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Influence of neck circumference and body mass index on obstructive sleep apnoea severity in males

Abstract

Introduction: Obesity and male gender are the main risk factors for the development of obstructive sleep apnoea (OSA); however, some epidemiological data has shown that neck circumference (NC) ≥ 43 cm is a better predictor of obstructive event frequency than body mass index (BMI). The aim of this study was to assess the relation between NC and BMI on OSA severity in males.

Material and methods: The subjects completed a sleep questionnaire and Epworth sleepiness scale before the sleep study (full polysomnography or PolyMesam study). We studied 133 consecutive males with confirmed OSA (AHI/RDI > 10, Epworth score > 9 points). Chest X-ray, spirometry, arterial blood gases, ECG, blood morphology and biochemistry were performed during treatment trial with autoCPAP.

Results: Subjects presented with obesity — BMI = 35.8 ± 6.1 kg/m^2, NC = 46 ± 3.4 cm and severe disease — AHI/RDI = 45.3 ± 23.6. Mean age was 52.7 ± 11.3 years. The majority of subjects had NC ≥ 43 cm (116 pts, 87.2% — group 1), 17 pts (12.8% — group 2) had NC < 43 cm had 17 pts. Comparison of both groups showed significant differences only for BMI (gr. 1 — 36.8 ± 5.7, gr. 2 — 28.6 ± 3.7; $p < 0.0001$). Linear regression analysis revealed significant correlation between NC and AHI/RDI ($R^2 = 0.07$, $r = 0.26$; $p = 0.003$); however, the correlation between BMI and AHI/RDI was stronger ($R^2 = 0.14$, $r = 0.37$; $p < 0.0001$). In multiple linear regression analysis we found significant correlation between AHI/RDI and age ($\beta = -0.31$, $p = 0.003$) and BMI ($\beta = 0.34$, $p = 0.02$).

Conclusions: The strongest correlation between AHI/RDI, younger age and BMI was found in males with OSA. Correlation between neck circumference and AHI/RDI was significant but less when compared to BMI.

Key words: neck circumference, BMI, OSA, AHI/RDI, males

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Introduction

Obesity remains one of the main risk factors for obstructive sleep apnoea (OSA). The incidence of OSA in the obese population ranges from 40% [1] to 93% [2]. In subjects diagnosed with OSA 61% to 78% are obese [3, 4]. A prospective study (4-year follow-up) conducted in 690 inhabitants of Wisconsin showed that a 10% increase in weight was related to a 6-fold greater risk of OSA [5]. Reduction of body weight by 10% was related to a 26% reduction in AHI. Other papers have also indicated a decrease in AHI related to reduction of body weight [6, 7].

The above data do not explain the incidence of OSA in obese people. Shwartz et al. [7] suggested a significant role of peri-pharyngeal muscle fat deposition (reduction in weight was related to decreased pharyngeal ability to collapse). Other authors indicated that neck circumference is more predictive for OSA severity than body mass index (BMI) [8–11].

Davies and Stradling [8] revealed in 66 OSA patients that neck circumference ($r = 0.65$; $p < 0.0001$) and retrolingual area ($r = 0.26$; $p < 0.01$) are independent risk factors for OSA. This was also confirmed by larger study from the same centre. In a po-

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pulation of 1001 males aged 35–65 years authors showed that neck circumference (r^2 = 7.9%), alcohol consumption (r^2 = 3.7%), age (r^2 = 1%) and obesity (r^2 = 1%) were independent risk factors for OSA [9].

Katz et al. [10] examined 123 patients suspected of OSA. The correlation was stronger between AHI and neck circumference ($r^2 = 0.29$; $p = 0.0001$) than AHI and BMI ($r^2 = 0.04$; $p = 0.0078$).

Hoffstein and Mateika [11] compared 156 OSA patients and 156 obese subjects without OSA adjusted for age and BMI (control group). OSA subjects had greater neck circumferences ($p < 0.0001$) than the control group. Multiple regression analysis revealed that neck circumference had better correlation with AHI than BMI ($r^2 = 0.27$; $p < 0.0001$ and $r^2 = 0.19$; $p < 0.001$, respectively).

The aim of the study was to analyze the relationship between neck circumference and body mass index in subjects with severe obstructive sleep apnoea (in comparison to the results with other authors).

