

Review Article

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Sleep & the metabolic syndrome

Jamie C.M. Lam & Mary S.M. Ip

*Division of Respiratory Medicine, University Department of Medicine, Queen Mary Hospital
The University of Hong Kong, SAR, China*

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Sleep is an essential part of our daily living, and sleep disturbances may intervene with the biological and physiological processes in human body leading to the development of metabolic dysfunction. Short sleep duration and poor sleep quality have adverse effects on metabolism and hormonal processes, contributing to increased cardiovascular risk. Obstructive sleep apnoea is a chronic condition characterized by repetitive upper airway collapse during sleep, causing intermittent hypoxaemia, recurrent arousals and sleep fragmentation. Sleep disturbances can increase sympathetic activity, provoke systemic inflammation and oxidative stress, and impair vascular endothelial function. Obstructive sleep apnoea is increasingly recognized to be an independent cardiovascular risk factor. There is intense research interest in the association between obstructive sleep apnoea and the metabolic syndrome - the constellation of inter-related metabolic derangements including central obesity, hypertension, insulin resistance and dyslipidaemia, which appears to directly promote the development of atherosclerosis. The underlying pathophysiologic pathways or mechanistic links between obstructive sleep apnoea and metabolic syndrome have not been well delineated. This article reviews the current knowledge of the relationship between sleep disturbances, sleep-disordered breathing and the metabolic syndrome in adults.

Key words Diabetes mellitus - hypertension - metabolic syndrome - obesity - obstructive sleep apnoea - sleep-disordered breathing - sleep disturbances

Introduction

Short sleep duration and poor quality of sleep, increasingly common in our modern society, have many effects on our endocrine and metabolic function. Sleep is a major buffer for hormonal release, glucose regulation and cardiovascular function¹. The quality of sleep declines with age, with predominant light and fragmented sleep in the elderly². Deep or slow wave sleep occurs during stages 3 and 4 of non rapid eye movement (NREM) sleep and is considered to be the most restorative of all sleep stages. Chronic sleep

insufficiency or deprivation not only leads to frequent mental and physical distress, physical incapability and anxiety³ but also contributes to the ageing process, and may increase the risk for diabetes and obesity⁴.

Sleep-disordered breathing (SDB) disrupts sleep pattern and quality. Obstructive sleep apnoea (OSA) is the most common sleep disorder being diagnosed. It is a chronic condition characterized by repetitive episodes of the upper airway collapse during sleep. The effects of intermittent hypoxia and re-oxygenation may provoke a number of pathological cascades

which involve sympathetic overactivity, systemic inflammation, oxidative stress and endothelial dysfunction. These are believed to be the underlying mechanisms of OSA contributing independently to increased cardiometabolic risk⁵. Untreated OSA subjects have been shown to suffer a significantly increased risk of both fatal and non fatal cardiovascular events by 3-fold, when compared to healthy subjects⁶.

The metabolic syndrome is a constellation of inter-related risk factors of metabolic origin and its prevalence is increasing due to the obesity epidemic. Metabolic syndrome is associated with cardiovascular mortality because it comprises established risk factors for cardiometabolic diseases⁷. Recent data show a strong association between OSA and the metabolic syndrome, which is indicative of adverse cardiovascular outcomes⁸. This article reviews the current knowledge of the relationship between sleep disturbances, sleep-disordered breathing and the metabolic syndrome in adults.

The metabolic syndrome

Metabolic syndrome was first described as a cluster of metabolic abnormalities, with insulin resistance as the central pathophysiological feature, and it was labelled as “Syndrome X”⁹. There are different accepted criteria for its definitions, and the

most widely used criteria have been proposed by the World Health Organization (WHO), the European Group for the Study of Insulin Resistance (EGIR), the National Cholesterol Education Program – Third Adult Treatment Panel (NCEP ATP III) and International Diabetes Federation (Table). All these organizations have suggested that the core features of metabolic syndrome are central/visceral obesity, hypertension, insulin resistance and dyslipidaemia but they have applied the criteria differently in identifying the cluster of syndrome components¹⁰. Therefore, there have been cases that could be classified as metabolic syndrome by one definition but not by the others. Today, insulin resistance and central obesity have been acknowledged as key driving forces for metabolic syndrome, and these are, independently, also well known cardiovascular risk factors. Patients with metabolic syndrome are at increased risk for the development of type II diabetes mellitus and cardiovascular disease¹¹.

