ORIGINAL RESEARCH

Low Quality of Life and Depressive Symptoms as an Independent Risk Factor for Erectile Dysfunction in Patients with Obstructive Sleep Apnea

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ABSTRACT

Introduction. Accumulating evidence indicates that obstructive sleep apnea (OSA) is associated with a high prevalence of erectile dysfunction (ED), but the factors that predict the risk of ED in OSA patients have yet to be defined clearly.

Aims. The aims of the present study were to investigate the clinical characteristics of OSA patients with ED and to identify plausible predictors of ED.

Methods. The present cross-sectional analysis included 713 male patients who visited Seoul National University Hospital for snoring and/or daytime sleepiness from 2006 to 2014. An in-laboratory polysomnography procedure was conducted to obtain objective recordings of OSA and other sleep parameters.

Main Outcome Measures. The demographic data of all patients were obtained, and each patient completed all requirements of the following questionnaires: the Calgary Sleep Apnea Quality of Life Index (SAQLI), the Korean version of the International Index of Erectile Function (KIIEF-5), the Beck Depression Inventory (BDI), and the Epworth Sleepiness Scale (ESS). ED and OSA were defined as a KIIEF-5 < 21 and a respiratory disturbance index (RDI) ≥ 5, respectively. Depressive symptoms were defined as a BDI ≥ 10.

Results. The frequency of ED did not differ significantly according to OSA severity. In Spearman's correlation analysis, the BDI and the ESS were inversely correlated with the KIIEF-5, whereas the SAQLI was positively correlated with the KIIEF-5. The RDI and the lowest oxygen saturation (SaO_2) did not exhibit significant correlations with the KIIEF-5. A multivariate logistic regression analysis adjusted for possible confounding factors showed that ED was independently associated with the SAQLI and depressive symptoms, but there was no significant association of ED with either the RDI or the lowest SaO_2.

Conclusions. The present study demonstrated that depressive symptoms and a low quality of life specific to sleep apnea are independent risk factors for ED in OSA patients. **Jeon YJ, Yoon DW, Han DH, Won T-B, Kim D-Y, and Shin H-W. Low quality of life and depressive symptoms as an independent risk factor for erectile dysfunction in patients with obstructive sleep apnea. J Sex Med 2015;12:2168–2177.**

Key Words. Obstructive Sleep Apnea; Erectile Dysfunction; Calgary Sleep Apnea Quality of Life Index; International Index of Erectile Function; Beck Depression Inventory; Epworth Sleepiness Scale; Polysomnography

[1]These authors contributed equally to this study.

Introduction

Obstructive sleep apnea (OSA) is a highly prevalent condition observed in 9% of women and 24% of men over 30 years of age that is characterized by repetitive upper airway obstructions during sleep [1]. Accumulating evidence has consistently demonstrated a significant association between OSA and chronic conditions such as cardiovascular disease, diabetes mellitus (DM), and depression, as well as a decreased quality of life (QOL; [2–6]).

Erectile dysfunction (ED) can be defined as the inability to achieve or maintain a penile erection sufficiently rigid for performing satisfying sexual intercourse [7]. ED is a common and important health issue affecting nearly 50% of men over 40 years of age that may result in a significant negative impact on the satisfaction and QOL of the affected individuals [8,9]. The prevalence of ED varies widely according to country and age distribution. For example, in the United States, the prevalence of ED in individuals 20 years of age and over was 18.4% when ED was assessed by a computer-assisted self-interview [10], while in France the prevalence rate of ED was found to be 31.6% in men over 40 years of age [11]. A meta-analysis that investigated the prevalence of ED in Asia found that the overall prevalence rate of this disorder ranges from 2% to 88% [12]. Additionally, according to a prospective population-based study conducted in Australia, the 5-year incidence of ED in 810 randomly selected men aged 35–80 years was 31.7%, and old age, low income, alcohol intake, high abdominal fat mass, and the high probability of OSA, DM, and depression were predictors of incident ED [13].

