Residual Sleepiness Risk in Aircrew Members with Obstructive Sleep Apnea Syndrome

Jonathan Monin; Erik Rebiere; Gaëtan Guiu; Sébastien Bisconte; Eric Perrier; Olivier Manen

BACKGROUND: Obstructive sleep apnea syndrome (OSAS) is a major problem in aviation medicine because it is responsible for sleepiness and high cardiovascular risk, which could jeopardize flight safety. Residual sleepiness after the treatment is not a rare phenomenon and its management is not homogenous in aviation medicine. Thus, we decided to perform a study to describe this management and propose guidelines with the help of the literature.

METHODS: This is a retrospective study including all aircrew members with a history of OSAS who visited our aeromedical center between 2011 and 2018. Residual sleepiness assessment was particularly studied.

RESULTS: Our population was composed of 138 aircrew members (mean age 50.1 ± 9.6 yr, 76.8% civilians, 80.4% pilots); 65.4% of them had a severe OSAS with a mean Epworth Sleepiness Scale (ESS) at 8.5 ± 4.7 and a mean apnea hypopnea index of 36.2 ± 19.2/h. Of our population, 59.4% performed maintenance of wakefulness tests (MWT) and 10.1% had a residual excessive sleepiness. After the evaluation, 83.1% of our population was fit to fly.

DISCUSSION: An evaluation of treatment efficiency is required in aircrew members with OSAS. Furthermore, it is important to have an objective proof of the absence of sleepiness. In this case, ESS is not sufficient and further evaluation is necessary. Many tests exist, but MWT are generally performed and the definition of a normal result in aeronautics is important. This evaluation should not be reserved to solo pilots only.

KEYWORDS: obstructive sleep apnea syndrome, sleepiness, maintenance of wakefulness tests, aircrew members.

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It has been known for many years that obstructive sleep apnea syndrome (OSAS) increases the risk of road accidents by a factor of 2 to 3.[7] We can of course transpose this risk to aeronautics, which requires particular vigilance. The FAA's booklet of recommendations on OSAS[8] gives an example of risk in aeronautics. On a daytime flight in the United States in 2008, an airliner with 40 passengers on board flew past its destination airport because both the captain and first officer fell asleep. Once they awakened, the plane was able to reach the destination airport without incident, but with a delay. The investigation uncovered an undiagnosed OSAS in the captain.

OSAS is synonymous of risk to flight safety for three reasons:

- It can be responsible for cognitive and psychological disorders: impaired memory and concentration, longer reaction time, irritability, mood disorders, etc.
- It can generate excessive daytime sleepiness, which can lead to an increased risk of accidents.
- OSAS is considered a cardiovascular risk factor.

This article will focus solely on the risk of sleepiness associated with OSAS. Its aim is to discuss the assessment of sleepiness in aircrew members treated for OSAS.

OSAS can be defined as the repetition of apneas and hypopneas during sleep. Many definitions exist and evolve with different recommendations. We cite the 2014 American Academy of Sleep Medicine definition[2] presented here.

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Definition 1:

- Polysomnography or home sleep apnea testing demonstrates ≥5 obstructive respiratory events per hour of sleep.
- Presence of one or more of the following:
  - The patient complains of drowsiness, nonrestorative sleep, fatigue, or insomnia symptoms
  - The patient wakes up with breath holding, gasping, or choking.
  - The patient's partner or other observer reports habitual snoring, breathing interruption, or both during the patient's sleep.
  - The patient has been diagnosed with hypertension, mood disorder, cognitive dysfunction, coronary artery disease, stroke, congestive heart failure, atrial fibrillation, or type 2 diabetes mellitus.

Definition 2:

- Polysomnography or home sleep apnea testing demonstrates ≥15 obstructive respiratory events per hour of sleep.

We note the definition is based on both clinical and polysomnographic criteria.

For the French military, it is specified in the 2021 regulation[4] that sleep apnea syndrome leads to unfitness for pilots, flight mechanics, or air traffic controllers. Aircrew members will then have to ask for a waiver from the military medical commission of aeronautics in order to be able to return to flying duties.

For civilian private and professional pilots, it is specified in the European regulations[6] that OSAS requires a referral to (or consultation with) the licensing authority. A satisfactory respiratory and cardiological assessment is also required. The acceptable means of compliance[1] specify that a pilot with unsatisfactorily treated sleep apnea syndrome should be assessed as unfit. It is this issue of satisfactory treatment that will be discussed in this article regarding the assessment of sleepiness.