Different definitions for the metabolic syndrome inevitably led to limited comparability between studies. Besides, there are problems of applicability of these definitions to different ethnic groups, especially in relation to obesity cut-offs. With the current metabolic syndrome definitions, particularly NCEP ATP III, low prevalence figures in Asian population resulted. In a study of over 2800 Chinese subjects, the prevalence of

Table . Different definitions of the metabolic syndrome

WHO (1999) ¹⁰	EGIR (1999) ¹⁰	NCEP ATP III (2001) ¹³	IDF (2005) ¹⁰
Diabetes or impaired glucose tolerance or insulin resistance, plus 2 or more of the following,	Insulin resistance or hyperinsulinaemia (only non-diabetic subjects), plus 2 or more of the following,	Three or more of the following,	Waist circumference – ethnicity specific, plus two or more of the following,
BMI > 30 kg/m ² or waist to hip ratio > 0.9 in men, > 0.85 in women	Waist circumference: > 94 cm in men, ≥ 80 cm in women	Waist circumference: >102 cm in men, >88 cm in women	
Triglycerides: ≥ 1.7 mmol/l	Triglycerides: > 2 mmol/l	Triglycerides: > 1.7 mmol/l	Triglycerides: ≥ 1.7 mmol/l or medication
HDL-C: < 0.9 mmol/l in men < 1.0 mmol/l in women	HDL-C: < 1.0 mmol/l	HDL-C: < 1.03 mmol/l in men < 1.29 mmol/l in women	HDL-C: < 1.03 mmol/l in men < 1.29 mmol/l in women or medication
Blood pressure: ≥ 140/90 mmHg or medication	Blood pressure: > 140/90 mm Hg or medication	Blood pressure: > 130/85 mmHg or medication	Blood pressure: > 130/85 mmHg or medication
Urine albumin excretion ≥ 20 µg/min or albumin:creatinine ratio > 30mg/g	Fasting plasma glucose: > 6.1 mmol/l	Fasting plasma glucose: > 6.1 mmol/l	Fasting plasma glucose: > 5.6 mmol/l or type II diabetes

WHO, World Health Organization; EGIR, European Group for the Study of Insulin Resistance; NCEP ATP III, National Cholesterol Education Program – Third Adult Treatment Panel; IDF, International Diabetes Federation; BMI, body mass index; HDL-C, high density lipoprotein cholesterol

the metabolic syndrome was at 16.7 per cent, however, if using WHO recommendations for waist circumference for Asians¹², the age and gender-adjusted prevalence significantly increased to 21.2 per cent¹³. Knowing the recent evidence and with the spreading obesity epidemic, the prevalence of metabolic syndrome and its associated complications is definitely on the rising trend regardless of the exact criteria used for the syndrome.

Obstructive sleep apnoea and metabolic syndrome

A number of neural, humoral, metabolic, vascular and inflammatory abnormalities are evident in subjects with OSA, and it is increasingly recognized to be an independent cardiovascular risk factor¹⁴. Current data suggest that OSA increases cardiovascular morbidity and mortality, and continuous positive airway pressure (CPAP) treatment has the potential to diminish such risk¹⁵. Different mechanisms have been proposed for these derangements to better understand the pathophysiologic core features and hence to formulate treatment strategies¹⁶.

Many studies have investigated the relationship of OSA and different cardiometabolic parameters¹⁷⁻²¹, and CPAP treatment has produced some beneficial effects on individual metabolic components^{22,23}. There is also recent focus on the relationship between sleep apnoea and the metabolic syndrome as a single entity²⁴. OSA or snoring is shown to be independently associated with an increased prevalence of metabolic syndrome, and this is consistent across different ethnic origins²⁵⁻³⁰.