ED may be the result of various psychological, neurological, hormonal, and vascular problems as well as drugs and systemic diseases, or a combination of these factors [14]. ED is frequently comorbid in patients with OSA [6,15,16], but the exact mechanisms underlying the development of ED in OSA patients are not yet fully understood. Endothelial dysfunction caused by oxidative stress, intermittent hypoxia, sleep fragmentation, and/or rapid eye movement (REM) sleep disturbances are regarded as the most plausible mechanisms that link OSA and ED [17], because these factors can impair the ability of endothelial cells to secrete nitric oxide, which, in turn, leads to inhibition of smooth muscle relaxation and, subsequently, inadequate endothelial vasodilation in the corpora cavernosa. In addition to endothelial dysfunction, depression may also play an important role in the relationship between OSA and ED, as evidenced by the high prevalence of ED in OSA patients. Additionally, depression is commonly comorbid in men with ED [18], and according to the Massachusetts Male Aging Study [8], subjects with depression have a 1.82-fold greater risk of experiencing ED than those who have not been diagnosed with depression. Depression may cause ED via reduction in the level of sexual desire and/or the inhibition of parasympathetic nerve activities, which decrease the blood volume entering the penis and lead to the impairment of penile smooth muscle relaxation [14].

Although a number of studies have identified an association between ED and OSA, the independent predictors of ED in patients with OSA remain unclear. This may be due, at least in part, to the well-known risk factors of ED, including hypertension (HTN), DM, obesity, age, and depressive symptoms, are frequently comorbid in OSA patients, but are often neglected in studies [15,19], or the main focus of the studies is the severity of OSA or sleep parameters. Thus, the primary aims of the present study were as follows: (i) to investigate the association between ED and OSA; (ii) to examine the differences in clinical characteristics between patients with ED and those without ED; and (iii) to identify any plausible predictors of ED, such as lifestyle or psychiatric conditions (e.g., daytime sleepiness, depression, and QOL), in OSA patients.

Materials and Methods

Study Sample

The present study adopted a cross-sectional design and analyzed data acquired from male patients who visited Seoul National University Hospital between December 2006 and November 2014 for snoring and/or daytime sleepiness. All participants completed a questionnaire concerning demographic information, medical history, sleepiness, mood status, and ED at the time that they visited the sleep clinic for a nocturnal polysomnography (PSG) examination.

Patients were excluded from the present study if they had psychiatric disorders, including anxiety disorders, and/or were taking antipsychotics. However, patients diagnosed with depression, whether or not they were taking antidepressants, were included in the final analyses if they had not been diagnosed previously with another psychiatric disorder. Patients who had the following symp-

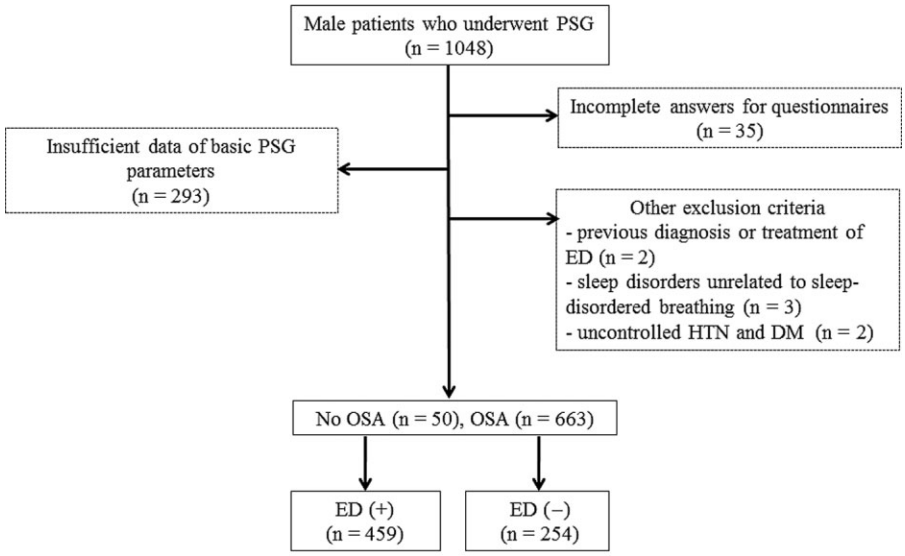

Figure 1 Flow of selection for analysis of erectile dysfunction in subjects with sleep apnea. PSG, polysomnography; DM, diabetes mellitus; ED, erectile dysfunction; HTN, hypertension; OSA, obstructive sleep apnea.

toms or diseases were also excluded from the study analyses: history of previous treatment for OSA, moderate or severe periodic limb movement disorder, endocrinological dysfunctions other than diabetes (e.g., Cushing's syndrome, abnormal pituitary function, hypogonadism etc.), severe cardiac or pulmonary disease, cardiovascular diseases such as severe HTN (systolic blood pressure > 160 mm Hg or diastolic blood pressure > 100 mm Hg), deep vein thrombosis, peripheral vascular disease, connective tissue disorders, metabolic or neurological disorders known to induce peripheral neuropathy or ED, and/or sleep disorders unrelated to sleep-disordered breathing (SDB). If a patient was diagnosed with ED prior to the present study or had previously taken medications that could influence erectile function (e.g., β-blockers and H_2 blockers), they were also excluded from the final analyses.