Material and methods

A sleep disordered breathing questionnaire was applied as a first. Patients were interviewed for snoring, witnessed apnoeas, awakenings from sleep as well as daily sleepiness. The other questions concerned difficulty to fall asleep, morning fatigue, mean hours of sleep duration and shift work. Afterwards, history of co-morbidities, current medication, operations performed on the throat and smoking habits was collected [12].

Patients were selected either to full PSG (Somnostar α, Sensormedics, USA) or limited PSG without sleep monitoring (PolyMesam MAP, Germany) depending on the results of the SDB questionnaire. The methodology and results of the above examinations were described in details previously [13].

OSA was diagnosed if AHI/RDI > 10 and was accompanied by excessive daytime somnolence (Epworth Sleepiness Score > 9) [14].

Study group consisted of 133 male OSA patients, mean age 52.7 ± 11.3 years. Other examinations (chest X-ray, ECG, spirometry, ABG, blood analyses) were performed during following in-hospital stay related to initiation of CPAP treatment.

The Sleep Heart Health Study (SHHS) [15] proved that 29% of patients with neck circumference exceeding 37.1 cm in females and 42.9 cm in males suffer from sleep disordered breathing. Therefore, we accepted the neck circumference of 43 cm in males as abnormal. Obesity was diagnosed in patients with BMI exceeding 30 kg/m^2, and overweight condition was diagnosed if BMI > 25 and ≤ 30 kg/m^2.

Diagnosis of arterial hypertension was based on history (previous measurement and on-going treatment) or repeated measurement during hospitalization (systolic pressure > 140 mm Hg, diastolic pressure > 90 mm Hg). Diagnosis of coronary artery disease was based on history, medication used and abnormal ECG recording demonstrating ischaemia, infarct lesion or LBBB if not explained by other cause.

The diagnosis of chronic heart failure was based on previous treatment history initiated in internal medicine or cardiologic departments, exertional dyspnoea, physical examination (leg swelling), pulmonary haemostasis, echocardiography (ejection fraction < 50% or disturbed diastolic function) or chest X-ray (enlarged heart, Kerley B lines).

Diabetes was diagnosed either based on previous confirmation and treatment or repeated measurement of fasting glucose > 126 mg%, an incidental glycaemia > 200 mg% or glycaemia during OGTT (75g of glucose) > 200 mg%.

Criteria for abnormal blood concentrations of evaluated markers were as follows. Hypertriglicerideaemia was diagnosed when fasting triglycerides were > 160 mg%. Hypercholesterolaemia was diagnosed when total cholesterol concentration was over 200 mg%. Mixed hyperlipidaemia was diagnosed when both triglycerides and total cholesterol were above the indicated range.

Hyperuricaemia was diagnosed when uric acid in fasting blood was over 7 mg%. Chronic obstructive pulmonary disease was diagnosed if FEV_1/FVC was below the lower limit of normal without reversibility following short acting beta agonist; usually typical history of chronic cough, exertional dyspnoea and tobacco exposition as present [16].

Statistical analysis

The data was analyzed using Statistica 6.0 software. The results were presented as mean and standard deviation. The differences between groups were established using Pearson's chi square test with appropriate modifications for N (Yates, Fisher). Quantitative differences between the groups were analyzed by ANOVA. To establish relations between OSA severity and its correlations with other variables, linear and multiple regression models were applied.

Results

The majority of OSA subjects had moderate or severe stage of the disease (mean AHI/RDI was 45.3

Table 1. Comparison of polysomnography/PolyMesam, age, BMI, neck circumference, Epworth score in groups 1 and 2

Variable	Group 1 n = 116	Group 2 n = 17	p
Age (years)	52.4 ± 10.5	54.7 ± 15.7	NS
AHI (n/h)	46.6 ± 24.2	36.8 ± 18.1	NS
BMI [kg/m^2]	36.8 ± 5.7	28.6 ± 3.7	p < 0.0001
Neck circumference [cm]	46.7 ± 2.9	41 ± 1.9	p < 0.0001
Mean SaO_2 (%)	88.7 ± 5.7	91.1 ± 3.6	NS
Lowest SaO_2 (%)	69.4 ± 11.4	71.2 ± 20.3	NS
T 90 (%)	42.4 ± 31.2	31.4 ± 26.7	NS
Epworth Sleepiness score (points)	13.8 ± 5.1	12.7 ± 5.9	NS