Residual sleepiness in patients with OSAS is generally defined as an Epworth score greater than or equal to 11 despite an appropriate treatment. Its prevalence is estimated at 12% at 1 yr from the start of OSAS treatment.[12]

Multiple causes are described in the literature.[10,15] The first and foremost cause is a defect in the efficacy, compliance, and tolerance of the treatment (mask or mouthpiece not adapted to, leaks, dryness of the mucous membranes, etc.). It has been shown that the prevalence of residual sleepiness is lower in patients who wear their continuous positive airway pressure (CPAP) for more than 6 hours/night than in those who wear it for less than 4 h (12% vs. 30%).

Once the treatment has been verified, it is also important to question the diagnosis in case of sleepiness in spite of a well-conducted treatment. This involves checking whether the initial problem was indeed OSAS, but also checking there is no other associated sleep pathology, such as restless legs syndrome, narcolepsy, or idiopathic hypersomnia.

It is also important to keep in mind that depression is a major cause of sleepiness. It will therefore be important to assess mental health, including the existence of possible mood disorders. Indeed, insomnia or hypersomnia is a criterion in the definition of severe depressive episode in the Diagnostic and Statistical Manual of Mental Disorders V.[3] In addition, an epidemiological study in 1989 shown that 40% of patients with insomnia and 46.5% of patients suffering from hypersomnia had an associated psychiatric disorder.[9]

Finally, when all other causes have been investigated, it is commonly described that residual sleepiness can be a sequel to intermittent cerebral hypoxia.[10,15] In this case, the patient must be referred to a sleep medicine department to discuss medications like wake-promoting agents.

How to assess this sleepiness? It is essential to look for this sleepiness in patients with treated OSAS and even more so in aircrews. In current clinical practice, this screening is essentially based on the Epworth Sleepiness Scale (ESS). In the case of a score compatible with subjective sleepiness, the causes described above are sought. Otherwise, there is generally no further exploration for sleepiness. We can ask ourselves if the ESS alone is sufficient for pilots, but it is also important to keep in mind that the ESS assesses sleepiness in situations of passivity, which does not correspond to piloting activities.

It has been shown in the literature[14] that there is not a good correlation between a subjective test such as the ESS and an objective measure such as the Maintenance of Wakefulness Tests (MWT). The main reason given is that patients with chronic sleep disorders have a poor perception of sleepiness, in which an improvement in the disorder may wrongly suggest that the disorder has disappeared. Moreover, in the context of fitness evaluation, the ESS may not always be honestly reported in a pilot who has been potentially declared unfit since the diagnosis of his/her illness, and who is hoping for a favorable decision from the medical center.

In this context, MWT are an interesting tool. These are sleep laboratory tests that measure a subject's ability to stay awake.[16] They are used in two situations: when hypovigilance is a public or personal safety issue, and to assess response to treatment in sleepy patients. This test is therefore doubly indicated in aircrews.

During this test, the patient is comfortably seated with electroencephalogram (EEG), electrooculogram (EOG), and electromyography (EMG) sensors in a semidark room. He is asked to look ahead, keep his eyes open, and stay awake, fighting sleep as much as possible. It is forbidden to do some waking maneuvers such as looking at the cell phone, reading, chewing gum, pinching oneself, etc. Between tests, the subject must not sleep but may go about his or her business.

This test is repeated four times in the same day, every 2 h, after a good quality sleep the night before the tests. If the subject does not sleep, the test lasts 40 min. Otherwise, the test is stopped as soon as the subject falls asleep (with the need for three consecutive 30-s epochs in the case of stage 1 sleep). The sleep latency corresponding to the average of the four tests is thus calculated. So, if the subject did not sleep during the test, the average sleep latency is 40 min.

To determine the values that may correspond to a decreased alertness, the MWT results were compared to actual driving performance. In this context, the 2008 study from Philip et al. is very interesting.[13] This involved 38 patients with untreated OSAS and 14 control subjects who were asked perform MWT and also a 90-min test of real driving performance. It was thus shown that patients considered as drowsy (MWT 20–34 min) or very drowsy (MWT < 20 min) made significantly more driving errors than control subjects and patients considered as vigilant (MWT 34–40 min). On the other hand, there was no significant difference between vigilant patients and control subjects. Thus, in France, according to the French sleep medicine society recommendations, a latency of more than 33 min is considered a good alertness, predicting actual safe driving.[16]

There are many other tests available for the assessment of sleepiness described in the literature. We will mention only two frequently used tests.

