Rapid Eye Movement (REM) Sleep Behavior Disorder and REM Sleep with Atonia in the Young

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ABSTRACT: *Background:* Rapid eye movement (REM) sleep behavior disorder (RBD) and REM sleep without atonia (RWA) have assumed much clinical importance with long-term data showing progression into neurodegenerative conditions among older adults. However, much less is known about RBD and RWA in younger populations. This study aims at comparing clinical and polysomnographic (PSG) characteristics of young patients presenting with RBD, young patients with other neurological conditions, and normal age-matched subjects. *Methods:* A retrospective chart review was carried out for consecutive young patients (<25 years) presenting with clinical features of RBD; and data were compared to data from patients with epilepsy, attention deficit hyperactivity disorder (ADHD), and autism, as well as normal subjects who underwent PSG during a 2-year-period. *Results:* Twelve patients fulfilling RBD diagnostic criteria, 22 autism patients, 10 with ADHD, 30 with epilepsy, and 14 normal subjects were included. Eight patients with autism (30%), three with ADHD (30%), one with epilepsy (3.3%), and six patients who had presented with RBD like symptoms (50%) had abnormal movements and behaviors during REM sleep. Excessive transient muscle activity and/or sustained muscle activity during REM epochs was found in all patients who had presented with RBD, in 16/22 (72%) autistic patients, 6/10 (60%) ADHD patients compared to only 6/30 (20%) patients with epilepsy and in none of the normal subjects. *Conclusion:* We observed that a large percentage of young patients with autism and ADHD and some with epilepsy demonstrate loss of REM-associated atonia and some RBD-like behaviors on polysomnography similar to young patients presenting with RBD.

RÉSUMÉ: Troubles du comportement en sommeil paradoxal et sommeil paradoxal sans atonie musculaire chez les jeunes. *Contexte*: Les troubles du comportement en sommeil paradoxal (TCSP) et le sommeil paradoxal sans atonie musculaire ont acquis une grande importance clinique. En effet, des données à long terme ont montré de quelle façon ils pouvaient progresser chez des adultes âgés atteints de maladies neurodégénératives. Toutefois, on en sait beaucoup moins au sujet des TCSP et du sommeil paradoxal sans atonie musculaire au sein des groupes d'âges plus jeunes. Cette étude entend donc comparer les caractéristiques cliniques et polysomnographiques (PSG) de jeunes patients donnant à voir des signes de TCSP à celles d'autres jeunes patients atteints d'autres troubles neurologiques et de sujets en bonne santé appariés en fonction de l'âge. ***Méthodes*:** Nous avons passé en revue de façon rétrospective les dossiers de jeunes patients (< 25 ans) donnant à voir des signes cliniques de TCSP et ayant été vus consécutivement. Les données recueillies ont été comparées aux données de patients atteints d'épilepsie, de troubles de l'attention avec hyperactivité et d'autisme ainsi qu'à celles de sujets en bonne santé soumis à des examens de PSG pendant une période de deux ans. ***Résultats*:** Au total, on a diagnostiqué chez 12 patients des TCSP. Ajoutons que 22 d'entre eux étaient atteints d'autisme alors que 10 étaient atteints de troubles de l'attention avec hyperactivité et 30 d'épilepsie. Mentionnons par ailleurs que 14 sujets en bonne santé ont été inclus dans cette étude. Après analyse, il s'est avéré que 8 patients atteints d'autisme (30 %), 3 de troubles de l'attention avec hyperactivité (30 %), 1 d'épilepsie (3,3 %) et 6 ayant donné à voir des symptômes ressemblant à ceux des TCSP (50 %) montraient des mouvements et des comportement anormaux en sommeil paradoxal. Des signes d'activité musculaire transitoire excessive et/ou d'activité musculaire durable lors d'épisodes de sommeil paradoxal ont été détectés chez tous les patients satisfaisant aux critères des TCSP, chez 16 patients autistes sur 22 (72 %), chez 6 patients atteint de troubles de l'attention avec hyperactivité sur 10 (60 %) en comparaison avec seulement 6 patients épileptiques sur 30 (20 %) et aucun parmi les sujets en bonne santé. ***Conclusion*:** Lors d'examens polysomnographiques, nous avons en définitive observé qu'une forte proportion de jeunes patients atteints d'autisme et de troubles de l'attention avec hyperactivité, ainsi que quelques-uns atteints d'épilepsie, donnaient à voir des signes de perte de sommeil paradoxal associés à l'atonie musculaire ainsi que des comportements ressemblant à ceux de jeunes patients atteints de TCSP.

