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Genesis of sleep bruxism: Motor and autonomic-cardiac interactions

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ABSTRACT

This is a short review paper presenting hypothesis to explain the mechanism that may be involved in the genesis of sleep bruxism (SB). In humans, SB is a repetitive sleep movement disorder mainly characterized by rhythmic masticatory muscle activity (RMMA) at a frequency of 1 Hz and by occasional tooth grinding. Until recently, the mechanism by which RMMA and SB episodes are triggered has been poorly understood. It is reported that during light sleep, most SB episodes are observed in relation to brief cardiac and brain reactivations (3–15 s) termed "micro-arousals". We showed that RMMA are secondary to a sequence of events in relation to sleep micro-arousals: the heart (increase in autonomic sympathetic activity) and brain are activated in the minutes and seconds, respectively, before the onset of activity in suprahyoid muscles and finally by RMMA in jaw closing masseter or temporalis muscles. In non-human primate study, we have shown that the excitability of cortico-bulbar pathways is depressed during sleep; no rhythmic jaw movements (RJM) are observed following intracortical microstimulation (ICMS) of cortical masticatory area (CMA) during sleep compared to the quiet awake state.

The above results suggest that the onset of RMMA and SB episodes during sleep are under the influences of brief and transient activity of the brainstem arousal—reticular ascending system contributing to the increase of activity in autonomic-cardiac and motor modulatory networks.

1. Definition and recognition of sleep bruxism

Sleep bruxism (SB) is defined as a stereotyped movement disorder occurring during sleep and characterized by tooth grinding (TG) and/or clenching.[1] SB should be distinguished from the daytime-awake bruxism that is mainly related to "stress/anxiety" reactivity and expressed as a jaw muscle clenching habit/tic. In the presence of medical disorders, medication or drug use, TG is described as secondary or iatrogenic.[2–5] In normal subjects, SB-TG is considered to be

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Abbreviations: SB, sleep bruxism; RMMA, rhythmic masticatory muscle activity; RJM, rhythmic jaw movement; ICMS, intracortical microstimulation; CMA, cortical masticatory area; TG, tooth grinding; OR, odds ratio; EEG, electroencephalographic; PPT, peduculopontine tegmentum; CAP, cyclic alternating pattern; MAD, mandibular advancement device; CPG, central pattern generator; MA, micro-arousal

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primary and is reported by 8% of the adult population. Its prevalence decreases with age from 14% in childhood to 3% in the elderly[6–9]; no gender difference is observed.

The consequences of SB may be tooth destruction, temporomandibular joint and muscle pain or jaw lock, temporal headaches and cheek-biting (worse if xerostomia).[2,10] The odds ratio (OR) of reporting temporomandibular disorders or chronic myofascial pain of masticatory muscles, when clenching and/or grinding are concomitant, have been estimated at between 4.2 and 8.4.[11,12] Up to 65% of SB patients of all ages report headaches.[13,14] The noise made by the TG can greatly disturb the sleep of bedroom partners. The following major risk factors have been shown to exacerbate SB-TG: (1) smoking, caffeine and heavy alcohol drinking[8,15]; (2) type A personality—anxiety[2,8,16–18]; (3) sleep disorders such as snoring (OR:1.4), sleep apnea (OR:1.8) or periodic limb movements (concomitant in 10%).[2,5,6,8,10,19]

Clinically, SB is diagnosed following report by the sleep partner or parent of recent/frequent TG (this is the most reliable criterion), the presence of tooth wear or jaw muscle hypertrophy, and awareness of jaw clenching while awake.[2] The sleep laboratory diagnosis of SB requires that it be distinguished from other oromandibular activity during sleep (e.g., oromandibular myoclonus, swallowing, coughing, grunting, tooth tapping, vocalization, etc.) that may represent up to 30% of all oral activities during sleep.[20–22] Episodes of jaw muscle contractions are scored as moderate to severe SB if more than four EMG events per hour of sleep are noted.[20] The final diagnosis is made if at least two SB episodes per night are associated with TG noise.

