflicting findings). Insomnia is therefore suggested to be characterised by *REM sleep instability* (Riemann et al., 2012) or *restless REM sleep* (Wassing et al., 2019a). Furthermore, interrupted REM sleep (cortical arousals and bouts of wakefulness/NREM sleep) attenuates the adaptive overnight decrease in amygdala reactivity (Wassing, Lakbila-Kamal, et al., 2019), a process linked to the overnight resolution of emotional distress (van der Helm et al., 2011), which may be dysfunctional in people with insomnia (Wassing et al., 2016). Together, these results suggest that unstable REM sleep may play a role in the pathophysiology of insomnia, interfering with basal processes of emotion regulation (Riemann et al., 2012), and potentially contributing to the development of common mental health problems like anxiety and depression (Hertenstein et al., 2019).

It has been hypothesised that curtailing time in bed (TIB; Van Someren, 2021) and reducing pre-sleep arousal (Vethe et al., 2022) may improve REM sleep consolidation. Sleep restriction therapy (SRT), an effective single component treatment for insomnia (Kyle et al., 2023; Maurer et al., 2021), systematically reduces TIB in order to consolidate and regularise sleep. We previously reported on a randomised controlled trial comparing SRT with a matched control arm (TIB regularisation; TBR). SRT was found to reduce insomnia symptoms and improve sleep continuity (Maurer et al., 2020), change sleep architecture during early intervention (reduced time spent in N1/N2 sleep), enhance sleep pressure and reduce pre-sleep arousal (Maurer et al., 2022). Given these findings, we performed unplanned exploratory analyses to assess for the first time if SRT reduces REM sleep fragmentation.

2 | METHODS

2.1 | Study design and participants

The MARTINI trial (ISRCTN10974094) was a parallel, randomised, controlled evaluation of SRT versus TBR. Fifty-six participants (39 female, mean age = 40.78 ± 9.08 years) meeting criteria for DSM-5 chronic insomnia disorder were assigned to 4 weeks of SRT ($n = 27$) or TBR ($n = 29$) after completing a baseline phase of 2 weeks. Exclusion criteria included: psychiatric diagnoses, symptoms of depression or anxiety (questionnaire-based cut-offs), alcohol misuse, other sleep disorders, CNS medication, shift work, and pregnancy. Both interventions were delivered across weekly 1:1 sessions. Bed- and rise-times were selected according to treatment-specific criteria. In the SRT group, participants were prescribed a sleep window that matched their average self-reported total sleep time (TST) for the previous 2 weeks (minimum TIB = 5 hr). In the TBR group, participants were prescribed a sleep window that matched their average self-reported TIB for the previous 2 weeks. More details can be found in the previous publications of this trial (Maurer et al., 2020, 2022). Polysomnography (PSG), from which REM sleep fragmentation was derived, was assessed at baseline, and at week 1 and week 4 post-randomisation alongside other study outcomes (see Maurer et al., 2020 for details).

The study was conducted in Oxfordshire, UK, and approved by the Central University Research Ethics Committee of the University of Oxford (CUREC R51331/RE005). The objectives for the present report were exploratory, but we registered our intentions with the Open Science Framework (10.17605/OSF.IO/5GR8A) prior to scoring of arousals and data analysis.

2.2 | Measures

2.2.1 | PSG acquisition and scoring

Sleep was recorded with a portable PSG system, SOMNO HD™ (Somnomedics GmbH, Germany) in participants' homes according to the recommended montage of the American Academy of Sleep Medicine (AASM; Iber, 2007). The set-up included six scalp electrodes (F3, F4, C3, C4, O3, O4), one ground electrode (forehead/FPz), one scalp reference electrode (CZ) and two reference electrodes placed on each mastoid process (M1, M2). Signals were sampled at 256 Hz, and filtered with a high-pass (0.2 Hz) and low-pass (35 Hz) filter. Recordings were blinded and scored according to AASM 2017 guidelines (Berry et al., 2017) by a trained sleep scorer (LFM). Reliability of sleep

stage scoring was confirmed by an ESRS-accredited Somnologist, who double-scored 10% of all recordings (agreement = 91.5%).