Of the 1,048 patients who were initially recruited for the present study, 335 were excluded for the following reasons: insufficient data regarding basic PSG parameters (n = 293), incomplete answers on the questionnaires (n = 35), a previous diagnosis of or treatment for ED (n = 2), a diagnosis of other sleep disorders unrelated to SDB (n = 3), and underlying diseases known to influence ED (n = 2, one with uncontrolled HTN and one with DM; Figure 1). Ultimately, 713 patients were included in the final analyses of the present study. All participants provided written informed consent prior to participation in the study, and the Institutional Review Board at the Seoul National University Hospital reviewed and approved the study protocol (No. 1411-025-623).

Definition of ED

ED was defined using the Korean version of the International Index of Erectile Function (KIIEF-5; [20]). The KIIEF-5 includes five items, numbers 15, 5, 13, 4, and 2 (in order of importance), that were selected from the 15 items on the International Index of Erectile Function (IIEF-15; [21]). Each of these five items is related to erection confidence, erection firmness, maintenance frequency, maintenance ability, and overall satisfaction during the previous 6 months. ED was defined as a KIIEF-5 score < 21. The corresponding sensitivity and specificity values were 0.97 and 0.9, respectively.

Assessments of Daytime Sleepiness, Depressive Symptoms, and QOL Associated with Sleep Apnea

Daytime sleepiness, depressive symptoms, and QOL associated with sleep apnea were evaluated in all participants in the present study. Daytime sleepiness was assessed using the Epworth Sleepiness Scale (ESS, [22]), which is an 8-item self-report measure. Each item is rated on a scale ranging from 0 to 3 that assesses the increasing possibility of falling asleep in different situations; an ESS score ≥ 11 was considered to indicate excessive daytime sleepiness (EDS). Depressive symptoms were evaluated using the Korean

version of the Beck Depression Inventory-I (BDI-I), which is a multiple-choice self-report inventory that is one of the most widely used instruments for the measurement of the severity of depressive symptoms in clinical studies [23]. This measure includes 21 items assessing how a subject has been feeling during the previous week, and each question has a set of at least four possible answers that range in intensity. A BDI-I score ≥ 10 was used as a cutoff value to define the presence of depressive symptoms [24]. QOL associated with sleep apnea was evaluated using the Calgary Sleep Apnea Quality of Life Index (SAQLI; [25]), which identifies conditions or factors that exhibit a within-subject change in response to a therapeutic intervention; it is specific to the measurement of clinical outcomes in patients with sleep apnea. This measure includes 35 questions across four domains: daily functioning, social interaction, emotional functioning, and symptoms. Additionally, a fifth domain, treatment-related symptoms, was developed for use with individuals currently undergoing therapeutic intervention. In the present study, the sum of first four domains was used to assess QOL associated with sleep apnea.

PSG Measurements

An in-laboratory PSG procedure was performed using the Embla™ N 7000 (Embla, Reykjavik, Iceland). The procedure consisted of a three-channel electroencephalogram (C3/A2, O1/A2, and O2/A1), based on the International 10–20 system, a two-channel electrooculogram using the chin and anterior tibialis muscle electromyograms, a thoracic and abdominal respiratory movement sensor, a nasal pressure sensor, and a pulse oximetry measurement. Using the criteria of the American Academy of Sleep Medicine scoring manual for respiratory events [26], apnea was defined as decrements in airflow of at least 90% from a previous baseline for at least 10 seconds. Hypopnea was defined as a substantial reduction in airflow (>50%) for at least 10 seconds or a moderate reduction in airflow (>30%) for at least 10 seconds accompanied by oxygen desaturation (based on a pulse oximetry value of ≥4%). Respiratory effort-related arousal (RERA) was defined as increasing respiratory effort or a flattening of the nasal pressure waveform leading to an arousal that lasted at least 10 seconds. The respiratory disturbance index (RDI) was defined as the total number of apnea, hypopnea, and RERA events per hour of total sleep time (TST). Sleep apnea was considered to be present if an RDI score ≥ 5 was observed, and the severity of sleep apnea was determined as follows: normal (RDI < 5), mild (5 ≤ RDI < 15), moderate (15 ≤ RDI < 30), and severe (RDI ≥ 30). Sleep efficiency was defined as the ratio of TST to the amount of time spent in bed. The same PSG device and scoring criteria were used to assess the sleep characteristics of the participants throughout the entire study period from 2006 to 2014.