2. Hypotheses on genesis of SB

Various hypotheses have been proposed to explain SB: changes in dental occlusion but no strong evidence-based data support this hypothesis[23]; stress and anxiety has also been suggested[2,5,8,16–18]; involvement of the dopaminergic system that remains to be confirmed since in most randomised experimental trials with dopaminergic medications (e.g., L-dopa, bromocriptine), the onset of SB episodes is only marginally reduced.[24,25] During wakefulness, dopamine has a role in the execution of movement and in maintaining vigilance; during sleep the dopaminergic system is probably minimally active at the exception of brief period of arousal related movements such as periodic limb movements.[26]

2.1. *Descending influences from cortex during sleep*

Another hypothesis on genesis of RMMA during sleep is that, conversely to wake state, cortico-bulbar influences are not dominant during sleep. The top-down circuits seem to be partially de-activated during sleep to preserve the so-called sleep continuity.[27,28] The following evidences support this hypothesis in the physiopathology of SB: (1) a specific increase in the cortical activity, over the motor cortex, precedes most limb movements. This brief and large deflection of brain wave activity is termed pre-motor potential. We have found that RMMA are not preceded by such pre-motor cortical potential during sleep (Kato et al., unpublished observation). This suggests that SB is not generated by a clear pattern of cortical activation. (2) We also found, during sleep of SB patients, that SB episodes are not associated with the so-called cortical K complexes that are electroencephalographic (EEG) marker of sudden changes in brain endogenous activity or secondary to sounds influences.[29] (3) In order to better understand the "basis" of the genesis of RJM, we directly tested if cortico-bulbar pathways remain active during sleep of primates (macaca fascicularis). We observed that the intracortical microstimulation (ICMS) threshold did not evoke RMMA (or a rhythmic jaw movements = RJM) responses from the cortical masticatory area (CMA) during light non-REM sleep (stages 1 and 2 in humans) in comparison to the quiet awake state.[30] However, as soon as the animal wakes up, there is a rapid return of RJM at ICMS threshold levels comparable to pre-sleep. These preliminary data suggest that the geneses of RJM or RMMA during sleep are probably not directly under the influence of the cortical network as seen during wake state.

2.2. *Sleep micro-arousal: brain and autonomic reactivation toward arousal*

It is possible that the sudden onset of RMMA during sleep is occurring in brief time windows at which the brain is switching from sleep to an aroused state. These periods are termed micro-arousal which is defined as 3–15 s abrupt shifts in EEG activity accompanied by a rise in heart rate and muscle tone.[31] Micro-arousals (MA) tends to recur 8–15 times per hour of sleep in young healthy subjects.[32,33]

To better understand the role of MA in sleep it is important to revise how sleep in initiated and maintained. To initiate non-REM (rapid eye movement) sleep, a massive inhibition of GABA on brain arousal ascending system is needed to reverse the influences of arousal related orexin/hypocretin, from the hypothalamus, and on acetylcholine, noradrenalin, histamine and serotonin brain networks.[34,35] Moreover, from the onset of sleep, a reduction in muscle tone to a clear hypotonia or a near limb paralysis in the REM sleep stages is observed. It is further suggested that the reduction of muscle tone during REM sleep is under the influences of noradrenergic neurons of the peduculopontine tegmentum (PPT) neurons and of GABA and glycine inhibition on both brainstem and spinal cord motoneurons.[34–38]

SB tends to occur in relation to recurrent MA within the so-called cyclic alternating pattern or CAP.[39] As described above MA are characterized by a repetitive rise in heart and brain activity within sleep and are thought to reflect a natural process that acts as a sensor for maintaining body homeostasis and as a protective sentinel during sleep.[40] We explored the role of MA, as a physiological state that may increase the probability of initiating an episode of SB, with the use of a sensory vibrator during sleep. Experimentally induced RMMA related MA were followed by TG in over 70% of trials in SB patients only and not in control subjects.[41] Our laboratory has further demonstrated that the onset of SB is related to a sequence of physiological activations in relation to the MA (see Fig. 1)[42,43]:

(1) A rise in sympathetic cardiac activity around 4 min before RMMA.