The EEG arousals during NREM and REM sleep were scored according to scoring recommendations by the Atlas task force of the American Sleep Disorder Association (Atlas task force, 1992). Because there is currently no standard for indexing REM sleep fragmentation in insomnia, multiple indices were derived. Of primary interest was the REM sleep fragmentation index (Wassing et al., 2019a), which included the number of cortical arousals and bouts of wakefulness or NREM sleep that interrupted REM episodes, the sum of which is then divided by the duration of all-night REM sleep (index 1 = [REM arousals + REM awakenings + NREM intrusions]/REM duration in hours). If a REM episode was interrupted by multiple shifts (e.g. wake and N1), only the first shift out of the REM epoch was counted. The combined index of REM arousals and awakenings from REM sleep per hour of REM sleep (REM arousal index) has been identified as the most sensitive to differentiate between patients with insomnia and good sleepers (Pérusse et al., 2015; Riemann et al., 2012; Wassing et al., 2019b), and is therefore presented alongside (index 2 = [REM arousals + REM awakenings]/REM duration in hours). In order to test whether any effects are specific to REM sleep, we also present the number of cortical arousals during REM sleep (index 3 = REM arousals/REM duration in hours) and NREM sleep (index 4 = NREM arousal/NREM duration in hours) (Feige et al., 2008, 2018).

2.3 | Statistical analyses

Available data from all randomised participants were analysed according to the intention to treat principle. For between-group comparisons, linear mixed-effects regression models were fitted for each of the fragmentation indices, with fixed effects of group and time point. Time point was entered as a repeated variable and participant as a random effect. Baseline values were added as covariate. An interaction between time point and group was included to estimate treatment effects at each time point. The covariance structure was set to unstructured. Cohen's *d* statistics were calculated as the adjusted treatment effect divided by the baseline standard deviation of the outcome for the combined groups (Cohen, 1988). Summary statistics are presented in the form of means and standard deviations. All analysis was conducted in SPSS.27 (IBM).

3 | RESULTS

One participant assigned to SRT withdrew from intervention and study procedures before the week 1 assessments. All other participants completed all treatment sessions and all assessments, yielding a total of 166 PSG recordings across groups and time points. Of these, two recordings were not suitable due to data loss (one baseline [TBR]

TABLE 1 Effects of SRT versus TBR on REM sleep fragmentation indices

	SRT			TBR							
	M	SD	*n*	M	SD	*n*	$Diff_{adj}$	95%	CI	*p*	ES
REM fragmentation index[a]											
Baseline	11.62	5.90	27	11.85	7.18	28					
Week 1	9.74	4.49	26	11.72	7.38	28	−2.06	−4.50	0.39	0.097	−0.31
Week 4	11.20	5.78	26	11.42	5.49	29	−0.39	−2.76	1.98	0.741	−0.06
REM arousal index[b]											
Baseline	10.73	5.68	27	10.69	6.94	28					
Week 1	8.22	4.52	26	10.94	7.39	28	−2.93	−5.43	−0.43	**0.023**	−0.46
Week 4	9.74	5.50	26	10.27	5.35	29	−0.80	−3.28	1.69	0.523	−0.13
Arousals per hr REM[c]											
Baseline	9.43	5.27	27	8.99	7.08	28					
Week 1	6.96	4.28	26	9.08	7.11	28	−2.38	−4.77	0.01	0.051	−0.39
Week 4	8.28	5.02	26	8.01	4.23	29	−0.12	−2.22	1.98	0.908	−0.02
Arousals per hr NREM[d]											
Baseline	7.69	4.64	27	8.33	3.93	28					
Week 1	6.33	2.95	26	7.17	2.47	28	−0.49	−1.65	0.66	0.395	−0.11
Week 4	6.58	3.48	26	8.14	3.67	29	−1.27	−3.02	0.49	0.153	−0.30

Note: Cohen's d. M and SD refer to unadjusted means and standard deviations.