Explanations of abbreviations in the text

± 23.6 during either full or limited PSG). Mean oxygen blood saturation (SaO_2 mean) during nocturnal sleep study was 89 ± 5.5%. Minimal nocturnal blood saturation (SaO_2 min.) during sleep was 69.6 ± 12.8%. Time spent in desaturation (SaO_2 < 90%) (T90) averaged 41 ± 30.8% of the study time. Mean sleepiness score (Epworth Sleepiness Scale) was 13.7 ± 5.2 points. The majority of patients were overweight (22 subjects; 16.5%) or obese (106 subjects; 79.7%). Mean BMI in whole group was 35.8 ± 6.1 kg/m^2. The mean neck circumference in the whole group was 46 ± 3.4 cm.

Arterial hypertension was diagnosed in 93 subjects (69.9%), and coronary artery disease was confirmed in 31 subjects (23.3%). Heart failure was diagnosed in 18 subjects (13.5%). Diabetes was highly prevalent in the cohort: one in five subjects suffered from this disease (25 subjects; 18.8%). Chronic obstructive pulmonary disease (COPD) was diagnosed in 31 subjects (23.3%). Seventy-six (57.1%) subjects presented elevated levels of triglycerides, 71 — high total cholesterol levels, while in 55 (41.3%) subjects the lipid disturbances were mixed. In 61 subjects (45.8%) high uremic acid levels were detected.

To assess the relationship between neck circumference and severity of OSA (AHI/RDI), body weight, age, lung function and co-morbid diseases the cohort was divided into 2 groups. The first group consisted of 116 subjects (87.2%) with neck circumference ≥ 43 cm (group 1). The second group consisted of 17 subjects (12.8%) with neck circumference < 43 cm (group 2).

Group 1 was characterized by higher AHI/RDI and sleepiness score. They spent more time in desaturation and had lower mean and minimal blood oxygen saturation when compared to group 2. The above differences were not statistically significant due to the low number of subjects in group 2. A significant difference was seen between groups in BMI ($p < 0.0001$). Mean age was similar in both groups. The polysomnographic data and anthropometry are shown in Table 1.

Heart diseases (arterial hypertension, coronary artery disease, heart failure), diabetes mellitus and COPD were more prevalent in group 1 (differences not significant). Metabolic disorders (high triglycerides, total cholesterol, mixed hyperlipidaemia, hyperuricaemia) were more frequent in group 1 (statistically significant for hyperuricaemia). Decreases of FVC and FEV_1 below the lower limit of normal, suggestive of a restrictive ventilatory pattern, was diagnosed in 23 subjects (17.3%) — only one person was from group 2. OSA complications and co-morbidity are presented in Table 2.

Subjects from group 1 had significantly lower FEV_1 given as a percentage of predicted lower PaO_2 during the day (on room air) and higher levels of fasting glucose and uremic acid in serum. The remaining spirometric and ABG variables, as well as biochemical measures, did not differ statistically between the groups. Lung function data and biochemical results are presented in Table 3.

Linear regression analysis revealed significant correlations between neck circumference and: AHI/ /RDI (R^2 = 0.07, r = 0.26; p = 0.003), BMI (R^2 = 0.57, r = 0.76; p < 0.0001), mean SaO_2 (R^2 = 0.07, r = –0.23; p = 0.008) and T90 (R^2 = 0.07, r = 0.24; p = 0.007). However, correlation between BMI and AHI/RDI was stronger (R^2 = 0.14, r = 0.37; p < 0.0001). Statistically significant correlations between BMI and mean SaO_2 and T90 (R^2 = 0.11, r = –0.33; p < 0.0001 and R^2 = 0.11, r = 0.34; p < 0.0001, respectively) were also seen.

Multiple regression analysis showed significant correlations between AHI/RDI and age (β = –0.31, p = 0.003) and BMI (β = 0.34, p = 0.02) (Table 4).

