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CLINICAL REVIEW

Impact of sleep apnea on economics

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S U M M A R Y

Obstructive sleep apnea syndrome (OSA) alters sleep quality and is associated with sleepiness and decreased cognitive functioning. It has therefore always been recognized as a major public health issue with potential societal consequences: accidents, increased morbidity, and cognitive deficits impairing work efficiency. The number of patients diagnosed and treated for OSA has increased drastically in the last few years.[1] In response to this epidemic, health authorities have encouraged studies investigating how patients cope with OSA and also its diagnosis, comparing ambulatory to hospital-based polysomnography. Based on epidemiological knowledge, this review aims to carefully describe the possible links between sleep apnea and public health concerns along with identifying the certitudes and missing data concerning the consequences of sleep apnea on accidents, work, economics and health-related quality of life.

Introduction

Although half a century ago obstructive sleep apnea (OSA) was mostly unknown and undiagnosed, the last few decades has seen OSA become a central problem in the pathogenesis of major public health issues such as cardiovascular diseases, accidents and metabolic syndromes.[1–5] The discovery of continuous positive air pressure (CPAP) treatment 30 years ago, drove doctors and public health authorities to dramatically increase patients' care, in the hope of preventing comorbidities which could possibly be associated with OSA.

Due to the important expenses devoted to sleep apnea care, health authorities of many countries have attempted to encourage economic evaluations and public health studies to better understand the utility of diagnosing and treating OSA. From its identification, OSA was immediately recognized as a potential public health issue, associated with societal consequences: accidents, comorbidities and cognitive impairment.[5,6]

This article not only aims to describe possible links between sleep apnea and public health concerns but also to identify certitudes and missing data concerning the consequences sleep apnea may have on work economics and health-related quality of life (HrQoL).

Epidemiology: the magnitude of sleep apnea, screening the disorder and seeking help

This section's aim is not to describe the epidemiology of sleep apnea but only to put the prevalence of OSA, its socio-demographics and access to care in a universal and economical perspective. Independently of the nationality or socio-economical characteristics of patients, sleep apnea has common features around the planet which have to lead to similar care (Table 1).

Prevalence

Since the first survey performed 18 years ago by Young et al.,[7] many others have focussed on the prevalence of sleep apnea in different areas and countries around the world (see Table 1).[11–17]

Most of these national and international studies have confirmed that obstructive sleep apnea (OSA) concerns 2–10% of adults,[1,8–18] with subgroups of the population bearing a higher risk. Factors that can predispose to developing OSA include age, male gender, obesity, family history, menopause, craniofacial abnormalities, and health behaviors such as smoking and alcohol use.

The majority of 21 studies show an increasing prevalence of sleep apnea in the aging population and amongst males.[1,8–18]

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Table 1
Prevalence of sleep apnea on an international setting (1993–2009).

Authors, place, year, reference number	Population	Number of subjects total (number registered)	Age (years)	Methods	Criteria	Prevalence (%)
Young, USA, 1993, [10]	White-collars	3513 (625)	30–60	Questionnaire, polysomnography	AHI≥5 + daytime sleepiness or non nrestorative sleep	M: 4.0, F: 2.0
Beapark, Australia, 1995, [11]	Males. General population	486 (294)	40–65	Questionnaire, polysomnography	AHI≥5 + occasional sleepiness, AHI≥5 + regular sleepiness	12.2 3.1
Duran, Spain, 2001, [12]	General population	2148 (555)	30–70	Face to face interview + ambulatory PSG	AHI≥10	M 19.0, F 14.9
Ip, Hong Kong, 2004, [13]	Females. General population	1532 (106)	30–60	Questionnaire, polysomnography	AHI≥5, AHI≥5 + daytime sleepiness	3.7 2.1
Noal, Brazil, 2005, [14]	General population	3136	≥20	Questionnaire		9.9
Plywaczewski, Poland, 2008, [15]	General population of Warsaw	(676)	30–60	Polygraphy	AHI >10 and Epworth sleepiness score≥11 points	7.5
Bouscoulet, 4 latino american cities Mexico, Montevideo, Santiago de Chile and Caracas, 2008, [16]	General population	4533 (188)	≥45	Questionnaire, polygraphy	AHI≥5 and AHI≥5, in subjects reporting snoring + sleepiness + reported sleep apnea	2.9 23.5
Reddy, India 2009, [17]	General population 4 economic zones of South Dely	2860 (365)	30–65	Questionnaire, polysomnography	AHI≥5	Non snorers: 2.8 Snorers: 9.4

Abbreviation: AHI = apnea–hypopnea index.

Seeking help for sleep apnea and access to the treatments

Despite growing knowledge of sleep apnea, numerous studies stress that many patients remain undiagnosed. According to Pang and Terris,[19] 93% of women and 82% of men with moderate to severe OSA may still be undiagnosed. The gold standard for diagnosing OSA is still attending an overnight level I polysomnogram. Due to limited resources, including the number of recording beds, high costs, long waiting lists and laboratory requirements, many authors have explored the use of clinical predictors or questionnaires that may help to identify higher-risk patients. Finkel et al.[20] recently illustrated the high rate of undiagnosed OSA in a prospective, observational study by systematically screening adult surgical patients in an academic hospital. Amongst the 2877 patients screened, 661 (23.7%) scored a high-risk for OSA, of which 534 (81%) did not have a previous diagnosis of OSA. A portable sleep study detected OSA in 170/207 (82%) high-risk patients without diagnosed OSA.