Abbreviation: 95% CI, 95% confidence interval of the adjusted mean difference; $Diff_{adj}$, adjusted mean difference derived from linear mixed model; ES, effect size; NREM, non-rapid eye movement; REM, rapid eye movement; SRT, sleep restriction therapy; TBR, time in bed regularisation.

[a](REM arousals + REM awakenings + NREM intrusions)/REM duration in hours.

[b](REM arousals + REM awakenings)/REM duration in hours.

[c]REM arousals/REM duration in hours.

[d]NREM arousal/NREM duration in hours.

and one week 1 [TBR] recording). Both groups adhered to their prescribed sleep window as indicated by continuous sleep diary reports during the intervention: average bed- and rise-times deviated between 0 and 18 min for SRT, and between 5 and 14 min for TBR, when compared with prescribed bed- and rise-times (Maurer et al., 2020). There were also large between-group differences in sleep opportunity, with both actigraphy and diary data showing lower TIB in the SRT group versus control (Maurer et al., 2020).

To test whether SRT reduces REM sleep fragmentation, we first conducted between-group comparisons on the REM sleep fragmentation index (index 1 = [REM arousals + REM awakenings + NREM intrusions]/REM duration in hours) at week 1 and week 4 (see Table 1). The SRT group showed a small and non-significant reduction in REM fragmentation index relative to control at week 1 ($p = 0.097$, $d = -0.31$). No between-group effect was found at week 4 ($p = 0.741$, $d = -0.06$). For the REM arousal index (index 2 = [REM arousals + REM awakenings]/REM duration in hours), the SRT group showed a statistically significant reduction at week 1 ($p = 0.023$, $d = -0.46$) but no effect was observed at week 4 ($p = 0.523$, $d = -0.13$). For index 3 (REM arousals/REM duration in hours), there was a medium-sized effect at week 1 ($d = -0.39$) in support of SRT, but this did not reach statistical significance ($p = 0.051$). Again, no effect was found at week 4 ($p = 0.908$, $d = -0.02$). There were no group effects for number of NREM arousals (index 4) at week 1 ($p = 0.395$, $d = -0.11$) or week 4 ($p = 0.153$, $d = -0.30$).

4 | DISCUSSION

To our knowledge, this is the first study to examine whether SRT reduces REM sleep fragmentation, a proposed sleep characteristic of insomnia, in comparison to a matched control group. In the absence of a standard REM sleep fragmentation index, multiple indices were considered. We did not find clear evidence of a treatment effect of SRT on REM sleep fragmentation, with a statistically significant reduction being observed for just one of the three REM indices at one time point. However, small-to-medium effect sizes in favour of SRT across all indices suggest a potential reduction of REM sleep fragmentation at week 1 in comparison to TBR (d range = −0.31 to −0.46). The absence of group effects at week 4 suggests that any treatment effect due to SRT may be of a temporary nature and potentially driven by mild sleep deprivation and/or reductions in pre-sleep arousal, both of which were prominent during early treatment (Maurer et al., 2020, 2022). High-resolution studies, assessing nightly change in pre-sleep (cognitive) arousal and REM fragmentation during SRT implementation, would be needed to appraise potential causal pathways and temporal dynamics.