In a cross-sectional clinic-based study³¹ of 184 patients with co-morbidities, those who suffered from OSA and the metabolic syndrome had higher brachial-ankle pulse wave velocity (a measure of endothelial dysfunction) and plasma levels of C-reactive protein (an inflammatory marker) compared to those without metabolic syndrome. Therefore, the concurrent presence of metabolic syndrome in OSA patients may have an additive effect on cardiovascular risk³¹. In another observational study of 195 patients with cardiovascular diseases, the metabolic syndrome was a better predictor of nocturnal desaturation than apnoea-hypoapnoea index (AHI) in those patients with sleep apnoea, with the odds ratio of 2.63³². However, in an interventional study of 89 OSA patients, the presence of metabolic syndrome did not increase the risk of cardiovascular events in OSA patients who had good CPAP compliance after 22±10 months of follow up³³.

The co-existence of OSA and metabolic syndrome may increase the risk for the development of cardiovascular diseases either additively or synergistically. The underlying mechanisms are as yet poorly defined, but intermittent hypoxia and sleep fragmentation in OSA are thought to be the main triggers of various pathogenetic mediating pathways leading to metabolic dysfunction with multi-directional interactions and feedback (Fig. 1).

Sleep and metabolic dysfunction

Sleep is closely related to the regulation of physical and emotional well being³⁴. Hormonal events during sleep are dependent upon sleep duration and sleep quality, and the multiple peripheral effects of sleep suggest that sleep loss might be associated with deleterious health consequences³⁵. Sleep duration plays a role in the regulation of leptin and ghrelin levels in humans. Both of these hormones integrate control of feeding, wakefulness and energy expenditure in the body although the mechanisms are unclear, and may act in parallel as metabolic counterparts for body weight control³⁶.

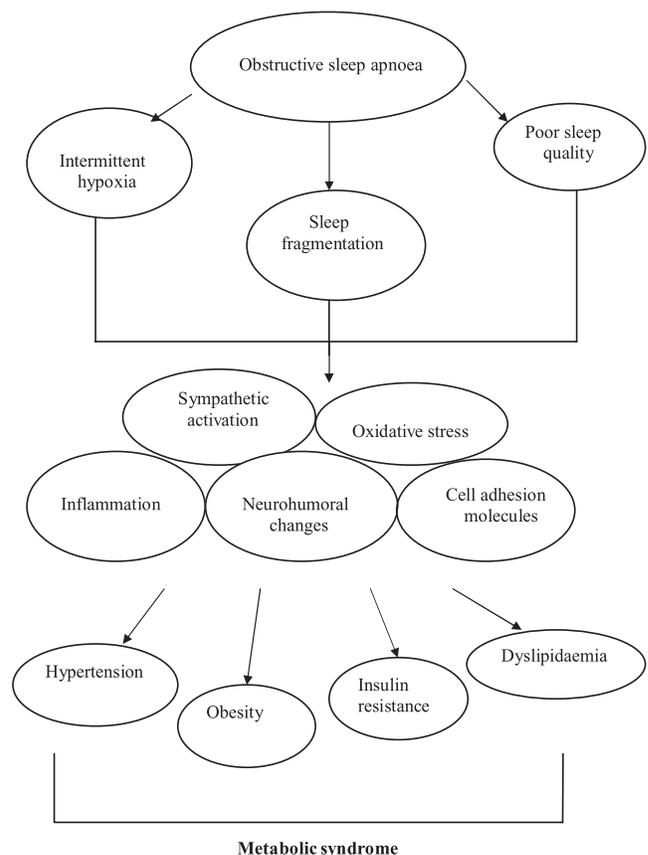


Fig. 1. Possible pathogenetic pathways between obstructive sleep apnoea and metabolic syndrome.

The Wisconsin sleep cohort study has provided important data on sleep duration, showing that a loss of 3 h of sleep from a baseline of approximately 8 h was associated with an average 4-5 per cent higher body weight³⁷. A recent systemic review of both cross-sectional and longitudinal studies revealed that short sleep duration is independently associated with weight gain, particularly in young age groups³⁸. In a retrospective study of 1000 patients from four different primary care practices, women were found to sleep more than men, and overweight [body mass index (BMI) 25 – 29.9 kg/m²] and obese (BMI 30-39.9 kg/m²) patients slept less than patients with a normal BMI (<25 kg/m²)³⁹. Interestingly, in a cross-sectional study of 500 Chinese adolescent twins who were relatively lean, short sleep duration was significantly associated with higher adiposity measures in terms of total and central adiposity rather than lean body mass⁴⁰.