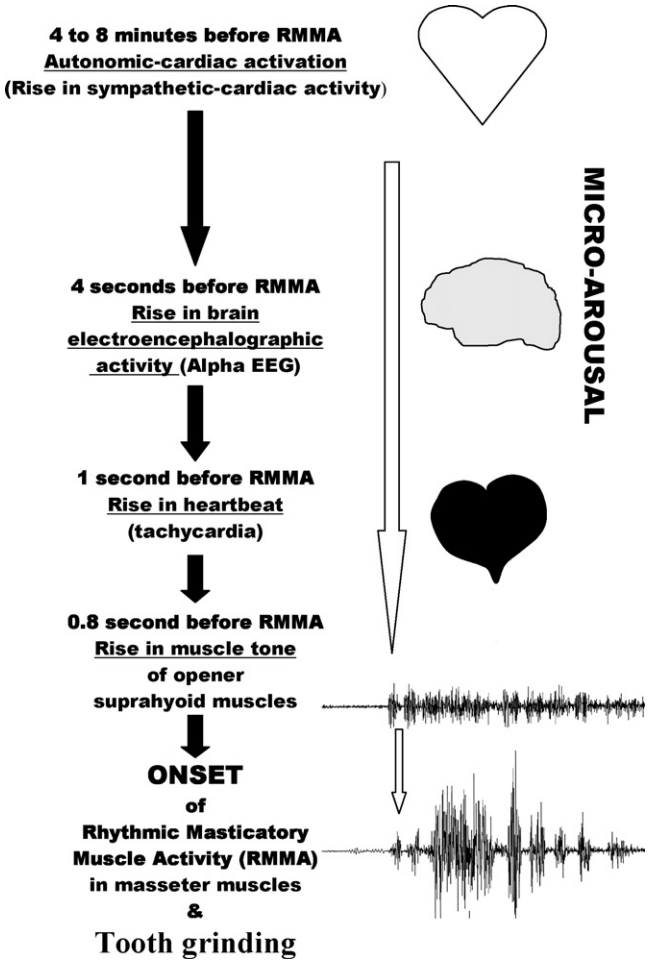

Fig. 1 – Sequence of physiological events in relation to micro-arousals, which precedes (from 4 to 8 min before) rhythmic masticatory muscle activity (RMMA) associated to sleep bruxism–tooth grinding in human sleep.

(2) A rise in the frequency of EEG activity 4 s before RMMA.
(3) A tachycardia starting one heart beat before RMMA.
(4) An increase in jaw-opener ''suprahyoid'' muscle activity (probably responsible for mandible and airway opening) 0.8 s before RMMA.
(5) Finally, RMMA EMG episodes scored as SB on masseter muscles, with or without TG.

Interestingly, we have recently shown that we can prevent the cardiac-sympathetic over-activation associated to SB episodes (step #1 of SB sequence, Fig. 1) by the use of the alpha-adrenergic agonist clonidine. The administration of clonidine at bedtime reduces cardiac-sympathetic activity and, secondarily, the number of SB episodes by 60%.[44] We further showed in a preliminary study that we could reduce the number of SB episodes by opening the airway (step #4 of SB sequence) since a mandibular advancement device (MAD) used in SB patients reduced (by 60%) the probability of SB episodes. However, these preliminary data require cautious interpretation since the MADs tend to trigger jaw discomfort that may have influenced the outcomes.[45]

Then, our data suggest that the episodic and transient re-activation of arousal ascending system may be associated to the sudden apparition of RMMA in relation to ''permissive'' excitation or disinhibition (inhibition of inhibition) on some motor trigeminal neuron or interneuron of the central pattern generator (CPG) network responsible of RMMA. The rhythm of jaw movements generated during bruxism is at 1 Hz frequency. Also, in contrast to mastication, sleep-related RMMA are characterized by co-contraction of opening and closing jaw muscles and these purposeless movements rarely last more than 8 s.[20,46]

3. Conclusion

The above results suggest that the onset of RMMA and SB episodes during sleep are under the influence of the brainstem arousal—reticular ascending system contributing to the increase of activity in motor and autonomic-cardiac neuronal networks.