Screening for sleep apnea may be useful in defined groups of patients commonly associated with obstructive sleep apnea syndrome (OSAS) and in which OSAS may be a contributing factor for other conditions: cardiovascular diseases, type 2 diabetes, obesity. West et al. recently assessed a group of 1682 males with type 2 diabetes using questionnaire-based interviews and found that 57% scored 'high' and 39% as 'low' risk for OSA. A further 4% had a previous diagnosis of OSA.[21] Oximetry was performed in 240 patients from both risk groups: 31% of the "high" and 13% of the "low" risk group had significant OSA (more than 10 > 4% SaO_2 dips/h or SaO_2 tracing consistent with OSA). These results were verified with detailed sleep studies. Extrapolation of the oximetry data to the population identified by questionnaire suggested that 23% had OSA. Multiple linear regression revealed that body mass index (BMI) and diabetes were significant independent predictors of OSA. Similarly, in a group of 98 consecutive patients treated for cardiovascular disease with a pacemaker intervention, without a pre-existing diagnosis of sleep apnea, Garrigue et al. found that 13 patients (25%) had an abnormal respiratory disorder index score >11/h. Fifty-seven patients (59%) had sleep apnea syndrome (SAS) of which 21 (21.4%) had a severe SAS (apnea–hypopnea index >30/h).[22] In a group of 290 morbidly obese patients who presented for weight loss surgery evaluation, Lopez et al. found that the incidence of sleep apnea was 78% (227 of 290).[23] All 227 affected patients were diagnosed by formal sleep study. The mean BMI was 52 kg/m^2 (range 31–94 kg/m^2). The prevalence of OSA was 71% in the severely obese group (BMI 35–39.9 kg/m^2), 74% in the morbidly obese group (BMI 40–49.9 kg/m^2) and 74% in the super obese group (BMI 50–59.9 kg/m^2) 77%. In patients with a BMI of 60 kg/m^2 or greater, the prevalence of OSA peaked at 95%. They concluded that patients presenting for weight loss surgery should undergo a formal sleep study to diagnose OSA before bariatric surgery.

Access to treatment for sleep apnea patients is often difficult due to the lack of availability of sleep labs and sleep specialists. It has frequently been argued that family physicians have difficulties confirming their clinical suspicions. The use of home-based rather than laboratory-based diagnostic testing and treatment titration is controversial but is often used when referral access is limited. There is growing evidence to support home versus laboratory-based diagnosis and treatment of sleep apnea.[24] In the United States, the Centers for Medicare and Medicaid Services (CMS) recently issued a memo revising their earlier position that authorized payment for CPAP could only be permitted after formal polysomnography (PSG) was performed and was diagnostic for OSA. The revised memo states that CMS will pay for 12 weeks of CPAP therapy (and subsequently if OSA improves) for adults diagnosed by either PSG or unattended home sleep monitoring devices. The use of portable home monitoring devices can greatly increase access to diagnosis and treatment of OSA. However, these devices must be used as part of a comprehensive sleep evaluation program that includes access to board-certified sleep specialists, PSG facilities, and professionals experienced in fitting and troubleshooting CPAP devices.[25] In Canada, Mulgrew et al.[7] have tested PSG versus ambulatory CPAP titration for the initial management of obstructive sleep apnea. Sixty-eight patients with a high pre-test probability of moderate to severe obstructive sleep apnea (apnea–hypopnea index [AHI] >15 episodes/h) were identified by sequential application of the Epworth sleepiness scale (ESS) score, sleep apnea clinical score, and overnight oximetry. They were randomly assigned to PSG or ambulatory titration by using a combination of auto-CPAP and overnight oximetry. After 3 months of observation, there were no differences in the primary outcome, AHI on CPAP between the PSG and ambulatory groups, or in the secondary outcomes, ESS score, sleep apnea quality of life index, and CPAP. Adherence to CPAP therapy was better in the ambulatory group than in the PSG group. They concluded that in the initial management of patients with a high probability of obstructive sleep apnea, PSG confers no advantage over the ambulatory approach in terms of diagnosis and CPAP titration. In Europe (Scotland), Cross et al.[26] came to the same conclusion for CPAP titration. Out of 200 patients, half were randomly assigned to a standard 1-night inpatient CPAP titration whereas the second half received 3 nights of home CPAP titration and then discharged with fixed pressure CPAP. The patient groups were matched to reduce confounding factors. The CPAP pressures defined at titration, number of mask leaks, and initial acceptance rates were similar in the sleep-laboratory and home-titrated groups. At 3-month follow up, there was no significant difference between the two study groups in CPAP use, ESS, the Oxford sleep resistance test (OSLER), functional outcomes of sleep questionnaire, or SF-36.