Limitations of this analysis need to be considered. First, this was a secondary analysis of previously collected data and therefore the study was not designed to investigate changes in REM specifically. While the analysis plan was registered prior to scoring of arousals, and the scorer was blind to treatment allocation and time point, other clinical and mechanistic outcomes, including sleep, were already known by the authors when performing this research. Second, effect sizes and p-values indicate that this study, which was designed to detect large effect sizes, may have been underpowered for appraising group differences in REM (and NREM) fragmentation variables. Third, the comparison group (TBR), while inferior to SRT (Maurer et al., 2020, 2022), *may* be therapeutically active through regularisation of TIB; and, therefore, our comparison could potentially *underestimate* the true effect of SRT on REM fragmentation. Future studies with a third arm (e.g. sleep hygiene or no treatment) would be needed to address this issue. Fourth, we analysed three correlated indices without adjustment for multiple testing. To let the reader judge, we provide exact statistical values and confidence intervals around the adjusted means. Fifth, data presented were collected as part of a mechanistic trial, which had strict inclusion and exclusion criteria. Consequently, results may not apply to the broader insomnia population.

In summary, results from this exploratory analysis indicate that SRT *may* have potential to decrease REM sleep fragmentation, a proposed manifestation of hyperarousal, but only during the acute treatment phase. Future, purposely-designed studies are warranted to assess whether SRT reliably (and selectively) modifies REM fragmentation, and whether changes relate to clinical improvement in symptoms and/or overnight emotion processing. To advance research, the field also needs to establish a clear definition of what constitutes marked or clinically relevant REM sleep fragmentation, and agree on a measurement hierarchy for outcome evaluation.

AUTHOR CONTRIBUTIONS

SDK was chief investigator and supervisor of this research, and helped draft the manuscript. LFM and SDK conceived of the study and study interventions, and led study design. LFM coordinated the trial, carried out statistical analysis and wrote the manuscript. RS contributed to the analysis plan, advised on polysomnographic set-up, scoring and analysis, and helped draft the manuscript. CAE contributed to the research design, supervised and helped design the clinical interventions, and helped to draft the manuscript. All authors reviewed and approved the final manuscript.

ACKNOWLEDGEMENTS

This research study was supported by the National Institute for Health and Care Research (NIHR), Oxford Biomedical Research Centre (BRC) and NIHR-Health Technology Assessment Programme (HTA Project: 16/84/01). SDK, RS and CAE are supported by the NIHR Oxford Health BRC. The views expressed are those of the authors, and not necessarily those of the NHS, the NIHR or the Department of Health. The research was also supported through a DPhil Scholarship (to LFM) from the Dr Mortimer and Theresa Sackler foundation.

CONFLICT OF INTEREST STATEMENT

CAE is co-founder of and shareholder in Big Health Ltd, a company that specialises in the digital delivery of cognitive behavioural therapy for sleep improvement (Sleepio). LFM is a salaried employee of mementor DE GmbH, a company that specialises in the digital delivery of cognitive behavioural therapy for sleep improvement in Germany (Somnio). The presented work was conducted outside these affiliations and is unrelated to the named products. SDK reports non-financial support from Big Health Ltd in the form of no-cost access to Sleepio for use in clinical trial research. All other investigators report no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ORCID

Leonie Franziska Maurer https://orcid.org/0000-0001-7335-2320
Colin Alexander Espie https://orcid.org/0000-0002-1294-8734
Simon David Kyle https://orcid.org/0000-0002-9581-5311

REFERENCES

Aston-Jones, G. S., & Bloom, F. E. (1981). Activity of norepinephrine-containing locus coeruleus neurons in behaving rats anticipates fluctuations in the sleep-waking cycle. *Journal of Neuroscience*, *1*(8), 876–886.

Aston-Jones, G. S., Gonzalez, M., & Doran, S. (2007). Role of the locus coeruleus-norepinephrine system in arousal and circadian regulation of the sleep–wake cycle. In A. Frazer, G. A. Ordway, & M. A. Schwartz (Eds.), *Brain norepinephrine: Neurobiology and therapeutics* (pp. 157–195). Cambridge University Press. https://doi.org/10.1017/CBO9780511544156.007

Atlas Task Force. (1992). EEG arousals: Scoring rules and examples: A preliminary report from the sleep disorders atlas task force of the American sleep disorders association. *Sleep*, *15*, 173–184.