Statistical Analysis

All data are expressed as means ± standard deviations (SDs). The differences in the means across groups were assessed based on assumption evaluations using the Kolmogorov–Smirnov test; nonparametric Kruskal–Wallis and chi-squared (χ^2) tests were used to assess continuous and categorical variables, respectively, and Mann–Whitney *U*-tests were utilized for the post hoc analyses and comparisons of variables between two independent groups. Additionally, Spearman's rank correlation coefficients were calculated to evaluate the correlations among the KIIEF-5, BDI-I, SAQLI, ESS, or RDI scores and the lowest peripheral oxygen saturation (SaO_2) value. A multivariate logistic regression analysis was conducted to estimate odds ratios (ORs; confidence interval [CI]: 95%) for the relationships of ED with sleep-related respiratory parameters, sleepiness, and mood status. The potential confounding factors included in the multivariate model (Model 1) were age, body mass index (BMI), and the presence of HTN and DM. Depressive symptoms, SAQLI, EDS, RDI, and the lowest SaO_2 value were additionally adjusted in Model 2. All statistical analyses were performed using IBM SPSS version 21.0 (SPSS; Chicago, IL, USA), and a P value < 0.05 was considered to indicate statistical significance.

Results

The present study included 713 patients who underwent a nocturnal PSG examination; the general characteristics of the patients according to OSA severity are provided in Table 1. The mean age of the total sample was 44.8 ± 12.4 years. Of the 713 patients, 663 (93.0%) were diagnosed with OSA. The severe OSA group exhibited the highest age, BMI, and neck circumference (P < 0.0001, for each), and there was a trend towards an increase in age, BMI, and neck circumference as the severity of OSA increased. The systolic and diastolic blood pressures and the KIIEF-5 and ESS scores significantly differed among the groups, and the severe

Table 1 General characteristics according to the severity of OSA

	Normal	Mild	Moderate	Severe	*P* value*
Number of subjects	50	141	210	312	
Age (years)	35.4 ± 13.7†	42.9 ± 12.4[c]	44.9 ± 12.3[d]	47.1 ± 10.9[d]	<0.0001
BMI (kg/m^2)	23.6 ± 2.2	24.8 ± 2.6[a]	25.4 ± 3.0[d]	26.6 ± 3.0[d]	<0.0001
Neck circumference (cm)	38.0 ± 2.2	38.9 ± 2.1[a]	39.2 ± 2.4[d]	40.6 ± 2.6[d]	<0.0001
SBP (mm Hg)	123.0 ± 9.3	122.8 ± 12.7	123.5 ± 12.0	126.3 ± 12.9[a]	0.002
DBP (mm Hg)	80.5 ± 8.4	80.4 ± 8.0	81.3 ± 8.2	82.6 ± 8.5[b]	0.023
KIIEF-5	14.2 ± 7.0	17.5 ± 6.3[c]	16.1 ± 6.7	16.1 ± 6.4	0.017
SAQLI	187.8 ± 42.3	194.5 ± 43.8	187.1 ± 40.7	185.8 ± 42.0	0.187
ESS	9.7 ± 5.0	10.1 ± 4.8	10.7 ± 4.8	11.4 ± 5.0	0.007
BDI	12.6 ± 7.6	10.9 ± 6.7	11.3 ± 6.6	11.3 ± 6.1	0.667
HTN, n (%)	8 (18.6)	31 (22.0)	43 (29.8)	116 (44.1)[a]	<0.0001
DM, n (%)	0 (0)	4 (2.8)	12 (5.7)	29 (9.3)[a]	0.015
Depressive symptoms, n (%)‡	22 (62.9)	50 (52.6)	71 (57.7)	139 (57.7)	0.729
Erectile dysfunction, n (%)§	28 (77.8)	54 (57.4)	79 (63.2)	162 (69.5)	0.071
EDS, n (%)¶	23 (53.5)	60 (42.6)	109 (51.9)	164 (52.6)	0.220
Polysomnographic measures					
RDI (/h)	3.3 ± 1.2	10.2 ± 2.9[d]	21.7 ± 4.4[d]	53.8 ± 16.8[d]	<0.0001
Lowest SaO_2 (%)	91.7 ± 2.5	87.9 ± 5.1[d]	84.0 ± 6.3[d]	76.3 ± 10.1[d]	<0.0001
Total sleep time (min)	433.4 ± 61.4	418.1 ± 59.1	421.5 ± 61.9	416.6 ± 53.9[a]	0.140
Sleep latency (min)	9.0 ± 9.3	12.1 ± 12.4[a]	11.6 ± 11.0	8.4 ± 10.4	<0.0001
REM latency (min)	102.5 ± 48.1	97.6 ± 58.0	98.3 ± 60.9	116.4 ± 71.1	<0.0001
Sleep efficiency (%)	91.7 ± 2.5	87.9 ± 5.1[d]	84.0 ± 6.3[d]	76.3 ± 10.1[d]	<0.0001