Education of patients may improve the acceptance but not the adherence to CPAP as shown by Meurice et al.[27] They studied the effects of four educational strategies on both compliance and quality of life changes with CPAP treatment amongst 120 patients from seven sleep centers. Patients received from prescribers either a simple oral explanation (SP) or an oral and written explanation (RP) of CPAP use. In addition, they received from homecare technicians either a single home visit (SH) at CPAP onset or repeated home visits at CPAP onset, then 1 week, 1 month and 3 months later (RH). Quality of life was evaluated using the generic SF-36 questionnaire, improved in the combined emotional domains. Compliance was over 5 h in all four education groups.

Impact of sleep apnea at work

Absenteeism, work limitation and other work characteristics

Sleep apnea patients may have multiple comorbidities which can contribute to disability, absenteeism and work productivity loss. Interestingly, despite major interest on the socioeconomic impact of sleep apnea, there is to our knowledge, only one study published concerning sleep apnea and absenteeism. Sjötsen et al.[28] established the total number of lost workdays caused by sleep apnea. The cohort was chosen through access to a register-linked case–control study of Finnish public sector employees who had received a diagnosis of sleep apnea between 1995 and 2005 ($n = 957$). Control subjects who had not received a diagnosis of sleep apnea were randomly selected ($n = 4785$) and matched for age, gender, socioeconomic position, employment, and organization. The absenteeism registered was either due to medically certified sickness absences or to disability pensions obtained during the 5 years prior to the year of sleep apnea diagnosis. After adjusting for comorbid conditions (i.e., hypertension, ischemic heart disease, diabetes, asthma/other chronic lung disease, and depression), an increased risk of missing workdays was found in employees with sleep apnea compared to control subjects (rate ratio [RR] = 1.61; 95% CI = 1.24–2.09 in men; and RR = 1.80; 95% CI = 1.43–2.28 in women). In women, the excess risk was already present 5 years prior to the year of diagnosis, whereas in men the highest risk was noticed 1 year before the year of diagnosis.

Sleep apnea is considered as a significant cause of work limitation by several studies. Mulgrew et al. demonstrated a clear relationship between excessive sleepiness and decreased work productivity in a population referred for suspected sleep-disordered breathing.[29] Using the ESS, work limitations questionnaire (WLQ), and an occupational survey, they studied patients undergoing full-night polysomnography for the investigation of sleep-disordered breathing. Data was collected and analyzed from 498 patients (average age of 49 ± 12 years, mean AHI 21 ± 22 events/h, ESS mean score 10 ± 5). Subjects worked a mean of 39 ± 18 h per week. The first 100 patients to complete the survey were followed up two years later. Across the studied group as a whole, there was no significant relationship between the severity of OSA and the four dimensions of work limitation. However, amongst blue-collar workers, significant differences were detected between patients with mild OSA (AHI = 5–15/h) and those with severe OSA (AH > 30/h) regarding time management (limited 23.1% of the time vs. 43.8%) and mental/personnel interactions (17.9% vs. 33.0%). In contrast, there were strong associations between subjective sleepiness (as assessed by the ESS) and three of the four scales of work limitation. That is, patients with an ESS of 5 had much less work limitation compared to those with an ESS of 18 in terms of time management (19.7% vs. 38.6%), mental-interpersonal relationships (15.5% vs. 36.0%) and work output (16.8% vs. 36.0%). Sivertsen et al. (Norway) also found that self-reported symptoms of obstructive sleep apnea syndrome were an independent risk factor for subsequent long-term sick leave and permanent work disability.[30] In Italy, Accatoli et al. concentrated on work performance amongst 331 sleep apnea workers compared to 100 non-apneics and found that workers with OSAS reported more impairments in work performance than non-apneics such as difficulties in memory, vigilance, concentration, performing monotonous tasks, responsiveness, learning new tasks and manual ability.[31] Omachi et al. compared work disability in 83 patients with OSA and excessive daytime sleepiness (EDS) who were referred to their sleep center, to a group of patients without EDS, and a group without both OSA and EDS.[32] They created their own work disability questionnaire and found that patients with the combination of OSA and EDS were at higher risk of both short-term work disability (adjusted odds ratio [OR] = 13.7; 95% CI = 3.9–48) and longer-term work duty modification (OR = 3.6; 95% CI = 1.1–12). However, when examining OSA independently from EDS, OSA only contributes to short-term work disability. Finally, Omachi et al. investigated work disability of 183 consecutive patients with sleep apnea with or without EDS referred to their clinical centre in California, USA.[33] Creating their own assessment tool, they considered work limitation as the outcomes of short-term productivity loss or longer-term work duty modifications. They quantified the frequency of short-term work disability based on self-report of the 4-week cumulative incidence of: missed complete work days recorded separately from missed partial workdays due to sleeping problems; falling asleep on the job; and low (<90%) self-rated job effectiveness. They defined these disability outcomes on a short time-scale as they felt subjects would have difficulty precisely recalling occasions such as missed work days further than the last 4 weeks. They quantified work duty modification based on self-report of the incidence of missed promotions, changes in job duties, job schedule, job pay, or change in job specifically attributed to problems with sleep. As such work duty modifications are by their nature unlikely to occur in a short period of time, they recorded such modifications as their 5-year cumulative incidence and termed this work disability category, "longer-term work duty modifications." They found that more than three quarters indicated recent work disability ($n = 64/83$; 77%; 95% CI 67–86). Overall, a substantial minority of patients had some form of longer-term work duty modification caused by sleep problems ($n = 19/83$; 23%; 95% CI 14–33). Although the prevalence of short-term work disability was found higher among the OSA population than in the controls, there was no clear association between OSA and longer-term work duty modification in univariate analyses. Having the combination of OSA and EDS diagnoses, however, was associated with an increased risk of both short-term work disability and longer-term work duty modification.