Short sleep duration is associated with an upregulation of appetite and has an adverse impact on glucose homeostasis⁴¹. A limited number of prospective studies have examined the association between sleep duration and the development of diabetes mellitus. The Sleep Heart Health Study of 1500 subjects shows that a sleep duration of 6 h or less or 9 h or more is associated with increased prevalence of diabetes and glucose intolerance, compared to those sleeping 7 to 8 h per night, after adjustment for age, sex, BMI and AHI⁴². In the Massachusetts Male Aging Study, 1139 men participated, those who had sleep duration < 5 h or > 8 h were found to be two to three times more likely to develop incident diabetes respectively⁴³. For over 70,000 middle-aged women in the United States Nurses Health Study, who were not diabetic at baseline, an increased risk of incident symptomatic diabetes was found among those reporting sleep durations of < 5 h and > 9 h over 10 yr, but the risk became insignificant after adjustment for BMI and other confounders⁴⁴. Similarly, in another Finnish study of 1336 men and 1434 women, sleep duration of < 6 h or > 8 h was independently associated with type II diabetes in women only after adjustment for confounders⁴⁵. For the First National Health and Nutrition Examination Survey (NHANES) in the United States, with a large population size of 8992 subjects, also concluded that subjects with sleep durations of < 5 h or ≥ 9 h were significantly more likely to have incident diabetes over 10 yr after controlling for covariates, with odds ratios of 1.47 and 1.52 respectively⁴⁶. Therefore, both short and long sleep durations may play a role in the aetiology of diabetes in some individuals.

The influence of sleep quality on glucose metabolism has also been investigated in some longitudinal studies⁴⁷⁻⁵⁰. Some reported that sleep disturbances, such as difficulty initiating sleep, difficulty maintaining sleep and regular use of hypnotics, were associated with an increased risk for incident diabetes⁴⁷⁻⁴⁹. However, in a prospective population study of female participants, there was no association between sleep problems at baseline and diabetic risk in a 32 yr follow-up⁵⁰. In addition, poor sleep quality was also reported by those who had diabetes compared to those did not⁵¹, and sleep duration and quality were shown to be significant predictors of glycaemic control in a cross-sectional study of volunteers with type II diabetes⁵². It is possible that both the quantity and quality of sleep are equally important in glucose regulation that involves β-cell responsiveness and insulin sensitivity, and the underlying mechanisms are likely to be multifactorial⁵³ (Fig. 2).

Hypertension is another component of the metabolic syndrome. It was reported that short sleep duration of < 5 h was associated with increased risk of hypertension in the NHANES⁵⁴. Further, the combination of short sleep duration and higher nighttime, relative to daytime and systolic blood pressure are strongly predictive of future cardiovascular disease⁵⁵.

There have been studies evaluating the relationship between sleep duration and the metabolic syndrome. In a community-based cross-sectional study of 1214 subjects, the odds for having metabolic syndrome was increased by 45 per cent in both short and long sleepers after adjustment of co-variables, compared to

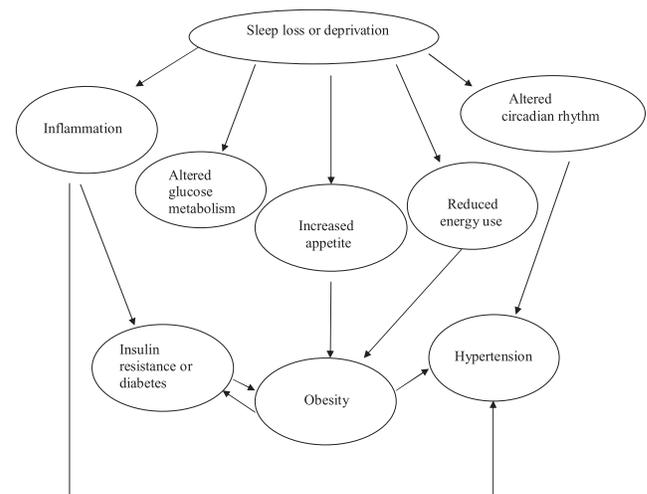


Fig. 2. Association between sleep duration and metabolic dysfunction.

those sleeping 7 to 8 h per night, and sleep duration was also associated with visceral obesity, elevated fasting glucose and hypertriglyceridaemia⁵⁶. In the Korean National Health and Nutrition Survey, of the 4222 participants, those who slept < 5 h and > 9 h had increased risk of developing metabolic syndrome with odds ratios of 1.74 (95% CI 1.33-2.26) and 1.69 (95% CI 1.17-2.45) respectively⁵⁷.