BDI, Beck Depression Inventory; BMI, body mass index; DBP, diastolic blood pressure; DM, diabetes mellitus; EDS, excessive daytime sleepiness; ESS, Epworth Sleepiness Scale; HTN, hypertension; KIIEF-5, Korean version of the International Index of Erectile Function; RDI, respiratory disturbance index; REM, rapid eye movement; SAQLI, Sleep Apnea Quality of Life Index; SBP, systolic blood pressure; SD, standard deviation.*Kruskal–Wallis test followed by post hoc Mann–Whitney *U*-test and χ^2 test were used for comparison of groups†Values are mean ± SD.‡Defined as ≥10 of BDI score.§Defined as <21 of KIIEF-5 score.¶Defined as > 10 of ESS score.[a]$P < 0.05$ versus normal. [b]$P < 0.01$ versus normal.[c]$P < 0.001$ versus normal.[d]$P < 0.0001$ versus normal.

OSA group had the highest frequencies of HTN and DM. The frequencies of depressive symptoms, ED, and EDS did not differ across the groups, but, as expected, the PSG variables, RDI scores ($P < 0.0001$), lowest SaO_2 ($P < 0.0001$), sleep latency ($P < 0.0001$), REM latency ($P < 0.0001$), and sleep efficiency ($P < 0.0001$) significantly differed across the groups.

The characteristics of the ED and no ED groups were also compared (Table 2). The ED group was older than the no ED group ($P < 0.0001$), and the KIIEF-5 and SAQLI scores were significantly lower in the ED group than in the no ED group ($P < 0.0001$, for each), but the ESS and BDI-I scores were higher in the ED group than in the no ED group ($P < 0.0001$, for each). The frequencies of HTN, depressive symptoms, and EDS were higher in the ED group compared with the no ED group, but no significant differences in the PSG parameters were observed between the groups.

Figure 2 depicts the scatter plots for the associations of the KIIEF-5 score with the BDI-I, SAQLI, and ESS scores and the sleep-related respiratory parameters. The BDI-I (Spearman's correlation coefficient = –0.22, $P < 0.0001$) and ESS (Spearman's correlation coefficient = –0.14; $P < 0.0001$) scores were inversely correlated with the KIIEF-5 scores, and the SAQLI score was positively correlated with the KIIEF-5 score (Spearman's correlation coefficient = 0.20; $P < 0.0001$). However, the RDI score (Spearman's correlation coefficient = –0.05, $P = 0.167$) and the lowest SaO_2 (Spearman's correlation coefficient = 0.04, $P = 0.257$) were not significantly correlated with the KIIEF-5 score.

To estimate the ORs for ED in relation to the psychiatric indices and the sleep-related respiratory parameters, a logistic regression analysis was conducted (Table 3). A univariate analysis revealed that EDS, low SAQLI score, and depressive symptoms were significantly associated with ED. In Model 1, which was adjusted for age, BMI, HTN, and DM, the ORs for the depressive symptoms, SAQLI score, and EDS score were 2.23 (95% CI: 1.50–3.30; $P < 0.0001$), 0.99 (95% CI: 0.98–0.99; $P < 0.0001$), and 1.64 (95% CI: 1.19–2.25; $P = 0.002$), respectively. The RDI score and lowest SaO_2 were not significantly associated with ED, as in the univariate model. In Model 2, which was additionally adjusted for depressive symptoms, SAQLI, EDS, and RDI scores, and the lowest SaO_2, the significant association between the EDS score and ED disappeared (OR = 1.12, 95% CI: 0.74–1.69; $P = 0.593$), but ED still exhibited a significant independent association with low SAQLI score (OR = 0.99, 95% CI: 0.98–0.99; $P = 0.0034$) and depressive symptoms (OR = 1.68, 95% CI: 1.10–2.58; $P = 0.017$).