Interestingly, it seems that some occupations bear a higher risk of having OSA. Li et al. investigated subjects over 35 years old who were hospitalized for obstructive sleep apnea after being diagnosed in Sweden during the study period of 1997–2001 (10,336 males and 2602 females).[34] Among male workers, increased risk was noted for several occupational groups such as sales agents, seamen, drivers, engine and motor operators, cooks and stewards. For female workers, increased risk was only observed among drivers. Adjustment for obesity had no effect on risk levels.

Sleep apnea and accidents

The impact of sleep apnea on car accidents is a crucial public health issue. Public authorities and the media are deeply aware of the risk of sleepiness at the wheel during the night and of the effects of sleep debt and sleep pathologies (sleep apnea, hypersomnia) on accidents.

Accidents in sleep apnea

The risk of accidents caused by sleepiness associated with sleep apnea has been extensively described. In 2004, George made a review of studies published in the field and found more than 10 studies confirming a higher risk of accidents in OSAS with an odds ratio varying from 1.9 to 10.8.[34] Despite methodological issues, most of the evidence continues to suggest that OSAS confers an increased risk for driving. The main issues are that almost all studies have been cross-sectional in nature with only one case controlled; there have been no prospective cohort studies to date; several of the studies are subject to selection bias as they involve clinic patients; information bias is also a concern due to a lack of similar information among control groups; the confounding effects of age, sex, driving exposure, alcohol, and drug use were not adequately considered in most studies. More recently Ellen et al. also reviewed more than 20 studies concerning apnea and accidents which confirmed a 2 to 3-fold increased risk in apneics. Data on the correlation between subjective daytime sleepiness and crash risk was also found in half of the studies reviewed.[35]

Mazza et al.[36] compared a group of 20 patients with OSA to 20 obese non-snoring subjects, performing on a road safety platform, and showed that driving ability was disturbed in OSA. Patients exhibited much longer reaction times than controls, leading to a lengthening of the vehicle's stopping distance of 8.8 m at 40 km/h and to twice the number of collisions.

After CPAP treatment, there was no longer any difference between patients and controls in driving and attention performances. Treatment of sleep apnea consistently improved driver performance (including crashes) across all studies, a point firmly confirmed by Ellen et al.[35] in their review. More recently Antonopoulos et al. also published a meta-regression analysis that examined the effect of nasal continuous positive airway pressure (nCPAP) treatment of OSA on road traffic accidents and driving simulator performance. Ten studies on real accidents (1221 patients), five studies on near-miss accidents (769 patients) and six studies on the performance in driving simulator (110 patients) were included.[37] They found a significant reduction of risk of both accidents and near-miss accidents in patients treated with nCPAP in real life and within a virtual environment.

Assessing the individual risk of accidents for apnea patients is a controversial issue. Subjective sleepiness evaluated by the ESS does not seem relevant enough as according to the review of Ellen et al.,[35] 50% of the victims of accidents did not feel sleepy. Objectively, the maintenance of wakefulness test (MWT) was used and compared to driving simulator performances by Philip et al.[38] They collected the number of inappropriate line crossings (on driving simulator) correlated with MWT scores ($p < 0.05$), Karolinska sleepiness scale scores measured at halfway in total driving distance ($p < 0.01$), and ESS scores ($p < 0.01$). They found a significant difference in the number of inappropriate line crossings among the four groups defined by MWT scores (very sleepy [0–19 min], sleepy [20–33 min], alert [34–40 min], and controls) ($p < 0.01$). Very sleepy and sleepy patients had more inappropriate line crossings than the control drivers ($p < 0.05$). Subjectively, Powell et al. recommended to interview patients about past "near-miss sleepy accidents".[39] The study included 35,217 (88% of sample) individuals with a mean age of 37.2 ± 13 years, of which 54.8% women, and 87% white. The risk of at least one accident increased monotonically from 23.2% if there were no near-miss sleepy accidents to 44.5% if there were 4 or more near-miss sleepy accidents ($p < 0.0001$). After covariate adjustments, subjects who reported at least one near-miss sleepy accident were 1.13 times more likely to have reported at least one actual accident as subjects reporting no near-miss sleepy accidents ($p < 0.0001$).