Firstly, Multiple Sleep Latency Tests (MSLT) are used to measure the diurnal tendency to fall asleep and to look for the presence of sleep onset rapid eye movement periods. Here it is very important to understand the difference from MWT: MSLT are used to measure the ability to fall asleep while MWT are used to measure the ability to stay awake, which is a totally different approach.[11] The MSLT will be useful when sleepiness is detected in order to try to determine the cause (hypersomnia, narcolepsy, etc.).

The Oxford sleep resistance test is also an interesting test. The principle is globally similar to the MWT, except that instead of the EEG, EOG, and EMG sensors which detect sleepiness, the subject is asked to press a button in response to a light signal about every 3 s, thus revealing sleepiness when there are repeated omissions.[5] There is a good correlation of this test with MWT. However, it has two major disadvantages: some subjects manage to press the button even when asleep, but above all, there is currently no real consensus on its procedure and interpretation criteria.

Thus, at the present time, MWT seem to remain the best choice for seeking objective sleepiness in a patient with a treated OSAS. Nonetheless, we have seen the residual sleepiness evaluation could also be based on ESS and other tests. That is why we decided to perform a study in order to describe how this evaluation is actually done for aircrew members with OSAS. It could help to propose guidelines in order to have homogeneous management in these cases.

METHOD

In order to study the evaluation of the risk of sleepiness in aircrew members, we decided to perform a retrospective monocentric study with cases of OSAS in aircrew members. The included population was composed of all aircrew members with a history of OSAS seen in our aeromedical center between 2011 and 2018. We decided to exclude cabin crews because of the less important consequences of sleepiness on flight safety in this population.

All files of aircrew members with a mild to severe OSAS and/or a treated OSAS were extracted from our database. Several data were reported: socio-demographic data, flight duty, disease severity, treatment, fitness assessment, and fitness decision. We focused in particular on the residual sleepiness evaluation (ESS, MWT, or others tests) in order to determine its prevalence in this population, and to describe the aeromedical assessment in this context. Aircrew members with residual sleepiness were compared to those without sleepiness in order to find risk factors of sleepiness which could be detected during the aeromedical examination.

This study was approved by a local ethics committee and by the commission on information technology and liberties (Commission Nationale de l'Informatique et des Libertés, CNIL). Quantitative data are described in terms of mean ± SD and compared with a Student test. Qualitative data are described in terms of percentage ± SD and compared with a Chi-squared test.

RESULTS

Our population is composed of 138 aircrew members (mean age 50.1 ± 9.6 yr, 76.8% civilians, 80.4% pilots). At the time of diagnosis, 60.1% of them were obese; the symptoms described were the following: snoring (66.7%), excessive daytime sleepiness (47.1%), and nocturnal respiratory pauses (15.2%).

Before the diagnosis, ESS was normal (i.e., <11) in 64.9% of cases, with a mean score of 8.5 ± 4.7. The OSAS was considered severe in 65.4% of cases (otherwise it was moderate) with a mean apnea hypopnea index (AHI) of 36.2 ± 19.2/h. In addition to lifestyle advice, the treatment was a CPAP in 87% of cases, or a mandibular advancement device in 8.7% of cases.

After the treatment was initiated, the ESS was normal in 93% of cases, with a mean score of 4.2 ± 3.4, the mean AHI was 4.1 ± 4, with 87.4% of cases having an AHI <10. Compliance was good, with a mean use of the CPAP of 6.4 ± 1.3 hours/night and 88.2% of nights with the device.

Among our population, 82 aircrew members (59.4%) performed the MWT; all of them were treated with CPAP. This test was normal with no sleep during each 40-min period for 85.4% of them. However, 12 of them had an abnormal test as shown on **Fig. 1**.

We compared those 12 aircrew members to others with normal MWT in order to find risk factors, as showed in **Table I**. We note differences concerning post-treatment ESS ($P < 0.01$) and compliance ($P < 0.01$). Nevertheless, 7 aircrew members out of 12 had a normal ESS with an abnormal MWT.