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INTRODUCTION

While many rapid eye movement (REM) sleep parasomnias have been described, a vast majority comprise the REM sleep behavior disorder (RBD), which is largely an illness seen among elderly males.[1] The clinical significance of RBD is now well established, not only for its medicolegal implications due to the violent nature of the abnormal movements during sleep but also mainly for the progression in more than 80% of patients with RBD to a neurodegenerative disorder, mostly synucleinopathies.[2] Over the past decades, a number of case reports have also described many conditions, which can have RBD as a manifestation of underlying neurological illness, for example, narcolepsy, brainstem lesions, encephalitis, autism, and others.[3–8] Among these, many patients are younger than the usual age of presentation of the commoner idiopathic RBD which may precede or is co-existent with neurodegenerative conditions such as Parkinson's disease, dementia with Lewy bodies, or multiple system atrophy.

The entity of REM sleep without atonia (RWA) has assumed much clinical importance since it is the essential polysomnographic (PSG) manifestation of RBD. The long-term clinical significance of isolated RWA remains a subject of investigation.[9]

The current study aims at evaluating clinical and PSG characteristics of young patients diagnosed to have RBD and to compare their REM sleep features with age-matched healthy controls and with patients suffering from autism, attention deficit hyperactivity disorder (ADHD), and epilepsy.

METHODS

This is a retrospective chart review-based study, including young subjects from the Neurology services sleep disorders facility at our center, an apex quaternary-care academic center, over a 2-year study period between 2012 and 2014.

Study Subjects

Consecutive young subjects, who were less than 25 years of age and who underwent video-PSG at our center, formed the study population. These were classified into the following groups:

(i) patients diagnosed with RBD, having been evaluated through the sleep disorders facility for abnormal behaviors during sleep,
(ii) patients with autism spectrum disorder,
(iii) patients with ADHD,
(iv) patients with epilepsy, and
(v) healthy age-matched control subjects

all of whom were in the same age group and underwent video-PSG during the same study period.

Patients with an established video-PSG diagnosis of non-rapid eye movement (NREM) parasomnia and unconscious or otherwise medically serious patients were excluded. Those with no REM period recorded during the PSG night were also excluded.

The "normal controls" were from a group enrolled in another ongoing study on children and adolescents with autism. All of them had been screened for sleep complaints and were asymptomatic for the same.

Video-PSG Procedure

As a routine for all the PSGs, overnight polysomnography (PSG) study had been performed by trained sleep technologists, according to the latest version of the American Academy of Sleep Medicine (AASM) scoring manual, for all subjects.[10] The monitored parameters included left and right electrooculogram, extended electroencephalogram (EEG), mental and submental electromyogram (EMG), left and right anterior tibialis EMG, single electrocardiogram waveform, snoring, continuous airflow via thermistor, nasal pressure transducer, chest and abdominal effort, oxygen saturation, and body position, which was also confirmed through video monitoring.

For the patients in group (i), additional EMG channels with electrodes having been placed on the left extensor digitorum and the right deltoid muscles were also recorded. A 16 channel EEG was also obtained as part of the detailed protocol for evaluation of patients with suspected parasomnias.

For patients in group (iv) also, 16 channel EEG had been obtained in addition to the PSG hook-up described above.

Video-PSG Interpretation

Definitions of all PSG parameters as well as specific diagnosis, for example, Obstructive sleep apnea and periodic limb movement disorder, were based on AASM guidelines.[10]

Clinical details of behaviors recorded during REM sleep (and other stages) had been noted and shown to carers, to ascertain habitual nature of the same, in case of patients who had presented to the clinic for abnormal behaviors during sleep.

Specific REM Sleep Analysis

For the purpose of this study, REM epochs of all subjects included were re-scored by two independent scorers (BS and AG). The following parameters were analyzed and tabulated, for each group:

a. total number of REM epochs during PSG night
b. REM percentage of total sleep time
c. Total number of REM epochs with excessive transient muscle activity (ETMA) or sustained muscle activity (SMA)*
d. Percentage of REM epochs with ETMA or SMA
e. Number (%) and percentage of epochs with ≥50% of 10-second mini-epochs with ETMA and/or SMA
f. Number (%) and percentage of epochs with ≥20% of 10-second mini-epochs with ETMA and/or SMA
g. Number (%) subjects in each group with ≥5% of REM epochs showing ETMA and/or SMA in ≥20% of the epoch
* SMA (tonic activity) in REM sleep: An epoch of REM sleep with at least 50% of the duration of the epoch having a chin EMG amplitude greater than the minimum amplitude demonstrated in NREM sleep.
ETMA (phasic activity) in REM sleep: In a 30-second epoch of REM sleep divided into 10 sequential 3-second mini-epochs, at least 5 (50%) of the mini-epochs contain bursts of transient muscle activity. In RBD, ETMA bursts are 0.1–5.0 seconds in duration and at least four times as high in amplitude as the background EMG activity.