Stoohs et al. first suggested that the prevalence of sleep apnea may be higher in commercial truck drivers.[40] In their study, about 20% of a group of 90 commercial long haul truck drivers presented symptoms indicating severe sleep-disordered breathing (SDB) and had a two fold increased accident risk per mile over drivers without SDB. More recently, Howard et al. measured the prevalence of excessive sleepiness and SDB and assessed the accident risk factors among 2342 drivers.[41] A questionnaire was distributed to a random sample of 3268 Australian commercial vehicle drivers. A sample group of 161 drivers was invited to undergo polysomnography. More than half (59.6%) of drivers had sleep-disordered breathing and 15.8% had obstructive sleep apnea syndrome. Twenty-four percent of drivers had excessive sleepiness. An increase in sleepiness was related to an augmentation of accident risk. The sleepiest 5% of drivers on the ESS and functional outcomes of sleep questionnaire had an increased risk of having one accident (odds ratio [OR] = 1.91, $p = 0.02$ and OR = 2.23, $p < 0.01$, respectively) and of multiple accidents (OR = 2.67, $p < 0.01$ and OR = 2.39, $p = 0.01$), adjusted for established risk factors.

However, even in sleep apnea patients, sleepiness is not always only due to apnea but can be related to sleep debt due to irregular work and sleep schedules.[41]

It seems reasonable that a common policy for driving with sleep apnea should be defined by international authorities. Actually, despite the available scientific evidence, most countries in Europe do not include sleep apnea syndrome or excessive daytime sleepiness among the specific medical conditions to be considered when judging whether or not a person is fit to drive. A unified European Directive seems desirable.[42]

Costs of sleep apnea

Direct costs of OSA

The studies devoted to the direct costs of OSA have mainly focussed on the cost of diagnosis (polysomnograpy versus ambulatory) and the cost/benefit of using CPAP.

Regarding the diagnosis of OSA, Whittle et al. were among the first to produce a cost-analysis study with the aim of recommending home sleep studies versus laboratory polysomnography. Comparing a group of 150 subjects "at home" to 75 patients "in the laboratory",[43] they calculated that home sleep studies gave a faster delay of diagnosis (median 18 days [range 0–221] versus 47 days [range 0–227] days, $p < 0.001$) and cheaper diagnosis (mean [SD] 164 pounds [104] vs. 210 pounds [0], $p < 0.001$). For diagnostic reliability, a further sleep study was required in 56% of cases. Treatment options were identical between the two groups. Chervin et al. refuted this when they performed a carefully thought out cost utility model (on a 5 years perspective) to compare the use of polysomnography with both home recording and no testing.[44] They used QALYs for the first 5 years after evaluation for OSAS (QALY5s). In cost utility ratios that compared polysomnography with either home study or no testing, the numerator was the 5-year difference in total costs and the denominator was the difference in QALY5s for the same period. Polysomnography generated higher QALY5s (4.019) than did home study (3.955) or no testing (3.934). The 5-year diagnostic and treatment charges for a patient with OSAS were $4210 for the polysomnography group, $3460 for the home group, and $3020 for the no testing group. Those charges for a random patient (who may or may not have OSAS) were $3799, $2939, and $3020, respectively. The incremental cost utility ratio for polysomnography compared with home study was $13,431 per QALY gained. The cost utility ratio for polysomnography compared with no testing was $9165. They concluded that polysomnography usually provides improved QALY5s over both home study and no testing. Reuven et al. in Israel also provided proof of concept that the cost of sleep study techniques can be modeled.[45] They reject the assumption that home portable sleep monitoring (PSM) is cost advantageous and declares the combination of PSG and attended PSM OSAS is the most cost-effective approach to sleep evaluation. A French study by Pelletier-Fleury et al. focussed on the economical consequences of delay (by 6 months) in the diagnosis and treatment of OSA due to the lack of facilities.[46] Costs were calculated based on quality of life and healthcare expenditure (hospitalizations, medical visits, complementary tests, biological tests and drug prescriptions). It concerned 171 patients followed over 6 months, with 82 patients randomized to group 1 “immediate polysomnography” and 89 in group 2 “polysomnography within 6 months”. Incremental cost-effectiveness ratios related to rapid introduction of treatment were significantly lower in the patients with more severe degree of OSAS. These results provide fairly clear medical and economic arguments in favor of early management of patients with more severe forms of obstructive sleep apnea syndrome.