Including 2 aircrew members with an abnormal post-treatment ESS who did not perform MWT, 10.1% of our population (14 aircrew members) had residual excessive sleepiness. After further evaluations in the sleep medicine department, this residual sleepiness was due to a bad tolerance/compliance to CPAP in four cases (28.6%), an associated mood disorder in

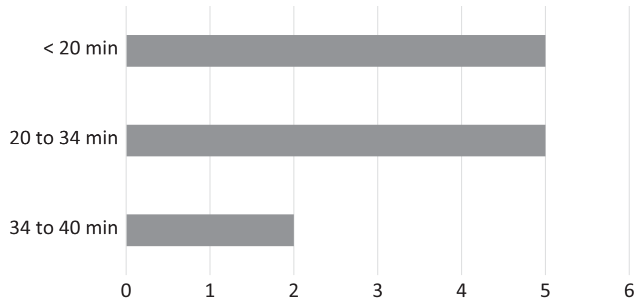

Fig. 1. Mean sleep latency in the aircrew members with abnormal MWT.

two cases (14.3%), and was considered sequalae residual sleepiness in seven cases (50%).

After the presentation to the licensing authority or to the military commission, 83.3% of aircrew members were declared fit, with limitations in 96.5% of cases. If the most frequent limitation is a time limitation, 53% of pilots had a multi-pilot limitation.

Concerning the unfit group (16.7% of aircrew members), 43.5% of them were declared unfit because of an associated psychiatric disease, 30.4% because of residual sleepiness, 17.4% because of an associated somatic disease, and two because they did not perform a required test (private pilots who did not want to perform MWT).

DISCUSSION

Thus, among our population, 14 aircrew members (10.1%) had residual sleepiness, which underlines the need for assessing sleepiness in aircrew members with OSAS. This result is comparable to those of the literature, such as Pepin et al.[12] or Gasa et al.,[10] who found, respectively, 12% and 13% of residual sleepiness in OSAS patients treated with CPAP.

It is interesting to note that the first cause of residual sleepiness in our population is not a defect in the compliance and tolerance of the treatment, as it is in the general population.[10,15] Indeed, Gasa showed a diminution in the number of hours per night of CPAP use in cases of residual sleepiness ($P < 0.0001$), which was not seen in our study. However, we must confess that the power of our study with a residual sleepiness group of 14 aircrew members limits these differences.

In aircrew members with cases of treated OSAS, the evaluation of sleepiness is firstly based on the ESS. However, in the case of a normal Epworth score (i.e., less than 11), we cannot be sure of the absence of sleepiness. MWT should then be performed. If these tests return normal, we will consider that there is no sleepiness. Conversely, if the Epworth score is greater than 10 and/or there is an abnormal MWT, there is residual sleepiness that should be explored before discussing the possibility of returning to flying duties.

This procedure for assessing sleepiness therefore seems to be quite easy, as shown on **Fig. 2**. However, this study is a reminder of the difficulty of evaluating sleepiness. As the use of MWT is not mandatory in the regulations, it could be left out of the evaluation. But we have seen mean sleep latency could be very low even with a normal ESS and a satisfactory compliance. So what MWT limit should we choose to affirm the absence of sleepiness among aircrews to protect flight safety?

The study of Philip et al.[13] described previously did not show any difference in driving performance between control subjects and those with a sleep latency between 34 and 40 min. But this does not mean, in our opinion, that we can declare fit a solo pilot who would have a mean sleep latency of 34 min on four tests. Indeed, this study was performed on a small population and we will probably not have the same level of requirement for a pilot as for another patient.

Thus, the American Academy of Sleep Medicine specifies in its 2005 recommendations that 40-min MWT remain the

Table I. Comparison Between Aircrew Members with Normal MWT and Those with Abnormal MWT.