Table 2. Concomitant diseases and complications of OSA in groups 1 and 2

Variable	Group 1	Group 2	p
Arterial hypertension (n/%)	84 (72.4%)	9 (52.9%)	NS
Coronary artery disease (n/%)	26 (22.4%)	5 (29.4%)	NS
Heart failure (n/%)	18 (15.5%)	0 (0%)	NS
COPD (n/%)	29 (25%)	2 (11.8%)	NS
"Restrictive" pattern in spirometry (n/%)	22 (19.3%)	1 (5.9%)	NS
Diabetes (n/%)	24 (20.9%)	1 (5.9%)	NS
Hyperuricaemia (n/%)	58 (50%)	3 (17.6%)	p = 0.01
Hypertrigliceridaemia (n/%)	70 (60.3%)	6 (35.3%)	NS
Hypercholesterolaemia (n/%)	62 (53.4%)	9 (52.9%)	NS
Mixed hyperlipidaemia (n/%)	50 (43.1%)	5 (29.4%)	NS

Explanations of abbreviations in the text

Table 3. Comparison of spirometry, arterial blood gases and biochemistry in groups 1 and 2

Variable	Group 1	Group 2	p
FVC (L)	4.2 ± 1	4.3 ± 1	NS
FVC (% n)	89.6 ± 16.1	96.6 ± 12.1	NS
FEV_1 (L)	3.1 ± 0.9	3.3 ± 0.8	NS
FEV_1 (%n)	84.6 ± 18.5	95 ± 12.8	p = 0.03
FEV_1%FVC (%)	72.9 ± 8.6	76.8 ± 5.4	NS
PaO_2 [mm Hg]	66.7 ± 7.9	73.6 ± 7	p = 0.009
$PaCO_2$ [mm Hg]	40.5 ± 4.1	40.6 ± 3.7	NS
Uric acid (mg%)	7.2 ± 1.5	6 ± 1.4	p = 0.003
Fasting glucose (mg%)	108.8 ± 35.9	89.7 ± 18	p = 0.03
Total cholesterol (mg%)	204.6 ± 38.9	201.9 ± 40.8	NS
Triglycerides (mg%)	197.2 ± 83.7	164 ± 117.6	NS

Explanations of abbreviations in the text

Discussion

In the group of 133 males with OSA (BMI — 35.8 ± 6.1 kg/m^2, AHI/RDI — 45.3 ± 23.6), mean age 52.7 ± 11.3 years, the factors predicting AHI/ /RDI were age (the older they were the lower AHI/ /RDI was) and BMI (significant correlations in multiple regression model). Neck circumference correlated with AHI/RDI; however, the correlation power was weaker than for BMI (linear regression).

Cardiovascular co-morbidities were present in a high proportion of the subjects (arterial hypertension in 69.9%, coronary artery disease in 23.3%, heart failure in 13.5%), which is in accordance with previous data on the relationship between OSA and cardiovascular diseases [17]. FVC and FEV_1 below the lower limit of normal (restrictive pattern in obese subjects) were diagnosed in 23 subjects (17.3%), mostly in group 1, with significantly higher BMI (36.8 ± 5.7 vs. 28.6 ± 3.7 kg/m^2, respectively).

Significantly lower day-time PaO_2 observed in group 1 was related to lower FEV_1 as the percentage of predicted as well as to COPD diagnosis more prevalent in this group (25% vs. 11.8%, respectively).

The direct relationship between OSA severity and neck circumference has been demonstrated in early 1990s [8–11] and recently reconfirmed.

Dancey et al. [18] examined a large cohort referred for PSG (2753 males and 1189 females). An AHI of over 10 per hour was diagnosed in 60% of males and 32% of females ($p < 0.0001$). The neck-height ratio (NHR) was higher in males than females (0.24 ± 0.02 vs. 0.23 ± 0.03, respectively, $p < 0.0001$). After adjustment for age, BMI and NHR males had significantly higher AHI than fe-