Mar et al. also used QALY based on the European quality of life (EuroQol) 5D to assess the cost-effectiveness of CPAP treatment in patients with moderate to severe obstructive sleep apnea in Spain.[47] Cost analysis was undertaken from the healthcare system’s perspective. The direct costs of diagnosis and treatment of OSAS and indirect costs attributable to cardiovascular morbidity were considered. Patients with OSAS used more healthcare services than the general population. They concluded that the incremental cost-effectiveness ratio of CPAP treatment was <6000€ per quality-adjusted life year. On disaggregated analysis, CPAP treatment accounts for 86% of incremental costs; 84% of incremental effectiveness is attributable to improved quality of life. Ayas et al. made a similar modelization in Canada.[48] They clarified and reaffirmed the point that the cost-efficiency of CPAP should be considered from different perspectives. From a third-party payer or a societal perspective, CPAP therapy was more effective but more costly than no CPAP, with incremental cost-effectiveness ratios of $3354 or $314 per quality-adjusted life-year gained, respectively. The incremental cost-effectiveness ratio estimate was mostly dependent on viewpoint (varying more than 10-fold between societal and third-party payer perspectives) and choice of utility measurement method (varying more than 5-fold between the use of standard gamble and Euro quality of life utility score (EuroQol) 5D utility assessment values). They concluded that when quality of life, costs of therapy, and motor vehicle costs outcomes are considered, CPAP therapy for patients with OSA is economically attractive. In the UK, Weatherly et al. recently estimated the cost-efficiency of CPAP (compared to dental device or life style advice), using a QALYs method on a lifetime perspective.[49] On average, CPAP was associated with higher costs and QALYs compared with dental devices or lifestyle advice. In the base-case analysis, the incremental cost-effectiveness ratio (ICER) for CPAP compared with dental devices was around 4000 pounds per QALY (2005-06 prices). The probability that CPAP is more cost-effective than dental devices or lifestyle advice at a threshold value of 20,000 pounds per QALY was 0.78 for men and 0.80 for women. They concluded that CPAP is cost-effective compared to dental devices and lifestyle advice for adults with moderate or severe symptomatic OSAS at the cost-effectiveness thresholds used by the national institute for health and clinical excellence in United Kingdom (NICE). This finding is reflected in the NICE guidance. In France, the cost of home-initiated auto-nCPAP was estimated lower that the conventional nCPAP by Planes et al. between two paired groups of 18 subjects each (1263€ $\pm$ 352 vs. 1720€ $\pm$ 455, respectively; $p < 0.05$).[50] Ayas et al. based on a meta analysis of 9 randomized trials studying a total of 282 patients in the United States concluded that, given that auto-titrating positive air pressure (APAP) was more expensive than standard CPAP, APAP should not be considered first-line chronic therapy in all patients with OSA. APAP may, however, be useful in other situations (e.g., home titrations, detection of mouth leakage). Identifying circumstances in which APAP is a definite improvement over CPAP in terms of costs or effects should be the focus of future studies.[51] Hillman et al. also reviewed the economic costs of sleep disorders in Australia based on 2000–2001 statistics extrapolated to 2004 based on demographic growth and inflation.[52] They estimated fractions of various conditions (such as cardiovascular diseases, diabetes or accidents) attributable to OSA (beside other costs attributable to other sleep disorders). They assumed that the fraction of cases of hypertension attributable to OSA was 2.1%, 0.5% of ischemic heart diseases, 0.7% of stroke, 2.1% of hypertensive heart diseases, 0.9% of renal diseases and 0.2% of peripheral vascular diseases. The fraction of diabetes attributable to OSA was estimated to be 2.9%. This implies a direct health cost for hospitalizations of 11 million US $ due to OSA in 2004 and an another 6.6 million due to other sleep related breathing disturbances.

Indirect costs of OSA

The issue of how OSA interferes with chronic diseases such as diabetes, obesity, cardiovascular diseases, depression is crucial in the discussion of the indirect costs of OSA. Understandably, controlling comorbidities in an OSA study remains challenging as finding a reasonable control group of OSA patients without comorbidities seems improbable. Several studies have, however, tried to assess indirect costs of OSA on healthcare consumption. Kapur et al. recorded the severity of sleep-disordered breathing and the magnitude of medical costs.[52] Mean annual medical cost prior to diagnosis in 238 patients with OSA was compared to that of age and gender matched controls ($p < 0.01$). The estimated cost was $2720 vs. $1384. Using available data on the prevalence of undiagnosed moderate to severe sleep apnea in middle-aged adults, they estimated that untreated sleep apnea may cause $3.4 billion in additional medical costs in the U.S. Albarrack et al. published an interesting retrospective observational cohort study in Canada.[53] Healthcare use was observed in 342 men with OSAS and matched controls 5 years prior to initial OSAS diagnosis, and for the 5 years of CPAP treatment post-diagnosis. In the year before diagnosis, the number of physician visits was higher in patients than in controls by 3.46 ± 0.2, as compared with the fifth year before diagnosis, then decreased over the 5 years after diagnosis by 1.03 ± 0.49 ($p < 0.0001$). Physician fees, in Canadian dollars, were higher by dollars $148.65 \pm$ dollars 27.27 in OSA cases in the year before diagnosis, compared with the fifth year before diagnosis, and then decreased over the next 5 years by dollars $13.92 \pm$ dollars 27.94 ($p = 0.0009$). They concluded that treatment of OSAS reversed the trend of increasing healthcare utilization seen prior to diagnosis.