Obstructive sleep apnoea and hypertension

There is strong evidence that OSA is an independent risk factor for hypertension independent of obesity⁵⁸. The putative mediating pathways involved are sympathetic activation, arterial chemoreceptor response, baroreceptor sensitivity and vasoactive mediators affecting endothelial function⁵⁹. The Wisconsin study with longitudinal follow-up of over 700 subjects is considered as a landmark study in the independent association of OSA and hypertension⁶⁰. For an AHI > 15 versus AHI=0 at baseline, the odds of developing hypertension over 4-8 yr was 2.89, independent of confounding factors. This association was present throughout the whole spectrum of OSA, from mild to severe degree, but those with moderate to severe OSA had almost three times greater risk for developing hypertension than controls without OSA⁶⁰.

Several randomized trials have assessed the effect of CPAP on ambulatory blood pressure in patients with OSA, and both positive⁶¹⁻⁶⁴ and negative findings have been reported⁶⁵⁻⁶⁷. In a study of 118 normotensive and sleepy patients, 1-month of CPAP treatment reduced 24 h mean blood pressure by 2.5mmHg. Further subgroup analyses showed that mean blood pressure reduced by 5mm Hg in those with severe OSA, and by 8 mmHg in those with hypertension on treatment⁶². In another randomized controlled study of 60 sleepy subjects, mostly hypertensive on medications, both systolic and diastolic blood pressures were reduced by 10 mm Hg after 2 months of CPAP treatment⁶³. However, in a 6 wk randomized controlled trial of CPAP treatment group (n=29) versus sham CPAP group (n=25), there was no improvement of arterial blood pressure in subjects with severe OSA but no daytime sleepiness after treatment⁶⁵. Further, in a study of 35 OSA patients without sleepiness, most of whom had elevated blood pressure at the entry point, 1- month therapeutic CPAP treatment did not reduce blood pressure⁶⁶. In another trial of 68 hypertensive patients, 1 month of CPAP treatment had no effect on blood pressure⁶⁷, but the lack of effect may be related to the

good baseline control of blood pressure by medications in these subjects.

All of these trials were of short treatment periods, and ambulatory blood pressure was measured with different ambulatory devices. Besides, blood pressure was on the rising trend in the sham CPAP groups in two of these trials^{62,64}, indicating that sham CPAP might not be the best placebo and tended to give more stress to subjects with OSA during sleep. In two recent meta-analyses of 12 and 16 placebo-controlled randomized trials respectively, comprising both normotensive and hypertensive subjects, an average reduction of 2 mm Hg in mean arterial blood pressure was reported^{68,69}, while a third meta-analysis did not show any therapeutic effect of CPAP on blood pressure⁷⁰. Taken together, these findings suggest that CPAP treatment of OSA can lower blood pressure, but the effect is not uniform in all, and a bigger blood pressure lowering effect is more likely seen in those with severe OSA, greater degree of sleepiness and higher baseline blood pressure.

The association of OSA and hypertension has additive effects on the development of atherosclerosis. In a recent study of 94 middle-aged patients, the intima-media thickness of carotid artery was positively related to systolic blood pressure and AHI⁷¹. So, the rate of progression of carotid atherosclerosis not only predicts future cardiovascular events but also contributes to the increased risk of cerebrovascular accidents.

Obstructive sleep apnoea and obesity

Obesity is becoming a global epidemic in both children and adults, and it is associated with a number of co-morbidities such as cardiovascular diseases, type II diabetes, hypertension and obstructive sleep apnoea⁷². The most important risk factor for OSA is obesity. The prevalence of OSA among obese patients has been reported to exceed 30 per cent, and 60-90 per cent of adults with OSA are overweight, and the relative risk of sleep apnoea from obesity with a BMI >30 kg/m² may be as great as 10⁷³. Previous studies revealed that a 10 per cent increase in body weight in 4 yr was associated with a six-fold higher risk of developing OSA⁷⁴, and a 6 kg/m² increase in BMI was associated with a four-fold increased risk for the development of OSA⁷⁵.