Based on AASM manual version 2.3.[10]

Table 1: Age/Sex distribution and REM sleep analysis of young subjects included in various clinical categories

Variable	Normal controls (N = 14)	Autism (N = 22)	ADHD (N = 10)	Clinic patients presenting as RBD (N = 12)	Epilepsy (N = 30)
Age					
Mean + SD	9.69 ± 1.93	5.16 ± 2.30	8.1 ± 1.72	13.73 ± 7.76	19.5 ± 5.74
Median (range)	10 (6–11)	5 (5–12)	7.5 (7–11)	13 (3–25)	19 (9–25)
Sex (Male) (%)	12	16	10	12	19
REM sleep percentage of total sleep time					
Mean + SD	15.14 ± 8.24	7.54 ± 5.4	13.73 ± 7.84	17.56 ± 5.9	12.85 ± 8.11
Median (range)	15 (1–24)	7 (1–50)	13 (3–36)	17 (5–38)	12 (1–23.49)
Total number of REM epochs during PSG night					
Mean ± SD	147.5 ± 42.6	84.13 + 69.7	106.1 ± 35.6	186.54 ± 82.27	109.42 ± 62.12
Median (range)	135 (79–256)	71 (4–258)	117 (36–145)	148 (120–380)	108 (1–238)
Number of patients with RWA N (%)[*]	0	16 (72.22)	6 (60)	12 (100)	6 (20)
Number of patients (%) with abnormal behaviors recorded on video corresponding to periods of RWA, suggestive of RBD	0	8 (36)	3 (30)	7 (58)	1 (3)

ADHD = attention deficit hyperactive disorder; REM = rapid eye movement; RWA = REM sleep without atonia.

Sustained muscle activity (tonic activity) in REM sleep: An epoch of REM sleep with at least 50% of the duration of the epoch having a chin EMG amplitude greater than the minimum amplitude demonstrated in NREM sleep.

Excessive transient muscle activity (phasic activity) in REM sleep: In a 30-second epoch of REM sleep divided into 10 sequential 3-second mini-epochs, at least 5 (50%) of the mini-epochs contain bursts of transient muscle activity. In RBD, excessive transient muscle activity bursts are 0.1–5.0 seconds in duration and at least four times as high in amplitude as the background EMG activity.

*RWA defined based on AASM scoring manual (2007)[10] version 2.3 guidelines.

Diagnosis of RBD

The diagnosis of RBD was made strictly in accordance with the criteria described in the International Classification for Sleep disorders, version 3,[11] while RWA (also a requirement for the diagnosis of RBD) was diagnosed in accordance with the AASM guidelines manual version 2.3.[10]

Parameters (f.) and (g.) mentioned under the previous subheading were computed for further quantification of the PSG abnormalities observed during REM sleep of included subjects, especially those not fulfilling AASM criteria for RWA.

RESULTS

During the study period, a total of 102 subjects in the specified age group were identified, who had undergone technically adequate polysomnography for at least one night. Among these, 32 had autism spectrum disorder, 10 of whose PSG studies recorded no REM epochs. Hence 22 from this group were included. PSG studies of 18 normal children were available, out of which 4 had no REM sleep recorded. Apart from these, there were 10 PSG studies of children with ADHD and 30 of those with epilepsy, which were analyzed. The rest were those of 12 patients who had presented to the clinic with episodic abnormal behavior during sleep and whose PSG did not identify findings supporting the diagnosis of NREM parasomnia or seizures. Hence, PSG studies of a total of 88 subjects were available for detailed REM sleep analysis.

This was a male-dominant population, with all 12 suspected RBD patients, 16/22 with autism, all 10 ADHD, 19/30 epilepsy patients, and 12/14 normal controls being male. Gender matching was not possible since this is a retrospective study, and it was important to include all consecutive patients in each group. Age range in various groups has been mentioned in Table 1.

Apart from the 12 patients who had presented with possible parasomnias, no other subjects included had history of abnormal behavior during sleep.

Limited details of imaging obtained for patients in included groups were available at the time of analysis:

Autism – Imaging was done among 19 out of 22 patients, 17 reported normal, 1 showed Ischemic changes in bilateral parietooccipital regions, and 1 had right frontal lobe dysplasia.

ADHD – MRI conducted whenever required clinically, but not as a part of study.

Epilepsy – All patients underwent either MRI or CT scans; nearly half of these were abnormal with focal brain lesions

RBD – Eleven patients underwent MRI/CT Scan. One MRI was reported abnormal – possible diffuse hypoxic ischemic changes over widespread regions bilaterally.