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REFERENCES

1. AASM. *International Classification of Sleep Disorders*. 2nd ed. Westchester: American Academy of Sleep Medicine; 2005.
2. Lavigne GJ, Manzini C, Kato T. Sleep bruxism. In: Kryger MH, Roth T, Dement WC, editors. *Principles & Practice of Sleep Medicine*. Philadelphia: Elsevier Saunders; 2005. p. 946–59.
3. Micheli F, Pardal MF, Gatto M, Asconapé J, Giannaula R, Parera IC. Bruxism secondary to chronic antidopaminergic drug exposure. *Clin Neuropharmacol* 1993;**16**(4):315–23.
4. Vollenweider FX, Gamma A, Liechti M, Huber T. Psychological and cardiovascular effects and short-term sequelae of MDMA (Ecstasy) in MDMA-naïve healthy volunteers. *Neuropsychopharmacology* 1998;**19**:241–51.
5. Lavigne GJ, Manzini C, Kato T. Sleep bruxism. In: Kryger MH, Roth T, Dement WC, editors. *Principles & practice of sleep medicine*. Philadelphia: Elsevier Saunders; 2005. p. 946–59.
6. Lavigne GJ, Montplaisir JY. Restless legs syndrome and sleep bruxism: prevalence and association among Canadians. *Sleep* 1994;**17**(8):739–43.
7. Laberge L, Tremblay RE, Vitaro F, Montplaisir J. Development of parasomnias from childhood to early adolescence. *Pediatrics* 2000;**106**(1):67–74.
8. Ohayon MM, Li KK, Guilleminault C. Risk factors for sleep bruxism in the general population. *Chest* 2001;**119**(1): 53–61.
9. Ng DK, Kwok KL, Cheung JM, Leung SY, Chow PY, Wong WH, et al. Prevalence of sleep problems in Hong Kong primary school children: a community-based telephone survey. *Chest* 2005;**128**(3):1315–23.
10. Bader G, Lavigne G. Sleep bruxism; an overview of an oromandibular sleep movement disorder. Review article. *Sleep Med Rev* 2000;**4**(1):27–43.
11. Huang GJ, LeResche L, Critchlow CW, Martin MD, Drangsholt MT. Risk factors for diagnostic subgroups of painful