Berry, R. B., Brooks, R., Gamaldo, C., Harding, S. M., Lloyd, R. M., Quan, S. F., & Vaughn, B. V.; for the American Academy of Sleep Medicine. (2017). *The AASM manual for the scoring of sleep and associated events: Rules, terminology and technical specifications*. American Academy of Sleep Medicine. Version 2.4.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences–second edition* (Vol. 13). 12 Lawrence Erlbaum Associates Inc.

Feige, B., Al-Shajlawi, A., Nissen, C., Voderholzer, U., Hornyak, M., Spiegelhalder, K., Kloepfer, C., Perlis, M., & Riemann, D. (2008). Does REM sleep contribute to subjective wake time in primary insomnia? A comparison of polysomnographic and subjective sleep in 100 patients. *Journal of Sleep Research*, *17*(2), 180–190. https://doi.org/10.1111/j.1365-2869.2008.00651.x

Feige, B., Nanovska, S., Baglioni, C., Bier, B., Cabrera, L., Diemers, S., Quellmalz, M., Siegel, M., Xeni, I., Szentkiralyi, A., & Doerr, J. P. (2018). Insomnia—Perchance a dream? Results from a NREM/REM sleep awakening study in good sleepers and patients with insomnia. *Sleep*, *41*(5). https://doi.org/10.1093/sleep/zsy032

Hertenstein, E., Feige, B., Gmeiner, T., Kienzler, C., Spiegelhalder, K., Johann, A., Jansson-Fröjmark, M., Palagini, L., Rücker, G., Riemann, D., & Riemann, D. (2019). Insomnia as a predictor of mental disorders: A systematic review and meta-analysis. *Sleep Medicine Reviews*, *43*, 96–105. https://doi.org/10.1016/j.smrv.2018.10.006

Iber, C. (2007). *The AASM manual for the scoring of sleep and associated events: Rules*. Terminology and Technical Specification.

Kao, C. H., D'Rozario, A. L., Lovato, N., Wassing, R., Bartlett, D., Memarian, N., Espinel, P., Kim, J. W., Grunstein, R. R., & Gordon, C. J. (2021). Insomnia subtypes characterised by objective sleep duration and NREM spectral power and the effect of acute sleep restriction: An exploratory analysis. *Scientific Reports*, *11*, 24331. https://doi.org/10.1038/s41598-021-03564-6

Kyle, S. D., Siriwardena, A. N., Espie, C. A., Yang, Y., Ogburn, E., & Aveyard, P. (2023). Clinical and cost-effectiveness of nurse-delivered sleep restriction therapy for insomnia in primary care: A pragmatic randomised controlled trial. *The Lancet in press*.

Maquet, P., Péters, J.-M., Aerts, J., Delfiore, G., Degueldre, C., Luxen, A., & Franck, G. (1996). Functional neuroanatomy of human rapid-eye-movement sleep and dreaming. *Nature*, *383*(6596), 163–166. https://doi.org/10.1038/383163a0

Maurer, L. F., Espie, C. A., Omlin, X., Emsley, R., & Kyle, S. D. (2022). The effect of sleep restriction therapy for insomnia on sleep pressure and arousal: A randomized controlled mechanistic trial. *Sleep*, *45*(1). https://doi.org/10.1093/sleep/zsab223

Maurer, L. F., Espie, C. A., Omlin, X., Reid, M. J., Sharman, R., Gavriloff, D., Emsley, R., & Kyle, S. D. (2020). Isolating the role of time in bed restriction in the treatment of insomnia: A randomized, controlled, dismantling trial comparing sleep restriction therapy with time in bed regularization. *Sleep*, *43*(11). https://doi.org/10.1093/sleep/zsaa096