	AM WITH MWT < 40 min *N* = 12	AM WITH MWT = 40 min *N* = 70	*P*
BMI (kg m^{-2})	31.7 ± 4.6	30.6 ± 5.2	NS
Pretreatment ESS	11.7 ± 4.5	8.3 ± 4.8	NS
Pretreatment ESS > 11 (*N*, %)	4 (57.1%)	12 (34.3%)	NS
Pretreatment AHI (event/hour)	41.0 ± 23.1	40.3 ± 16.8	NS
Post-Treatment ESS	7.9 ± 5.9	3.4 ± 2.2	<0.02
Post-Treatment ESS > 11 [*N* (%)]	5 (41.7%)	0	<0.01
Post-Treatment AHI (event/hour)	4.1 ± 7	3.9 ± 3.5	NS
CPAP Compliance (hours/night)	6.1 ± 1.4	6.4 ± 1.3	NS
CPAP Compliance (% of nights)	86.4 ± 14.6	90.1 ± 9.6	NS
Unsatisfactory CPAP Compliance [*N* (%)]	4 (30%)	4 (5.7%)	<0.01

MWT = Maintenance of Wakefulness Tests; NS = not significant; BMI = body mass index; ESS = Epworth Sleepiness Score; AHI = Apnea Hypopnea Index; CPAP = continuous positive airway pressure device; unsatisfactory CPAP compliance is defined as a use less than 6 h per night and/or less than 80% of nights.

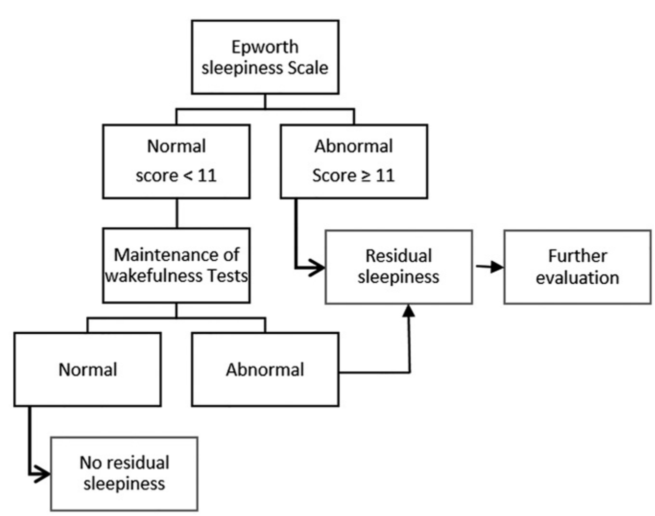

Fig. 2. Residual sleepiness screening in aircrew members treated for OSAS.

strongest objective data to assert a person's ability to stay awake.[11] In addition, we can read that it is an appropriate expectation for individuals requiring the highest level of safety, which in our opinion includes aircrews.

Another important question in this context is which aircrew members should perform MWT? It does not seem necessary to discuss the interest of these tests in a solo pilot: a complete sleepiness evaluation has to be done.

Is this test necessary for a multipilot, such as an airline pilot? To answer this difficult question, it may be easier to take it the other way around. Are there cases where a pilot would be declared unfit, even in case of multipilot, because of sleepiness on MWT? We have to keep in mind that in our study, five aircrew had an average sleep latency between 0 and 19 min on MWT, with a normal Epworth score for two of them. In particular, there was the case of a 44-yr-old airline pilot with a severe OSAS (apnea hypopnea index = 35/h) treated by CPAP with excellent compliance, a residual apnea hypopnea index at 4/h, and an Epworth score of 8. MWT were performed, showing a mean sleep latency of 11 min on the four tests, i.e., severe sleepiness. The patient was referred to a sleep department and was finally treated with wake-promoting agents. It seems obvious here that such a situation is not compatible with flight safety, even in multipilot. MWT are, therefore, important tests for all pilots with treated OSAS, but also by extension for other specialties (air traffic controllers for example).

In conclusion, the evaluation of residual sleepiness in aircrew with a history of OSAS is an important step in its rehabilitation. This study reminds us that residual sleepiness in aircrew members with OSAS is not rare and that it could be diagnosed even in patients with a normal Epworth score. In this context, MWT are an interesting tool, in association with the Epworth score and the CPAP efficiency and compliance evaluation, to be sure of the absence of sleepiness. From various studies and recommendations on this topic, MWT showing no sleepiness at 40 min seem to be an appropriate expectation to maintain flight safety at a high level. In our opinion, these tests are also necessary even for a multipilot to ensure the absence of severe sleepiness. Finally, it is important to keep in mind that the sleepiness evaluation is only one part of the OSAS evaluation. This condition is a cardiovascular risk factor and should be explored with a complete cardiological evaluation.

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