Obesity affects upper airway anatomy because of increased fat deposition in the neck region which in turn predisposes to upper airway collapsibility during sleep. In addition to anatomical factors, collapsibility

can be increased by upper airway structural / functional control, disturbances in neuromuscular balance and genetic predisposition⁷⁶. Hormonal status and metabolic activity of adipose tissue may impact on sleep apnoea susceptibility, particularly in women. In postmenopausal women fat redistribution to a more central pattern may be responsible for the increased risk of developing OSA⁷⁷.

Adipose tissue is metabolically active, it secretes humoral factors and adipokines that regulate the distribution of body fat⁷⁸. Leptin plays a key role in body weight regulation through the stimulation of satiety hypothalamic pathways. Human obesity is typically associated with increased leptin levels, thus suggesting a condition of leptin resistance which may contribute to the pathogenesis of sleep apnoea. On the other hand, adiponectin is closely related to visceral adiposity and insulin resistance⁷⁹. Recent data suggest that hypoadiponectinaemia is related to sympathetic activity and severity of OSA⁸⁰. Obesity and sleep apnoea are often associated with dysregulation of glucose and lipid metabolism, although the precise mechanisms are not clear. Visceral fat produces large amounts of proinflammatory cytokines which are thought to provoke inflammation, oxidative stress, cell adhesion and endothelial dysfunction, and hence, contributing to the development of atherosclerosis as well as the sleep-disordered breathing in association with the metabolic syndrome⁸¹.

Obstructive sleep apnoea and insulin resistance/ glucose intolerance/diabetes mellitus

There are accumulating data that obstructive sleep apnoea is independently associated with adverse glucose homeostasis. Previous studies have found increased insulin resistance/glucose intolerance/diabetes in OSA patients, independent of obesity⁸²⁻⁸⁵, particularly amongst those with excessive daytime sleepiness⁸⁶. Very recently, a study on in vivo kinetics of glucose and insulin confirmed that sleep-disordered breathing is associated not only with insulin sensitivity but also with the ability of glucose to mediate its own disposal and pancreatic beta-cell function⁸⁷. However, in the Winconsin Sleep Cohort, a four-year follow up of 1387 participants failed to find increased incidence of diabetes mellitus in those with OSA defined by AHI >15⁸⁸.

Previous studies on the treatment effects of CPAP on insulin resistance or glycaemic control in OSA subjects showed conflicting results^{89,90}. Most did not show

any improvement in glucose metabolism^{91,92}. It was reported that two nights of CPAP treatment improved insulin sensitivity as assessed by the hyperinsulinaemic euglycaemic clamp in a group of non-diabetic men with moderate OSA, and the effect was more prominent in non obese patients with a BMI <30 kg/m² compared to those who were obese with a BMI > 30 kg/m²⁹³. Recently, it was reported that the improvement in insulin sensitivity was well maintained at 3 yr in the same group of subjects⁹⁴. However, in a randomized controlled study with a cross-over design, otherwise healthy men with severe OSA showed no difference in insulin resistance, estimated by Homeostasis Model Assessment Method, after 6 wk of CPAP treatment versus 6 wk of sham CPAP⁹⁵.

Interventional studies on glucose metabolism in diabetic subjects with OSA are scanty. Three observational studies of small sample sizes showed improvement in glycaemic control with CPAP treatment⁹⁶⁻⁹⁸. A randomized controlled study of diabetic patients treated with CPAP for 3 months demonstrated that there was no effect on insulin resistance or glycaemic control compared to sham CPAP⁹⁹.

Obesity is a risk factor for both OSA and insulin resistance. The strong association between OSA and obesity has long been recognized, and the severity of OSA is significantly correlated with visceral fat volume rather than subcutaneous fat in the body or in the neck¹⁰⁰. However, in the recent Sleep Heart Health Study of nondiabetic subjects in the community, those who suffered from sleep disordered breathing had higher prevalence of impaired glucose metabolism, in both non-overweight and overweight subjects¹⁰¹. So, adiposity may play a role in some but not all individuals to account for the adverse glucose metabolism. The underlying pathophysiological pathways between sleep disordered breathing and altered glucose metabolism may involve adipose tissue as a source of sympathetic activation or inflammatory mediators¹⁰². Indeed, sympathetic activation can affect glucose homeostatic state by increasing muscle glycogen breakdown, hepatic glucose output, and the release of free fatty acids via lipolysis.