Indirect costs for snoring, OSA and obesity hypoventilation syndrome (OHS) were also calculated in Denmark based on the Danish national patient registry (1998–2006) database.[54] Twelve thousands and forty-five snorers, 19,438 OSA cases and 755 OHS patients were identified. For every patient, four (age-, sex- and socioeconomic-matched) citizens were randomly selected (48,180, 77,752 and 3020, respectively) from the Danish civil registration system statistics. Direct costs were obtained from the Danish Ministry of Health, Danish Medicines Agency and National Health Security and indirect costs were based on data derived from the coherent social. They found that snoring, and especially OSA and OHS were associated with significantly higher rates of health-related contact, medication use, unemployment and accounted for increased socioeconomic costs (especially indirect costs). These effects increased with the severity of OSA and patients with OHS had the lowest employment rates. The income level of patients with OSA and OHS who were employed was lower than that of employed control subjects. The annual excess total direct and indirect costs for patients with snoring, OSA and OHS were €705, €3860 and €11,320, respectively. Patients with snoring, OSA and OHS received an annual mean excess social transfer income of €147, €879 and €3263, respectively. Treatment with CPAP reduced mortality in patients with OSA but not in those with OHS within an observation period of 8–14 years.

Modeling the risk of accidents due to OSA, Sasani et al. also calculated the estimated indirect cost which could be saved annually in the USA by treating patients.[55] They concluded that 800,000 drivers were involved in OSAS-related motor-vehicle collisions in the year 2000. These collisions cost 15.9 billion dollars and 1400 lives. In the United States, treating all drivers suffering from OSAS with CPAP would cost 3.18 billion dollars, but save 11.1 billion dollars in collision costs, and save 980 lives annually.

Quality of life in sleep apnea

The specific impact of OSA on quality of life

About 15 years ago, Smith and Shneerson used the short form 36 health survey questionnaire (SF-36) to test the impact of sleep disruption in 223 patients with OSA before and 6 months after treatment (CPAP).[56] Subjects with OSA requiring treatment scored lower on all dimensions of the SF-36 ($p < 0.05$) than the general population. The differences were most important for vitality (24%) and social functioning (27.9%). After six months of treatment with CPAP there was an improvement in all scores and the vitality score was no longer significantly lower than that of the general population. Impaired QoL in OSA was widely demonstrated by Baldwin et al. in the sleep heart health study (USA, $n = 5816$; mean age = 63 years; 52.5% women).[57] Vitality was the only SF-36 dimension to have a linear association with all clinical categories of sleep-disordered breathing (mild, moderate, severe sleep disorders breathing (SDB). Akashiba et al. interestingly concentrated on the symptoms impacting QoL in OSA: mood, sleepiness or severity of the SDB index.[58] Sixty patients with OSAS and 34 normal control subjects were assessed for QoL using SF-36, for EDS using the ESS, and for mood using the Zung self-rated depression scale (SDS). Stepwise multiple regression analysis selected three variables, the SDS score (partial $R^2 = 0.505$), the lowest arterial oxygen saturation during sleep (partial $R^2 = 0.064$), and ESS score (partial $R^2 = 0.053$), as independent factors for predicting the total score on the SF-36 questionnaire. These three variables accounted for 62.2% of the total variance in the final SF-36 score ($R^2 = 0.622$, $p < 0.0001$). Goncalves et al. (2004) focussed on the effects of short arousals (>3 s) on SF-36 in 135 patients with OSA.[59] They concluded that the "physical functioning", "general health", and "physical role" subscales of the SF-36 correlated with the arousal index (see Table 2).

A specific instrument for OSA QoL: the SAQLI

A specific instrument for assessing QoL in OSA, the Calgary sleep apnea quality of life index (SAQLI) was suggested and compared with the SF-36 in 90 subjects with OSA.[60] SAQLI includes five domains: symptoms, activities, emotions, and social interactions. In this study, the SAQLI was found to have a very high responsiveness index of 1.9 and an effect size of 1.1, which was greater than the domains of the SF-36. There were statistically significant longitudinal correlations (range 0.24–0.54) between the SAQLI and seven of the SF-36 domains in a pattern that was anticipated and predicted and which demonstrated the validity of the SAQLI as an evaluative instrument. The SAQLI also had a range of baseline correlations with the SF-36 (range 0.36–0.71) and the ESS (−0.26). It had a reliability coefficient of 0.92 when testing and retesting at 2 weeks.

Quality of life in the treatment of OSA

The benefit of treating patients with CPAP on QoL has been confirmed by several studies.[61–67] Jenkinson et al. used SF-36 in a randomized prospective parallel trial of therapeutic nCPAP for obstructive sleep apnea in 57 patients compared with a control group on sub-therapeutic nCPAP of 54 subjects.[62] Effect sizes for SF-36 measures of energy and vitality were 1.68 for therapeutic and 0.97 for sub-therapeutic nCPAP (between treatments $p < 0.0001$). For mental summary score, the corresponding values were 1.02 and 0.4 for each treatment ($p = 0.002$). Sin et al. also demonstrated that there was a long-term benefit of using CPAP on QoL.[63] At the start of the study, SF-36 scores were similar in the 365 patients with an AHI >20 and treated with CPAP and in 58 patients with an AHI <20 and not treated. After 3 months of therapy, the CPAP group had higher adjusted emotional summary

Table 2
The specific impact of OSA on quality of life using SF-36 scale.