temporomandibular disorders (TMD). *J Dent Res* 2002;**81**(4):284–8.
12. Velly AM, Gornitsky M, Philippe P. Contributing factors to chronic myofascial pain: a case-control study. *Pain* 2003;**104**(3):491–9.
13. Bader GG, Kampe T, Tagdae T, Karlsson S, Blomqvist M. Descriptive physiological data on a sleep bruxism population. *Sleep* 1997;**20**(11):982–90.
14. Camparis CM, Siqueira JTT. Sleep bruxism: clinical aspects and characteristics in patients with and without chronic orofacial pain. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2006;**101**:188–93.
15. Lavigne GL, Lobbezoo F, Rompre PH, Nielsen TA, Montplaisir J. Cigarette smoking as a risk factor or an exacerbating factor for restless legs syndrome and sleep bruxism. *Sleep* 1997;**20**(4):290–3.
16. Major M, Rompre PH, Guitard F, Tenbokum L, O'Connor K, Nielsen T, et al. A controlled daytime challenge of motor performance and vigilance in sleep bruxers. *J Dent Res* 1999;**78**(11):1754–62.
17. Pingitore G, Chrobak V, Petrie J. The social and psychologic factors of bruxism. *J Prosthet Dent* 1991;**65**:443–6.
18. Pierce CJ, Chrisman K, Bennett ME, Close JM. Stress, anticipatory stress, and psychologic measures related to sleep bruxism. *J Orofacial Pain* 1995;**9**(1):51–6.
19. Sjoholm TT, Lowe AA, Miyamoto K, Fleetham JA, Ryan CF. Sleep bruxism in patients with sleep-disordered breathing. *Arch Oral Biol* 2000;**45**(10):889–96.
20. Lavigne GJ, Rompre PH, Montplaisir JY. Sleep bruxism: validity of clinical research diagnostic criteria in a controlled polysomnographic study. *J Dent Res* 1996;**75**(1):546–52.
21. Velly-Miguel AM, Montplaisir J, Rompré PH, Lund JP, Lavigne GJ. Bruxism and other orofacial movements during sleep. *J Craniomand Dis Fac Oral Pain* 1992;**6**:71–81.
22. Kato T, Montplaisir JY, Blanchet PJ, Lund JP, Lavigne GJ. Idiopathic myoclonus in the oromandibular region during sleep: a possible source of confusion in sleep bruxism diagnosis. *Mov Disord* 1999;**14**(5):865–71.
23. Kato T, Thie NM, Huynh N, Miyawaki S, Lavigne GJ. Topical review: sleep bruxism and the role of peripheral sensory influences. *J Orofac Pain* 2003;**17**(3):191–213.
24. Lobbezoo F, Lavigne GJ, Tanguay R, Montplaisir JY. The effect of catecholamine precursor L-dopa on sleep bruxism: a controlled clinical trial. *Mov Disord* 1997;**12**(1):73–8.
25. Lavigne GJ, Soucy JP, Lobbezoo F, Manzini C, Blanchet PJ, Montplaisir JY. Double-blind, crossover, placebo-controlled trial of bromocriptine in patients with sleep bruxism. *Clin Neuropharmacol* 2001;**24**(3):145–9.
26. Mignot E, Taheri S, Nishino S. Sleeping with the hypothalamus: emerging therapeutic targets for sleep disorders. *Nat Neurosci* 2002;**5**(Suppl):1071–5.
27. Steriade M, Timofeev I, Grenier F. Natural waking and sleep states: a view from inside neocortical neurons. *J Neurophysiol* 2001;**85**(5):1969–85.
28. Massimini M, Ferrarelli F, Huber R, Esser SK, Singh H, Tononi G. Breakdown of cortical effective connectivity during sleep. *Science* 2005;**309**(5744):2228–32.
29. Lavigne GJ, Rompre PH, Guitard F, Sessle BJ, Kato T, Montplaisir JY. Lower number of K-complexes and K-alphas in sleep bruxism: a controlled quantitative study. *Clin Neurophysiol* 2002;**113**(5):686–93.
30. Adachi K, Rompre S, Yao D, Lavigne G, Sessle BJ. Loss of corticobulbar motor excitability during sleep in primates: preliminary findings. *Society for Neuroscience 35th meeting*. Washington, DC. 2005:399.17.
31. EEG arousals: scoring rules and examples: a preliminary report from the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association. Sleep 1992;15(2): 173–184.
32. Parrino L, Smerieri A, Rossi M, Terzano MG. Relationship of slow and rapid EEG components of CAP to ASDA arousals in normal sleep. *Sleep* 2001;**24**(8):881–5.
33. Boselli M, Parrino L, Smerieri A, Terzano MG. Effect of age on EEG arousals in normal sleep. *Sleep* 1998;**21**(4):351–7.
34. Nelson LE, Guo TZ, Lu J, Saper CB, Franks NP, Maze M. The sedative component of anesthesia is mediated by GABA(A) receptors in an endogenous sleep pathway. *Nat Neurosci* 2002;**5**(10):979–84.
35. Saper CB, Scammell TE, Lu J. Hypothalamic regulation of sleep and circadian rhythms. *Nature* 2005;**437**(7063):1257–63.
36. Montagna P. Hypothalamus, sleep and headaches. *Neurol Sci* 2006;**27**(Suppl 2):S138–43.
37. Pal D, Mallick BN. Role of noradrenergic and GABA-ergic inputs in pedunculopontine tegmentum for regulation of rapid eye movement sleep in rats. *Neuropharmacology* 2006;**51**(1):1–11.
38. Hou RH, Freeman C, Langley RW, Szabadi E, Bradshaw CM. Does modafinil activate the locus coeruleus in man? Comparison of modafinil and clonidine on arousal and autonomic functions in human volunteers. *Psychopharmacology (Berl)* 2005;**181**(3):537–49.
39. Macaluso GM, Guerra P, Di Giovanni G, Boselli M, Parrino L, Terzano MG. Sleep bruxism is a disorder related to periodic arousals during sleep. *J Dent Res* 1998;**77**(4):565–73.
40. Terzano MG, Parrino L. Origin and significance of the cyclic alternating pattern (CAP): review article. *Sleep Med* 2000;**4**(1):101–23.
41. Kato T, Montplaisir JY, Guitard F, Sessle BJ, Lund JP, Lavigne GJ. Evidence that experimentally induced sleep bruxism is a consequence of transient arousal. *J Dent Res* 2003;**82**(4): 284–8.
42. Kato T, Rompre P, Montplaisir JY, Sessle BJ, Lavigne GJ. Sleep bruxism: an oromotor activity secondary to micro-arousal. *J Dent Res* 2001;**80**(10):1940–4.
43. Huynh N, Kato T, Rompré PH, Okura K, Saber M, Montplaisir JY, et al. Sleep bruxism is associated to mico-arousals and an increase in cardiac sympathetic activity. *J Sleep Res* 2006;**15**(3):339–46.
44. Huynh N, Lavigne GJ, Lanfranchi P, Montplaisir J, de Champlain J. The effect of two sympatholytic medications, propranolol and clonidine, on sleep bruxism: experimental randomized controlled trials. *Sleep* 2006;**29**(3):307–16.
45. Landry M-L, Rompré PH, Manzini C, Guitard F, de Grandmont P, Lavigne GJ. Reduction of sleep bruxism using a Mandibular advancement device: an experimental controlled study. *Int J Prosthodont* 2006;**19**:549–56.
46. Lavigne GJ, Kato T, Kolta A, Sessle BJ. Neurobiological mechanisms involved in sleep bruxism. *Crit Rev Oral Biol Med* 2003;**14**(1):30–46.