The average number of REM epochs (85.47 ± 70.12) and REM percentage (7.54 ± 5.4) was lowest in the group of

Table 2: REM characteristics of subjects manifesting RWA

Variable	Autism (N = 22)	ADHD (N = 10)	Clinic patients (N = 12)	Epilepsy (N = 30)
Number of patients with REM epochs showing >50% of ETMA and/or SMA	16 (72.22)	6 (60)	12 (100)	6 (20)
Total number of REM epochs				
Mean ± SD	85.47 + 70.1	108 + 38.09	183 + 79.23	127 + 63.23
Median (range)	71 (4–258)	117 (36–149)	148 (120–380)	129 (40–198)
Number of REM epochs with RWA (>50% occupied by ETMA/SMA)				
Mean ± SD	4.25 + 3.51	14.5 + 10.6	29.67 + 33.36	3.0 + 2.76
Median (range)	3.5 (1–14)	13.5 (3–29)	12 (3–103)	1.5 (1–7)
Percentage of mini-epochs having EMA				
Mean ± SD	19.64 + 23.2	15.05 + 15.7	33.83 + 24.1	3.79 + 2.88
Median (range)	11.76 (3.62–100)	8.78 (2.06–48.4)	25.35 (7.43–80.7)	3.78 (0.53–7.5)

ADHD = attention deficit hyperactive disorder; REM = rapid eye movement; RWA = REM sleep without atonia; ETMA = excessive transient muscle activity; SMA = sustained muscle activity; EMA = excessive muscle activity.
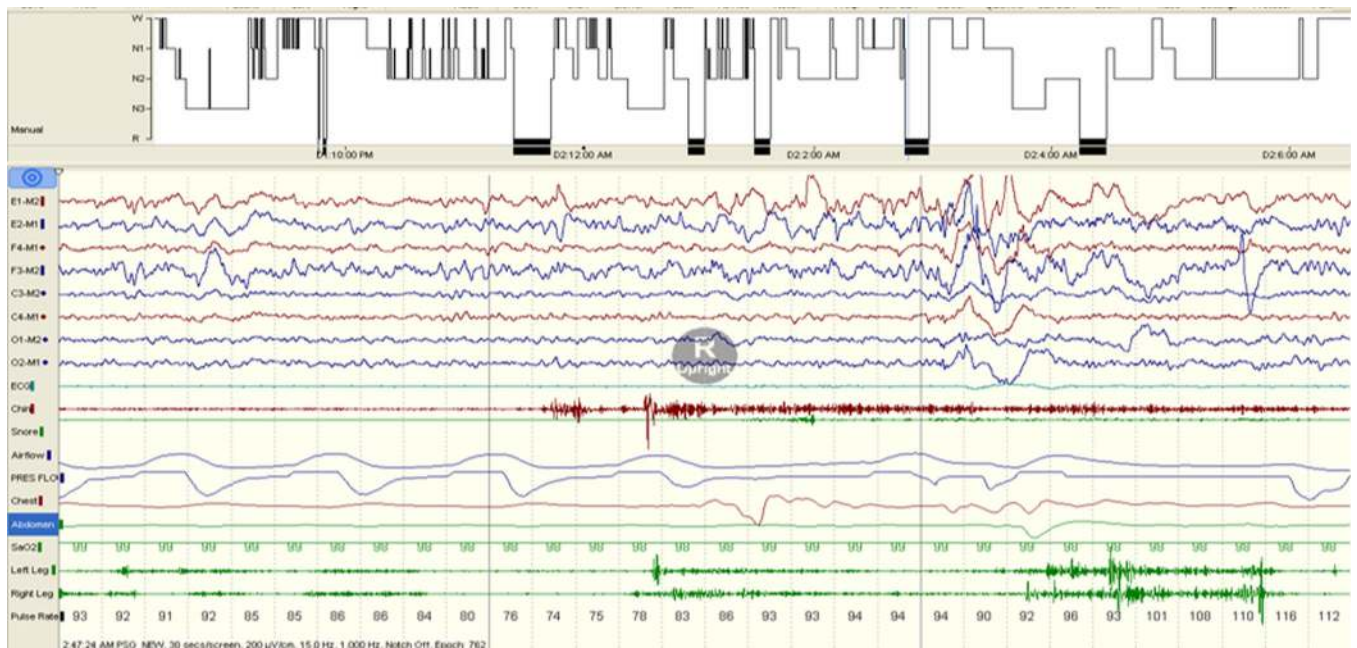

Figure 1: Sustained muscle activity (SMA).

patients with autism and highest in clinic patients who had presented with suspected RBD (183 ± 79.23). Expectedly, the latter was also the group with maximum number and percentage of REM epochs with ETMA and/or SMA. ETMA and/or SMA during REM epochs was found in all clinic patients diagnosed with RBD, in 16/22 (72%) autistic patients, 6/10 (60%) ADHD patients compared to only 6/30 (20%) patients with epilepsy, and none of the normal subjects (Table 2) (Figures 1–3).

On analysis of video on the video-PSG, eight patients among autistic and three among ADHD subjects were observed to have non-specific body movements during REM sleep ranging from sudden jerky movements of limbs or head, rolling of legs, repetitive but not stereotyped movements of upper limbs with

occasional crying. One patient in the epilepsy sub-group had non-specific upper limb movements without any concomitant ictal EEG correlates. Details of clinical presentation of patients in the suspected RBD group are listed; details of associated conditions and medication history along with the video-PSG findings for this group are described in Table 3.