Study	Design of the study and sample	Quality of Life
Smith and Shneerson, J Sleep Res, 1995[57]	223 patients with OSA before and after 6 months of treatment with CPAP	Before treatment: patients with OSA had lower scores in all dimensions of the SF-36 ($p < 0.05$) than normative scores for general population After treatment: improvement in all scores
Baldwin et al., Sleep, 2001[58]	Sleep heart health study (n=5816)	Individuals with severe SDB indicated poorer QoL on several SF-36 sub scales
Akashiba et al., Chest, 2002[59]	Symptoms impacting QoL in OSA 60 patients with OSA versus 34 normal control subjects	SF-36 were correlated with depression scale but not with the severity of OSA and ESS score
Goncalves et al., Chest, 2004[60]	Effects of short arousal on QoL 135 patients with OSA	Some sub scales such as "physical functioning", "general health", and "role physical" are correlated with the arousal index

Abbreviations: OSA = obstructive sleep apnea; CPAP = continuous positive air pressure treatment; SDB = sleep disorder breathing; QoL: quality of life; SF-36: short for 36 health survey questionnaire; ESS = Epworth sleepiness scale; n = number.

Table 3
Effect of treatment of OSA on quality of life.

Study	Design of the study and sample	Quality of life
Jenkinson et al., Lancet, 1999[63]	Randomized prospective parallel trial 57 patients treated with CPAP vs. 54 control subjects	CPAP treatment improve subscales "energy" and "vitality" of SF-36 ($p < 0.0001$)
Sin et al., Chest, 2002[64]	365 patients treated with CPAP vs. 358 patients not treated with CPAP Follow up at 3 and 6 months	At baseline: similar SF-36 score 3 and 6 months: higher adjusted emotional summary scores maintained at 6 months
Jin et al., Lung, 2008[65]	Meta analysis of 20 studies on the effects of CPAP	CPAP improves "physical function", "body pain", "energy vitality", and "physical component summary"
Li et al., Arch Otolaryngol Head Neck Surg, 2004[66]	55 patients treated with surgery	Uvulopalatal flap surgery improves QoL
Vecchierini et al., Sleep Med, 2008[67]	Effect of mandibular repositioning device	Mandibular repositioning devices improve QoL

Abbreviations: OSA = obstructive sleep apnea; CPAP = continuous positive air pressure treatment; QoL: quality of life; SF-36: short for 36 health survey questionnaire.

scores than those who had not received CPAP therapy (score increase, 1.72). These improvements were maintained for 12 months. The increase in the SF-36 scores was most striking in the vitality domain with a score increase of 10.52. The severe OSA group (i.e., AHI $\geq$40) experienced the greatest benefit. Their adjusted vitality scores were 12.3 higher than those without OSA (i.e., AHI <5) (see Table 3).

More recently, Jing et al. conducted a meta analysis of 20 recent studies on the effects of CPAP on the QoL of patients with OSA.[64] They concluded that CPAP does not improve general QoL scores but does improve physical domains and vitality. Using SF-36, the patients undergoing CPAP scored better in physical function (OR 3.5; $p = 0.041$), body pain (OR = 4.0; $p = 0.05$), energy vitality (OR = 7.0; $p = 0.033$) and physical component summary (PCS) (OR = 2.0; $p = 0.045$). Regarding other treatments, Li et al. also described an improvement of QoL in 55 patients attending uvulopalatal flap surgery for OSA.[65] Patients demonstrated significant increases in 7 of 8 SF-36 subscales ($p < 0.05$ for all). Vecchierini et al. further reported that OSA patients treated with a mandibular repositioning device had an improved QoL.[66]

Final comments

OSA affects the daily lives of millions of people around the world. The economic impact of this most prevalent sleep disorder on the collectivity seems enormous. There is also increasing evidence linking OSA to several severe public health major concerns: obesity, diabetes, depression, cardio-vascular diseases and accidents. Beside the patients themselves, their family and work relatives may also be deeply concerned by the consequences of snoring and OSA in their own lives.

Practice points

- The usual association of OSA with one or several of the other major comorbidities (diabetes, overweight, cardiovascular diseases) drives us to be careful in the evaluation of economic consequences of OSA.
- OSA is severely under diagnosed especially in patients with comorbidities.
- The access of sleep apnea patients to treatment is often difficult due to the lack of availability of sleep labs and sleep specialists.
- OSA patients have a clearly impacted work limitation compared to non-apneics and a higher risk of accidents.
- Ambulatory methods for the diagnosis of OSA are generally considered as more cost effective than inpatient PSG.
- Treating OSA with CPAP reduces direct and indirect costs.

Research agenda

- Specific data are needed on the impact of OSA on absenteeism.
- Utility cost studies of treatments with surgery or mandibular repositioning device are lacking.
- Longitudinal studies on patients with OSA at work before and after treatment would be useful.
- Epidemiology of accidents in patients correctly treated with CPAP is unclear.

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