Table 4. Multiple linear regression analysis

n = 123	Summary of regression for dependent variable: AHI/RDI R = 0.45597136, R^2 = 0.20790988, corrected R^2 = 0.11344042 F (13.109) = 2.2008, p < 0.01389, std. err. estim.: 22.046					
	β	Std. err. *β*	B	Std. err. *β*	t (109)	p
Factor			50.49063	52.30960	0.96523	0.336568
BMI	**0.336168**	**0.137968**	**1.29593**	**0.53187**	**2.43655**	**0.016447**
Age	**–0.308138**	**0.100019**	**–0.64181**	**0.20833**	**–3.08079**	**0.002614**
Arterial hypertension	0.072981	0.096599	3.77173	4.99232	0.75551	0.451575
Diabetes	0.075969	0.115094	4.47010	6.77223	0.66006	0.510606
Atrial fibrillation	0.020171	0.094401	1.52986	7.15995	0.21367	0.831204
Coronary artery disease	0.009266	0.099661	0.50316	5.41159	0.09298	0.926092
Fasting glucose	–0.096390	0.122129	–0.06637	0.08409	–0.78924	0.431683
Total cholesterol	–0.006537	0.096033	–0.00401	0.05884	–0.06807	0.945851
Triglycerides	–0.043155	0.103828	–0.01154	0.02775	–0.41564	0.678491
PaO_2	–0.058096	0.105130	–0.16811	0.30422	–0.55261	0.581659
$PaCO_2$	0.034125	0.091840	0.19340	0.52049	0.37157	0.710938
Tobacco smoking	0.010482	0.089140	0.31206	2.65373	0.11759	0.906607
Neck circumference	–0.028598	0.135328	–0.19249	0.91088	–0.21132	0.833031

Explanations of abbreviations in the text

males did (24.4 ± 0.4 vs. 14.8 ± 0.7, p < 0.0001). Multiple regression analysis showed the strongest correlation of NHR with AHI. The differences between our and Dancey's data may be related to the number of investigated subjects and the use of NHR instead of neck circumference.

Sharma et al. [19] examined 118 subjects with BMI ≥ 25 kg/m² who were admitted to the hospital for other than OSA indications. The diagnosis of OSA (AHI ≥ 15) was established by means of PSG in 53 subjects. Independent risk factors for OSA were male gender (OR 3.97; p = 0.046), neck circumference (OR 1.23; p = 0.023) and waist to hip ratio (OR 1.07; p = 0.047). No correlation between BMI and AHI was observed.

Resta et al. [20] examined 161 obese subjects (BMI ≥ 30 kg/m²), mean age 43.4 ± 13.3 years. In the majority of the subjects BMI exceeded 40 kg/m² while mean BMI for the whole group was 43.4 ± 8.1 kg/m². RDI ≥ 10 was diagnosed in 83 subjects (51.5% of the whole group), including 43 males (75%) and 40 females (38%). The strongest correlations observed were: in males — between RDI and neck circumference (r = 0.42; p < 0.01), in females — between RDI and BMI (r = 0.49; p < 0.001).

Schellenberg et al. [21] examined 420 subjects suspected of OSA (RDI ≥ 15). The disease was confirmed in 158 subjects. Important factors predicting apnoeas were airway narrowing by the lateral throat wall (OR 2.5; 95% CI, 1.6–3.9), enlarged tonsils (OR 2.0; 95% CI, 1.0–3.8), enlarged uvula (OR 1.9; 95% CI, 11.2–2.9) and tongue hypertrophy (OR 1.8; 95% CI, 1.0–3.1). After adjustment for BMI and neck circumference the only remaining factors indicative for OSA were hypertrophy of the tonsils and narrowing of the throat by the lateral walls (OR 2.6; 95% CI, 1.3–5.2 and OR 2.0; 95% CI, 1.3–3.3, respectively). The methodology used in both papers was different, thus it is not possible to compare data.

Mortimore et al. [22] looked at the influence of fat tissue deposition on apnoea occurrence using magnetic resonance imaging. Authors examined 9 obese subjects (control group, BMI — 25 ± 0.7 kg/m²), 9 patients with confirmed OSA without obesity (BMI — 25.7 ± 0.4 kg/m²) and 9 obese patients with OSA (BMI — 34 ± 1.1 kg/m²). Neck soft tissue volume related to fat was higher by 27% and 67% in non-obese and obese patients with OSA when compare to controls. Antero-lateral fat tissue volume located in relation to upper airways was higher by 52% in non-obese OSA subjects and by 88% in obese OSA subjects when compare to the control group. Authors deduced that the crucial significance for the development of OSA play deposition and volume of fat tissue on the neck, instead of BMI and neck circumference.