All patients diagnosed with RBD were treated with 0.125–0.25 mg of nightly Clonazepam and at a mean follow-up of 6 ± 5.66 months; they were all free from symptoms of the nocturnal events. Apart from oral Clonazepam, one patient who was on multiple narcotic drugs underwent successful de-addiction over a period of 4 months, two patients who were receiving selective serotonin reuptake inhibitor (SSRI) medications tapered the same off, while the two patients who were
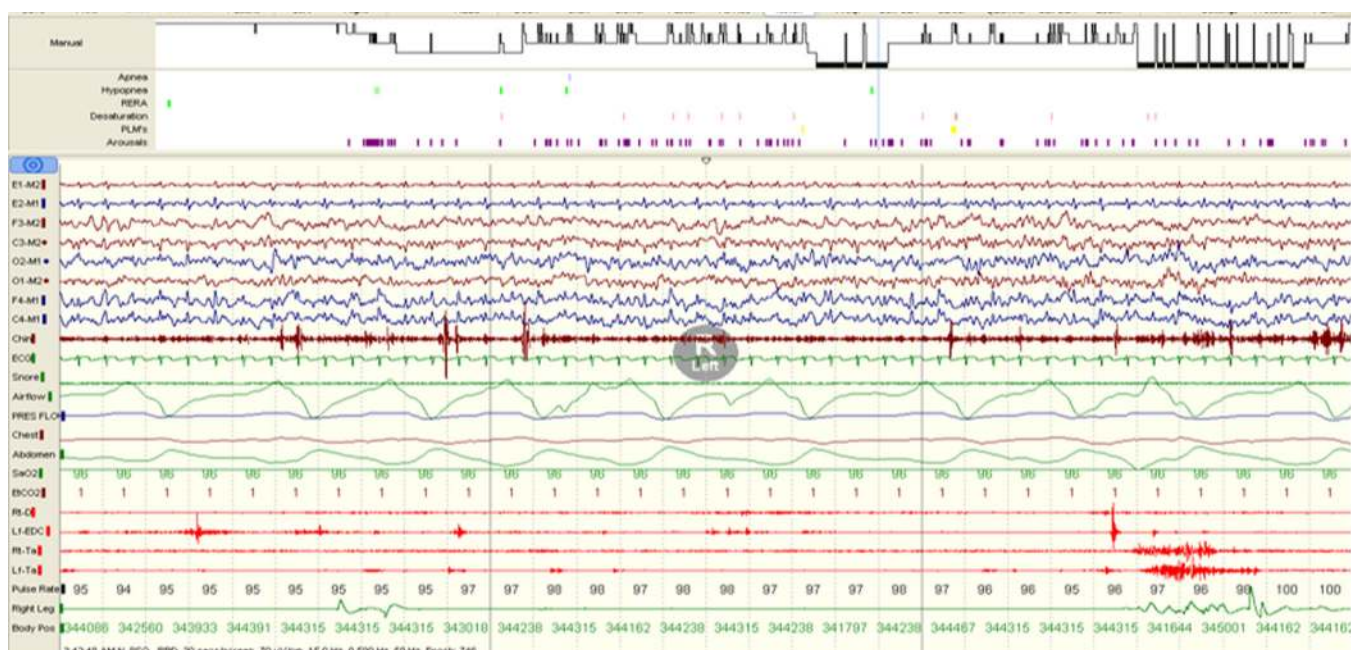
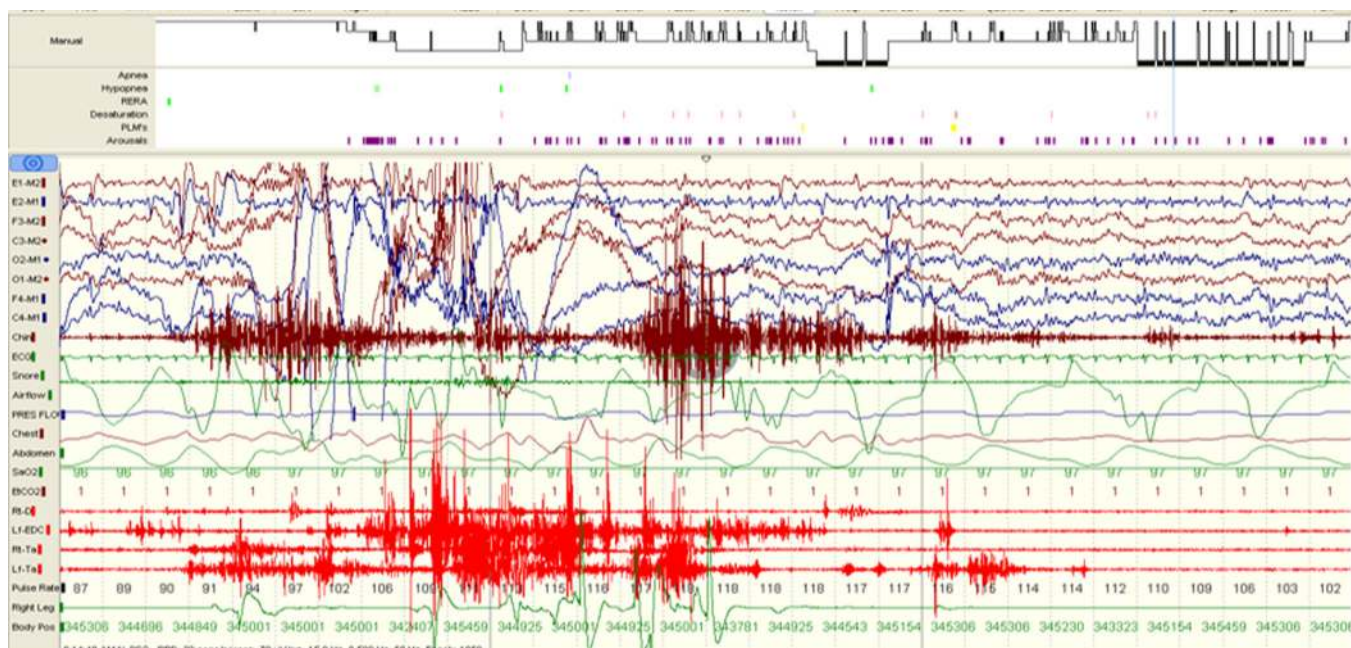**Figure 2:** *Excessive transient muscle activity (ETMA).*