Maurer, L. F., Schneider, J., Miller, C. B., Espie, C. A., & Kyle, S. D. (2021). The clinical effects of sleep restriction therapy for insomnia: A meta-analysis of randomised controlled trials. *Sleep Medicine Reviews*, *58*, 101493. https://doi.org/10.1016/j.smrv.2021.101493

Pérusse, A. D., Pedneault-Drolet, M., Rancourt, C., Turcotte, I., St-Jean, G., & Bastien, C. H. (2015). REM sleep as a potential indicator of hyperarousal in psychophysiological and paradoxical insomnia sufferers. *International Journal of Psychophysiology*, *95*(3), 372–378. https://doi.org/10.1016/j.ijpsycho.2015.01.005

Riemann, D., Spiegelhalder, K., Nissen, C., Hirscher, V., Baglioni, C., & Feige, B. (2012). REM sleep instability–a new pathway for insomnia? *Pharmacopsychiatry*, *45*(5), 167–176. https://doi.org/10.1055/s-0031-1299721

Swift, K. M., Gross, B. A., Frazer, M. A., Bauer, D. S., Clark, K. J. D., Vazey, E. M., Aston-Jones, G., Li, Y., Pickering, A. E., Sara, S. J., & Sara, S. J. (2018). Abnormal locus coeruleus sleep activity alters sleep signatures of memory consolidation and impairs place cell stability and spatial memory. *Current Biology*, *28*(22), 3599–3609. https://doi.org/10.1016/j.cub.2018.09.054

van der Helm, E., Yao, J., Dutt, S., Rao, V., Saletin, J. M., & Walker, M. P. (2011). REM sleep Depotentiates amygdala activity to previous emotional experiences. *Current Biology*, *21*(23), 2029–2032. https://doi.org/10.1016/j.cub.2011.10.052

Van Someren, E. J. W. (2021). Brain mechanisms of insomnia: New perspectives on causes and consequences. *Physiological Reviews*, *101*(3), 995–1046. https://doi.org/10.1152/physrev.00046.2019

Vethe, D., Drews, H. J., Scott, J., Engstrøm, M., Heglum, H. S. A., Grønli, J., Wisor, J. P., Sand, T., Lydersen, S., Kjørstad, K., & Faaland, P. M. (2022). Evening light environments can be designed to consolidate and increase the duration of REM-sleep. *Scientific Reports*, *12*(1), 8719. https://doi.org/10.1038/s41598-022-12408-w

Wassing, R., Benjamins, J. S., Dekker, K., Moens, S., Spiegelhalder, K., Feige, B., Riemann, D., van der Sluis, S., Van Der Werf, Y. D., Talamini, L. M., & Walker, M. P. (2016). Slow dissolving of emotional distress contributes to hyperarousal. *Proceedings of the National Academy of Sciences*, *113*(9), 2538–2543. https://doi.org/10.1073/pnas.152252011

Wassing, R., Lakbila-Kamal, O., Ramautar, J. R., Stoffers, D., Schalkwijk, F., & Van Someren, E. J. (2019). Restless REM sleep impedes overnight amygdala adaptation. *Current Biology*, *29*(14), 2351–2358. https://doi.org/10.1016/j.cub.2019.06.034

Wassing, R., Schalkwijk, F., Lakbila-Kamal, O., Ramautar, J. R., Stoffers, D., Mutsaerts, H. J. M. M., Talamini, L. M., & Van Someren, E. J. W. (2019). Haunted by the past: Old emotions remain salient in insomnia disorder. *Brain*, *142*(6), 1783–1796. https://doi.org/10.1093/brain/awz089

How to cite this article: Maurer, L. F., Sharman, R., Espie, C. A., & Kyle, S. D. (2024). The effect of sleep restriction therapy for insomnia on REM sleep fragmentation: A secondary analysis of a randomised controlled trial. *Journal of Sleep Research*, *33*(1), e13982. https://doi.org/10.1111/jsr.13982