OSA results in intermittent hypoxaemia with repetitive oxygen desaturation and re-oxygenation during sleep. In experimental animal models, leptin-deficient obese mice exposed to intermittent hypoxia for 12 wk had increased insulin levels and glucose intolerance¹⁰³. Another study showed that lean mice

exposed to intermittent hypoxia had decreased glucose disposal as assessed with hyperinsulinaemic euglycaemic clamp, and the impairment of insulin sensitivity was independent of sympathetic activation as well as obesity¹⁰⁴.

Obstructive sleep apnoea and dyslipidaemia

Dyslipidaemia is a major cardiovascular risk factor and also part of the metabolic syndrome, characterized by elevated levels of triglycerides, decreased high-density lipoprotein cholesterol and normal or slightly elevated low-density lipoprotein cholesterol. There are a number of reports of abnormal lipid profiles in subjects with sleep-disordered breathing^{17,19,20,21,25}. In the Sleep Heart health study, there was an independent association between the severity of OSA and high-density lipoprotein cholesterol levels in females only; and in males, a minor but significant association with total cholesterol levels. These findings were evident in the age group < 65 yr after adjustment for co-variables¹⁷. In contrast, in a recent case-control study of apnoeic obese, non apnoeic obese and non obese subjects, there was no significant difference in the lipid profile between obese apnoeic subjects and obese controls¹⁸.

The effects of CPAP treatment of OSA on lipid parameters are inconsistent. In an analysis of 2 randomized placebo-controlled trials of one-month CPAP treatment, a significant fall of total cholesterol in OSA patients was observed but the difference between changes in the therapeutic CPAP and subtherapeutic CPAP groups failed to achieve statistical significance¹⁰⁵. In another randomized study with a cross-over design for 6 wk of CPAP treatment, there were no changes in the lipid profiles compared to sham CPAP²². Nevertheless, there are positive studies with increase in high-density lipoprotein cholesterol by 5.8 per cent after CPAP treatment¹⁰⁶, and with good CPAP compliance, total cholesterol, triglycerides, low-density lipoprotein cholesterol and apolipoprotein B levels were all reduced²³.

Lipid metabolism involves a series of enzymatic interactions. Lipoprotein lipase may play a major role in lipid metabolism by hydrolyzing triglyceride-rich lipoproteins. Decreased lipoprotein lipase activity can trigger early inflammatory responses central to atherosclerosis. In an interventional study, lipoprotein lipase was found to be decreased with the severity of OSA, and 3-month CPAP treatment significantly increased its concentrations¹⁰⁷. This may imply that CPAP treatment could be effective in

reducing inflammatory responses and ameliorating lipid metabolism in OSA subjects. Interestingly, sleep apnoea may affect the function of lipids. In a Chinese study, high-density lipoprotein cholesterol was found to be less effective in preventing low-density lipoprotein oxidation in vivo¹⁰⁸. In addition to clinical data, animal experiments also support a role of intermittent hypoxia in the pathogenesis of dyslipidaemia in sleep-disordered breathing¹⁰⁹⁻¹¹¹.

There is evidence that insulin resistance is the major underlying abnormality that drives the dyslipidaemia¹¹². There are convincing data showing that the effect on the assembly and secretion of very-low-density lipoprotein apolipoprotein B and triglycerides is central abnormality, especially in diabetic patients, and therefore, it appears that OSA, insulin resistance and dyslipidaemia are inter-related in a complex cascade of cardiovascular co-morbidities¹⁴.

Conclusions

Both sleep disturbances and the metabolic syndrome are escalating throughout the world, in spite of, or perhaps due to modernization. Understanding the relationships between sleep disturbances, sleep-disordered breathing and metabolic syndrome will enable medical practitioners to approach the common problems, such as hypertension, diabetes, obesity and dyslipidaemia, in a rational and holistic manner.

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Reprint requests: Dr M.S.M. Ip, University Department of Medicine, Queen Mary Hospital, 102 Pokfulam Road
Hong Kong, SAR, China
e-mail: msmip@hkucc.hku.hk