Figure 3: *Sustained muscle activity (SMA) and excessive transient muscle activity (ETMA).*

diagnosed to have narcolepsy continued to remain on the tricyclic anti-depressant (TCA) medication which had been prescribed to them.

Medications used in different groups studied were as follows:

- ADHD: Atomoxetine, Methylphenidate, and Sodium valproate
- Autism: Risperidone, Olanzapine, Atomoxetine, Sodium valproate, Carbamazepine, and Levetiracetam
- Epilepsy: Oxcarbazepine, Carbamazepine, Levetiracetam, Sodium valproate, Lacosamide, and Clobazam.

Patients in all groups, who did not demonstrate RWA, were also on the same group of medications. It is noteworthy that, apart from SSRI/TCA use in four patients detailed above, no other medications used by patients in different groups are known to affect muscle tone in REM sleep, except for potential for some anti-psychotic medications used for patients with autism.

DISCUSSION

This is the largest study reporting REM sleep characteristics of young subjects with RBD, as well as those with other

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Table 3: Clinical presentation, additional clinical details, and video-PSG findings of young patients undergoing video-PSG evaluation for suspected RBD and with a final diagnosis of RBD (N = 12)

S. No.	Age/Sex	Clinical presentation	Associated condition	History	Medication	PSG/Video findings
1	18/M	Episodes of abnormal behavior in sleep daily for last 12 years. Consisting of mumbling, crying, rolling, and blinking of eyes. Sometimes associated with shivering and delayed response to calling. Episodes occurring 1–2 hours after sleep onset, no day time events. Family history positive in 32-year-old maternal uncle. MRI brain normal.	Narcotic drug addiction	Nocturnal episodes with family history	Opium Cannabis Tobacco "Apra" "Spasmindon" Cyclodon	Four events recorded in REM sleep: gesturing movements with both upper limbs, mumbling (none during NREM sleep) ETMA + SMA AHI = 0.69, REM% 17, Arousal index = 16
2	10/M	Recurrent episodes of hyperventilation lasting for several minutes, with thrashing of limbs since July 2010, always about 2 hours after sleep onset. CT scan (Head) showed left parietal inflammatory granuloma.	H/o three seizures	GERD	Sodium valproate	One event during REM sleep: restless side-to-side movements of body ETMA + SMA AHI = 4, REM% = 14, Arousal Index = 16
3	22/M	Abnormal Behavior in sleep, elaborate sexual behavior present during episodes. History of sexual harassment at age of 6 years present.	Sexsomnia- or Sleep-related dissociative disorder with sexual behaviors	Nocturnal episodes of dream-enacting behavior in 2nd part of night, with vocalization	None	No events recorded ETMA
4	22/M	Episodes of violent behavior during sleep with gesturing with both upper limbs and face of 3 years duration. Delayed speech milestones, mild intellectual subnormality, aggressive personality. History of Nocturnal enuresis	Delayed speech, nocturnal enuresis	Nocturnal episodes of dream-enacting behavior in 2nd part of night, with vocalization	Risperidone (prescribed for behavioral problems)	No events recorded ETMA + SMA
5	20/M	History of episodic abnormal gesturing and vocalization during sleep, starting an hour after sleep onset, several episodes per night sometimes.	Night terror and confusional arousal	Dream-enacting behavior while sleeping	Olanzepine (prescribed by psychiatrist for the nocturnal behaviors)	No events recorded ETMA
6	13/M	History of talking about daytime events during sleep, occasionally trying to get up and sit in bed, for last 2 years. H/O two episode of seizures several years back, no recurrence after treatment with Carbamazepine for 2 years.	Seizures	H/o sleep-onset hallucinations and sleep talking	None	No events recorded ETMA + SMA AHI = 1.41, REM% 19, Arousal index = 18.2
7	23/M	Episodes of limb thrashing and talking in sleep. Diagnosed to have obsessive–compulsive disorder and also has initiation insomnia.	OCD TTH	Dream-enacting behavior in sleep. Problem in sleep initiation	Fluoxetine (possible SSRI medication-induced RBD)	One event recorded: dream enactment with vivid gesturing and talking during first REM episode ETMA AHI = 0.8, REM% 15, Arousal index = 27