Schäfer et al. [23] examined a group of 85 males suspected of OSA using PSG and magnetic resonance imaging (measurement of neck and abdominal tissue fat). Quantitative measurement of body fat tissue was assessed by measurement of bioelectrical impedance analysis (BIA). Logistic regression analysis revealed significant correlations between OSA (AHI > 10) and BIA (p = 0.008) as well as BMI (p = 0.046). The amount of neck fat was not related to OSA incidence.

Lam et al. [24] assessed the influence of craniofacial profile and upper airway constitution on the incidence of apnoeas in 239 subjects (164 Asians and 75 Caucasians). The measurements were neck circumference, thyromental distance (TMD), thyromental angle (TMA) and assessment upper airway using Mallampati's scale [25].

The best indicators for OSA were, in order, Mallampati's score (F = 0.70), TMA (F = 0.60), neck circumference (F = 0.54), BMI (F = 0.53) and age (F = 0.53). The above results are similar to those presented in our paper (better correlation of BMI than neck circumference with AHI/RDI).

Oǧretmenoǧlu et al. [26] assessed the relationship between BIA and incidence of apnoeas in 51 subjects referred for PSG. The only variables influencing AHI were BMI and the percentage of body FAT (r = 0.782 and r = 0.647, respectively). The results are similar to ours. The strong correlation between BMI and AHI suggests the selection bias (OSA patients were obese, controls were non-obese).

Deegan et al. [27] assessed the effects of symptoms and clinical presentation in OSA diagnosis. Among 250 patients referred for PSG, OSA (AHI ≥ 15) was diagnosed in 136 subjects — 119 males and 17 females. In comparison to healthy subjects, OSA patients more frequently reported: habitual snoring (p < 0.005), sleeping in supine position (p < 0.025), awakenings with heartburn (p < 0.025), and drowsy driving (p < 0.05). Significant correlations between AHI and BMI, age and alcohol intake were revealed. After adjustment for age and BMI, AHI correlated with waist circumference in males and neck circumference in females. Our findings showed a significant influence of BMI on AHI, similarly to the above findings. However, our correlation between age and BMI was negative while in Deegan's paper it was positive.

Levinson et al. [28] examined 45 males aged from 26 to 65 years with confirmed OSA (AHI > 5). AHI correlated with thickness of skin fold over the triceps muscle of the arm (r = 0.4; p < 0.01). Neither BMI, waist to hip ratio or neck circumference correlated with AHI. The results might be biased by the low number of subjects and the criteria used to diagnose OSA.

Grunstein et al. [29] analyzed the influence of obesity on incidence of apnoeas in 1464 males referred for PSG. The majority of them were overweight (47%) or obese (28%). The strongest correlations were found between AHI and abdominal circumference (r^2 = 0.156; p < 0.001), and age (r^2 = 0.013; p = 0.003). The authors did not observe correlations between AHI and BMI or neck circumference. Our cohort included almost 80% obese patients, while in Grunstein's paper only 28% of the subjects were obese. Both cohorts differed also in the number of examined subjects.

The negative correlation between age and AHI/RDI supports the previous results of Bixler et al. [14]. Authors examined 741 males using PSG (236 aged 20–44 years, 430 aged 45–64 years, 75 aged 65–100 years). AHI ≥ 5 was diagnosed in 17%, AHI ≥ 10 in 10.5% and AHI ≥ 20 in 5.6% of the subjects. OSA (AHI ≥ 10 with symptoms) was diagnosed in 3.3% of subjects. Sleep disordered breathing was observed most frequently in the oldest age group. AHI ≥ 5 was present in 7.9% of the youngest subjects, in 19.7% in ages 45–64 years and 30.5% in those over 65 years old. A similar trend was observed for AHI ≥ 10 (3.2%, 11.8% and 23.9%, respectively) and AHI ≥ 20 (1.7%, 6.4% and 13.3%, respectively). The severity of the disease decreased with age in males; OSA was the most severe in both younger groups.

Conclusions

In 133 males with OSA (BMI 35.8 ± 6.1 kg/m^2, AHI/RDI 45.3 ± 23.6), mean age 52.7 ± 11.3 years, factors influencing AHI/RDI were age (AHI/RDI decreased with age) and BMI (significant correlations in multiple regression analysis). Relationship between neck circumference and AHI/RDI was weaker than for BMI (linear regression).

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