Table 2 General characteristics between normal erectile function and erectile dysfunction groups

Variables	No ED	ED	*P* value*
Number of subjects	254	459	
Age (years)	42.9 ± 9.9†	47.2 ± 12.4	<0.0001
BMI (kg/m^2)	25.6 ± 2.6	25.9 ± 3.2	0.866
Neck circumference (cm)	39.9 ± 2.3	39.9 ± 2.7	0.619
SBP (mm Hg)	125.4 ± 13.4	124.5 ± 12.3	0.449
DBP (mm Hg)	80.8 ± 8.4	82.1 ± 8.4	0.888
KIIEF-5	22.6 ± 1.2	12.8 ± 5.5	<0.0001
ESS	10.0 ± 4.9	11.3 ± 4.8	<0.0001
SAQLI	198.6 ± 38.7	182.6 ± 42.8	<0.0001
BDI	9.1 ± 4.7	12.5 ± 6.9	<0.0001
HTN, n (%)	56 (22.0)	143 (31.2)	0.009
DM, n (%)	12 (4.7)	33 (7.2)	0.260
Depression, n (%)	74 (44.3)	208 (63.6)	<0.0001
EDS, n (%)	110 (43.3)	250 (54.5)	0.005
Polysomnographic measures			
RDI (/h)	32.0 ± 23.5	34.6 ± 23.2	0.057
Lowest SaO_2 (%)	82.0 ± 10.0	81.0 ± 9.9	0.230
Total sleep time (min)	424.4 ± 59.2	422.3 ± 49.2	0.582
Sleep latency (min)	8.3 ± 11.2	8.5 ± 9.6	0.635
REM latency (min)	119.3 ± 73.8	109.1 ± 64.7	0.789
Sleep efficiency (%)	82.0 ± 10.0	81.0 ± 9.9	0.186
Sleep apnea, n (%)‡	241 (95.6)	422 (93.0)	0.189

BDI, Beck Depression Inventory; BMI, body mass index; DBP, diastolic blood pressure; DM, diabetes mellitus; ED, erectile dysfunction; EDS, excessive daytime sleepiness; ESS, Epworth Sleepiness Scale; HTN, hypertension; KIIEF-5, Korean version of the International Index of Erectile Function; RDI, respiratory disturbance index; REM, rapid eye movement; SAQLI, Sleep Apnea Quality of Life Index; SBP, systolic blood pressure; SD, standard deviation.*Mann–Whitney *U*-test and χ^2 test were used for comparison of groups†Values are mean ± SD.‡Defined as RDI ≥ 5.