8	25/M	Episodes of getting up in bed and abnormal behavior, once in 2–3 months for last 1 year. Mother complains about keeping company with anti-social persons	Somnambulism, psychological stressors	Dream-enacting behavior in sleep.	Escitalopram (possible SSRI medication-induced RBD)	No events recorded ETMA + SMA AHI= 5, REM% = 31, Arousal index = 14.3
9	18/M	Excessive daytime somnolence with single episode of sleep-onset hallucination – 5 years	Idiopathic hypersomnia	EDS	Modafinil	Two events recorded: unclear semi-purposive movements only during REM episodes AHI = 3.26, REM% = 18, Arousal index = 8
10	8/M	Excessive daytime somnolence and history suggestive of Cataplexy for last 3 years. Delayed speech milestones, but normal intelligence. Polydactyly in both lower limbs.	Delayed speech, Polydactyly in both lower limbs Narcolepsy	EDS and Cataplexy Dream-enacting behavior	Modafinil and TCA (the TCA can trigger or exacerbate RBD)	Two events: body movements and facial grimacing as if in conversation – in REM sleep? ETMA AHI = 2.69, REM% = 14, Arousal index = 14

Table 3: *(Continued)*

S. No.	Age/Sex	Clinical presentation	Associated condition	History	Medication	PSG/Video findings
11	9/M	Excessive daytime somnolence with sleep attacks for last 4 years, along with several episodes suggestive of cataplexy	Narcolepsy	EDS and cataplexy	Modafinil, TCA	One event: low amplitude repetitive kicking movements ETMA + SMA AHI = 0.83, REM% = 18, Arousal index = 11
12	3/M	History of rhythmic body movements at sleep onset, and several times during night-time sleep – for last one and a half year. History of restless legs syndrome, responsive to oral iron therapy – 6 months.	RMD, RLS	Cries excessively on sleep initiation	Oral Iron	Rhythmic movements of both lower limbs only during REM sleep ETMA + SMA AHI = 0.83, REM% = 18, Arousal index = 11

AHI = apnea hypopnea index, EDS = excessive daytime sleepiness, GERD = gastroesophageal reflux disorder, NDD = neurodevelopmental disorder, OCD = obsessive compulsive disorder, RLS = restless legs syndrome, RMD = rhythmic movement disorder, TTH = tension type headache.

Table 4: Review of published Case reports and series of RBD and RWA in young

Reference	Type of study details reported	Associated condition	Clinical/PSG data	Remarks
Barros Ferreira et al.[3]	Case report 8 F	Infiltrating Pontine tumor	Movements during REM sleep	
Schenck et al.[4]	Case report 10 F	After removal of middle cerebellar Astrocytoma	Movements during REM sleep	8-year-old brother had same findings
Sheldon et al.[14]	Case Series five patients	One patient had Narcolepsy, others characterized as Idiopathic	Complex motor behavior associated with dreams	Responded well to Clonazepam
Thirumalai et al.[8]	Prospective PSG study 5/11 found to have RBD	Autism spectrum disorder	Both clinical and PSG findings of RBD	4/5 responded well to Clonazepam
Blaw et al.[15]Herman[16]	Case reports 2 year/Male 18 month/Male	Hereditary quivering with tongue biting	Complex motor behavior and loss of REM atonia	Both improved with Clonazepam
Trajanovie et al.[17]	Case report 4 year old /Male	Tourette's Syndrome	Move in sleep, flail his hand and vocalize RWA + nt	No pharmacological treatment
Nevsimalova et al.[18]	Case report 7 and 9 year/Female	Narcolepsy	1st: harmful behavior and sleep-talking appeared. Attacked sister, kicking, and striking wall repeatedly 2nd sleep talking and complex movements	Treated with Clonazepam
Turner et al.[19]	Case report	Narcolepsy		
Lloyd et al.[12]	Reported 15 cases of RBD in children and adolescents	Anxiety, ADHD, NDD, Smith Magenis Syndrome, Pervasive developmental disorder, Narcolepsy, Idiopathic hypersomnia, and Moebius syndrome	RBD and RWA	One patient developed depression and ADHD on a 6-year follow-up.
Rye et al.[7]	Case reports	Juvenile PD, NDD, Narcolepsy, Medication	RWA	

neurological disorders. While quantitative analysis of the REM periods of the young patients suffering from RBD is presented, the main observations made are of a large proportion of PSG studies of patients diagnosed with autism spectrum disorders and those with ADHD also show loss of normal REM-associated atonia during nearly 10% of the REM epochs recorded. This compares with no similar findings among normal age-matched subjects and a small percentage of patients with epilepsy.

RBD among children, adolescents, and young adults has been reported only in small case series and is evidently an uncommon clinical problem. Lloyd et al. reported a series of 15 patients younger than 18 years of age, with RBD, 2 of which had only RWA. The associated co-morbidities and response to treatment were similar to our observations, in the group of RBD patients reported.[12] Another series of 22 patients younger than 40 years age also reported similar clinical and PSG findings.[13] Apart from these a number of case reports have been published and co-morbidities ranging from brainstem tumors to juvenile Parkinson's disease have been observed with young RBD (Table 4). The interesting and novel part of our study is the

observation of RWA and motor behaviors recorded during REM sleep of children with autism, ADHD, and some children with epilepsy, which may not necessarily give the appearance of dream enactment as often and as clearly as in adults.[6,14–18,20] History of episodic abnormal behaviors during sleep was not reported for any subjects apart from the group which presented with suspected parasomnia. This can be attributable to the often non-specific and non-stereotyped characteristics of behaviors and abnormal movements observed on video among patients included. Many abnormal behaviors are commonly observed among patients with autism spectrum disorders, and it is possible that caregivers would be unable to differentiate between behaviors observed during wakefulness versus those in sleep. Hancock et al. studied RWA quantification in children with RBD and a control group without RBD and found significantly greater amounts of RWA among the former.[19]

We categorized RWA features in greater detail than required per the AASM guidelines for RWA among adults. Apart from the requirement by AASM guidelines for greater than 50% of 10 three-second mini-epochs for labeling any particular epoch to show ETMA or SMA, various cut-off percentages for individual muscles and muscle combinations showing RWA have been identified, for the diagnosis of RBD, in previous studies. These authors found that for clinical purposes, a cut-off of 18.2% of "any," that is, tonic or phasic or both EMG activity in the mentalis muscle was sufficient for diagnosis of RBD.[21] We have reported our analysis by both, this less stringent cut-off as well as that of 50%, for the epochs showing increased muscle tone during REM sleep. Some other authors reporting EMG quantification among patients with RBD have also aimed at identifying cut-off values to label abnormal muscle tone during REM sleep indicative of a diagnosis of RBD.[22] Postuma et al. suggest that the amount of RWA appears to predict the development of PD, showing that idiopathic RBD patients who developed PD had baseline abnormal tonic chin muscle activity of 73% compared to 41% of those who remained disease free. They also reported high RWA rates (54%) among those suffering from Lewy body dementia.[23] Nevertheless, it is important to note that such quantification and cut-off rates for RWA, as well as values correlative with clinical RBD are currently unavailable, for *younger patients presenting with RBD* or those whose PSG shows only RWA. Our study is important in gathering information required to establish clinical significance of the unusual PSG findings among various young populations studied by us.

The finding of prominent RWA among young patients with various disorders studied by us, notably autism as well as ADHD, has not been reported before. The clinical and, especially, the prognostic implications should be of considerable interest and should encourage future research in this area. An observation of prognostic concern from recent studies is the higher prevalence of Parkinson's disease than normal age-matched population, among adults with autism.[24,25] In addition, mutations in the Parkinson's disease-associated, G-Protein-coupled receptor 37 (GPR37) gene, which is associated with the dopamine transporter, have been identified in some patients with the autism spectrum disorder and proposed to be related to the deleterious effects of the autism spectrum disorders.[26] Such genetic associations among Parkinsonism with ADHD and autism have also been a matter of intensive exploration and may be of relevance to patients with autism and ADHD with RWA/RBD.[27–29]

While this is the first large study on RWA and RBD in children, adolescents, and young adults, its limitations are the small numbers in each group and non-availability of adequate follow-up data for most of these.

CONCLUSION

We observed that a large percentage of young patients with autism and ADHD and some with epilepsy demonstrate loss of REM-associated atonia and some RBD-like behaviors on polysomnography similar to young patients presenting with RBD. The clinical significance of this finding thus forms an interesting subject of future research.

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