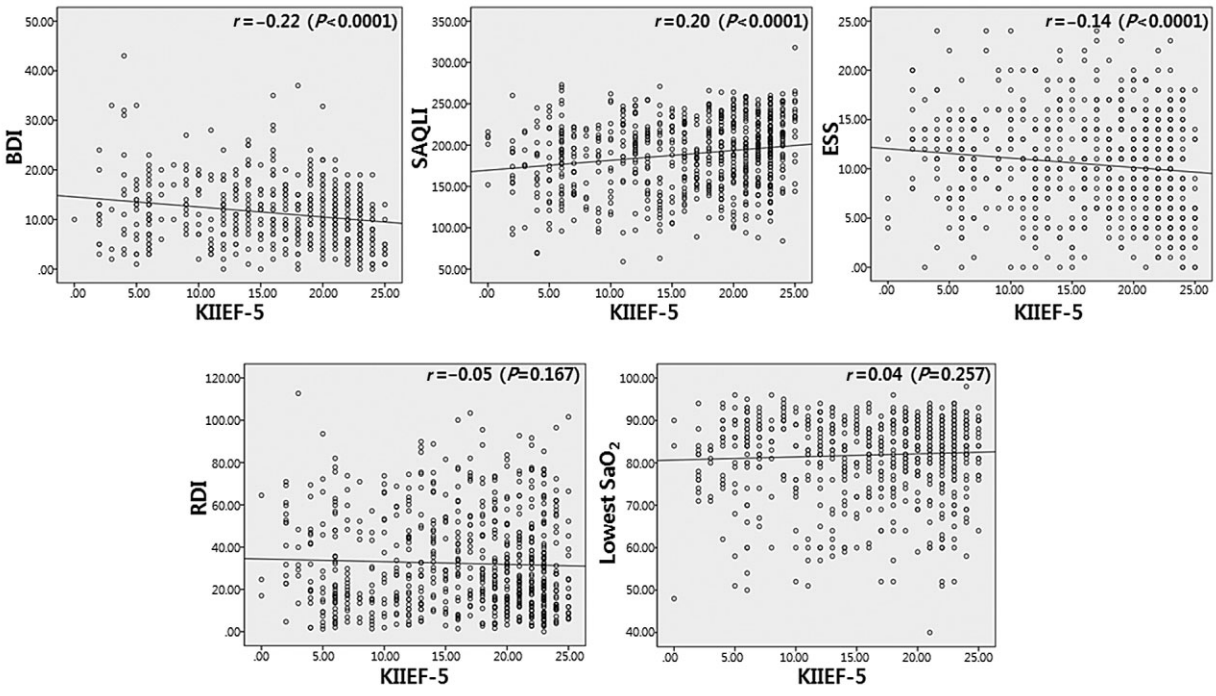

Figure 2 Correlations among KIIEF-5 score, psychosocial index and sleep-related respiratory parameters. Scatter plots for correlations were presented with a best fit line and Spearman's correlation coefficients. BDI, Beck Depression Inventory; ESS, Epworth Sleepiness Scale; KIIEF-5, Korean version of the International Index of Erectile Function; RDI, respiratory disturbance index; SAQLI, Sleep Apnea Quality of Life Index.

Table 3 Logistic regression analysis of possible risk factors for erectile dysfunction

Variables	Univariate OR (95% CI), *P* value	Multivariate OR (95% CI), *P* value	
		Model 1*	Model 2†
Depressive symptoms	2.20 (1.50–3.21), <0.0001	2.23 (1.50–3.30), <0.0001	1.68 (1.10–2.58), 0.017
SAQLI	0.99 (0.98–0.99), <0.0001	0.99 (0.98–0.99), <0.0001	0.99 (0.98–0.99), 0.003
EDS	1.57 (1.15–2.13), 0.004	1.64 (1.19–2.25), 0.002	1.12 (0.74–1.69), 0.593
RDI (/h)	1.01 (1.00–1.01), 0.064	1.01 (0.99–1.01), 0.181	1.00 (0.98–1.01), 0.922
Lowest SaO_2 (%)	0.99 (0.97–1.01), 0.253	0.99 (0.98–1.01), 0.475	1.00 (0.97–1.03), 0.998

CI; confidence interval; EDS, excessive daytime sleepiness; OR, odds ratio; RDI, respiratory disturbance index; SAQLI, Sleep Apnea Quality of Life Index*Model 1: adjusted for age, body mass index, hypertension and diabetes mellitus†Model 2: adjusted for covariables in model 1 plus depressive symptoms, SAQLI, EDS, RDI and lowest SaO_2

Discussion

The main finding of the present study was that depressive symptoms and low SAQLI scores were independent risk factors for ED in OSA patients, even after controlling for well-known potential confounding variables. Unexpectedly, there were no significant differences between the ED and no ED groups in terms of the PSG parameters and RDI score, and the lowest SaO_2 value, which represented the severity of OSA, was not significantly associated with ED in either the correlation analyses or the multivariate logistic regression analysis. The present findings do not agree with those of previous studies, which reported that sleep apnea is independently correlated with ED [15,19,27]. Budweiser et al. [15] analyzed data from 401 male patients who underwent PSG and found that the mean nocturnal SaO_2 was independently associated with ED even after accounting for possible confounding factors, while Margel et al. [19] found that only the severe OSA group with RDI scores greater than 40 was associated with ED. Age, morning tiredness, and RDI scores are considered to be predictive factors of ED [19], but Goncalves et al. [27] reported that minimal SaO_2 and age, but not the apnea-hypopnea index, are predictors of ED.

There are several possible reasons for the discrepancies between the present findings and those of previous studies. First, previous analyses did not consider psychiatric factors, such as depressive symptoms, which are commonly observed in OSA patients, and there are differences among these studies in terms of ethnicity and the methods used to measure ED. In fact, it has been reported that depression has a highly prevalent association with OSA. In population and community settings, the prevalence of depression in OSA patients is 17% [28], but this rate is even higher in clinical populations. Vandeputte and deWeerd [29] found that depression was present in 41% of Dutch OSA patients with sleep clinic referrals, based on a cutoff value of ≥ 10 on the BDI, which is similar to the criterion used to define depression in the present study. Other studies have also observed high depression rates in patients with OSA between 30% and 69% [30,31]. The observed differences in the prevalence of depression could be due to different ethnicities, diverse types of mood assessment methods, and discrepant cutoff values despite the use of the same questionnaire. Previous studies have also identified a decreased QOL in patients with OSA using the Medical Outcomes Study Short-Form 36 Health Survey Questionnaire [32] and the SAQLI [6], although this trend was not observed in the present study. It is possible that the cutoff value used to define OSA and differences in the sample sizes of the studies contributed to the lack of a significant effect.

ED can be classified as psychogenic, organic (neurogenic, hormonal, vasculogenic, drug-induced, or caused by systemic diseases and aging), or mixed [14]. The mixed type of ED, with both psychogenic and organic components, is the most frequent, while depressive mood and psychological stress belong to the psychogenic category of ED. A loss of libido, over-inhibition, and impaired nitric oxide release are considered causal mechanisms linking these factors with ED [14].

Due to the relative contribution of OSA to ED, the effects of OSA treatment on the development of ED have been investigated by several studies. The medical treatment options for OSA, including continuous positive airway pressure (CPAP) and other oral applications, are promising therapies but fail to relieve ED fully in OSA patients [33,34]. Furthermore, several studies have revealed that surgical treatments in OSA patients can also improve ED, but the subjects included in these studies did not fully recover

from the disorder [35,36]. This suggests that ED is a multifactorial disease. In a study investigating the effects of long-term CPAP use (mean follow-up time: 36.5 ± 3.7 months) on sexual function in men with OSA, there were no significant differences in erectile function between the CPAP-treated and non-CPAP-treated groups of moderate-to-severe ED patients [37]. However, these authors reported improvements in overall sexual function, particularly in the subdomains of orgasmic function, sexual desire, and overall satisfaction. According to Goncalves et al. [27], who examined the effects of CPAP on changes in psychiatric factors, such as QOL and ESS and BDI scores in OSA patients with ED, 1 month of CPAP use significantly increased QOL and decreased ESS and BDI scores in subjects both with and without ED. However, because this study did not determine whether ED was also improved by CPAP use in conjunction with improvements in psychiatric factors, the causal relationship between psychiatric variables and ED in OSA patients remains unknown.

In the present study, it is likely that the high significance among the KIIEF-5, BDI-I, SAQLI, and ESS scores was due to the large number of participants, despite the small correlation coefficients between these scores.

The strengths of the present study include the use of an objective sleep assessment measure, gold standard PSG, rather than self-reported evaluations, as well as the exclusion of patients with possible diseases known to be associated with ED. However, the limitations of the present study also must be acknowledged. First, causal inferences among the depressive symptoms, QOL, and ED in OSA patients cannot be made due to the cross-sectional nature of the study design. Second, factors such as the oxygen desaturation index, which represents the severity of hypoxemia, were not considered. Third, a large number of participants were excluded due to insufficient PSG data and incomplete questionnaire responses, which would increase the possibility of selection bias potentially accounting for the exceptionally high prevalence of ED in the present study. However, when the KIIEF-5 scores of the 293 patients without full PSG data were analyzed, 53% of these patients showed ED (data not shown). Thus, the influence of the missing PSG data on the high proportion of ED patients might be small. Fourth, the normal sleep apnea group (RDI < 5) also exhibited a very high rate of depressive symptoms, a high incidence of ED, and low SAQLI scores that were similar to the other severity groups. However, it should be noted that the participants in the present study consisted of patients who visited a clinic due to sleep problems rather than randomly selected subjects from the general population. Fifth, the effects of uncontrolled confounding factors cannot be ruled out as a further limitation. Finally, although subjects who were previously diagnosed with anxiety disorders were excluded from the present analyses, the possibility of undiagnosed anxiety patients within the study sample still exists because of the absence of psychometric evaluations for anxiety.

In conclusion, depressive symptoms and low QOL specific to sleep apnea were independent risk factors of ED in OSA patients in the present study. Thus, it should be emphasized that a psychological approach and psychological management are required to treat ED in OSA patients. However, further studies are required to clarify the causal relationship between ED and depression in patients with OSA and to determine whether ED is reversible following pharmacological and psychotherapeutic interventions for the treatment of depression and/or to improve QOL.

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