Contents available at **PubMed**
www.anmm.org.mx

PERMANYER

Gac Med Mex. 2016;152:542-8

GACETA MÉDICA DE MÉXICO **ORIGINAL ARTICLE**

Obesity and its respiratory effects detected through levels of partial pressure of carbon dioxide in the supine position

América Sánchez-Medina[1], Marcela Ma. Sánchez-Medina[2], María Dolores Ochoa Vázquez[3], Simón Barquera Cervera[1] and Luis Gerardo Ochoa Jiménez[1]*

[1]Pulmonology Department, Centro Médico Nacional La Raza, IMSS, Morelia, Mich., Mexico; [2]Health Science, [3]Jefe del servicio de Neumología, Centro Médico Nacional La Raza, IMSS, Morelia, Mich., Mexico

Abstract

Introduction: *Obesity is a disease that is closely associated with deleterious respiratory effects such as the Obesity Hypoventilation Syndrome which conventionally includes awake hypercapnia. There are studies addressing the detection of daytime hypercapnia with the patient either in sitting or standing position. However, there are no studies in obese subjects with a normal daytime $PaCO_2$ in whom the detection of hypercapnia is made in the supine position. It is feasible that the physiopathological changes that occur in obese patients when they adopt the supine position lead to increased $PaCO_2$ levels or hypercapnia.* **Objective:** *To determine the levels of $PaCO_2$ in obese patients with a normal daytime $PaCO_2$ in the supine position using arterial blood gas test. Methods: Fifty patients with BMI > 30 Kg/m², with a normal daytime $PaCO_2$ were included. Daytime arterial blood gas test was performed first with the patient in a standing position along with pulmonary function test. A second arterial blood gas test was made 15 minutes after the patient adopted the supine position. Polisomnography was performed.* **Results:** *Mean BMI was 40 kg/m². $PaCO_2$ levels in the standing position were less, statistically significant, than the $PaCO_2$ levels in the supine position, 30.7 ± 2.5 mmHg vs 35.6 ± 6.7 mmH, p < 0.001.* **Conclusions:** *We can achieve an early detection of Obesity hipoventilation syndrome in obese patients with a normal daytime $PaCO_2$ by performing the arterial blood gas test in the supine position before these patients develop severe complications.* (Gac Med Mex. 2016;152:542-8)

Corresponding author: *América Sánchez-Medina, jamericasan530@hotmail.com; marcela.masanchez@gmail.com*

KEY WORDS: *$PaCO_2$. Hypercapnia. Arterial blood gas. Obesity hypoventilation syndrome. Obstructive sleep apnea-obesity.*

Introduction

Today, one of worldwide health main challenges is obesity. Mexico and the USA are the two countries with the highest world-wide prevalence of obesity in the adult population (30%), with this proportion being ten times higher than in countries such as Japan and Korea (4%)[1].

From the physiological point of view, the presence of obesity impacts on respiratory mechanics especially in the supine position, owing to the sum of effects of gravity itself, which causes for abdominal viscera to project onto the diaphragm and, by compressing the chest, decrease respiratory muscles' efficacious movement, tidal volume (TV), forced vital capacity (FVC) and functional residual capacity (FRC) which, combined, produce hypoxemia and hypercapnia[2,3].

Correspondence:
*América Sánchez-Medina
Servicio de Neumología
Centro Médico Nacional La Raza, IMSS
Rubén C. Navarro, 398 Camelinas
C.P. 58290, Morelia, Mich., México
E-mail: americasan530@hotmail.com
marcela.masanchez@gmail.com

Date of reception: 18-06-2015
Date of acceptance: 15-07-2015

In addition, the chest wall distensibility is also altered, which is associated with decreased expiratory reserve volume (ERV), FRC and maximum voluntary ventilation (MVV), which clearly explain the presence of hypercapnia in the supine position[4].

In the year 2001, Berger, and later Akashiba[5,6], described the factors that contribute to the presence of hypercapnia in the obese patient, with restrictive-type alterations standing out, as well as increased body mass index (BMI), which play an important role in the evolution of obesity hypoventilation syndrome (OHS), so that gas exchange is frequently altered when the supine position is adopted[7,8].

These physiological mechanisms are responsible for airway closure and alveolar collapse, which increase ventilation/perfusion alterations and shortcuts with different degrees of severity, which range from their absence in the simple obese subject to being severe in alveolar hypoventilation, with observed differences being more pronounced with regard to gender, as mentioned by Sahebjami et al.[9], who described that a $PaCO_2$ increase in obese women without any other pulmonary pathology is less important than in men with similar ages and BMI. The explanation given on the subject is that, most probably, this is due to adipose tissue different distribution, which in women occurs mainly subcutaneously, whereas in men, its distribution is visceral.

In addition to these differences, Resta et al.[10] assessed in 2004 daytime $PaCO_2$ and its possible relationship with the presence of obstructive sleep apnea syndrome. They found that 10% of obese women had daytime hypercapnia, that most of them were postmenopausal and had worst results on respiratory function tests, but they did not determine their alterations by placing the patient in the supine position, and its possible implications, which is a situation that has not been documented and that, in case of being corroborated, would be helpful to detect the disease at initial phases. Therefore, we hypothesized that even in the absence of daytime hypercapnia, the presence of a $PaCO_2$ elevation when placing the obese patient in the supine position might suggest the presence of OHS at early stages.

Methods

A descriptive, prospective, observational study was carried out with a recruitment period from May 1 to October 30, 2013, and after the protocol was approved by the Mexican Institute of Social Security (IMSS – *Instituto Mexicano del Seguro Social)* Scientific and Ethical Committee. The population was comprised by those patients attending the sleep clinic of the Pulmonology Department from the *La Raza* National Medical Center of the IMSS, Mexico. All subjects who were interested in participating granted written informed consent previously.

Patients

Patients were older than 18 years, from both genders, with a BMI $\geq$ 30 kg/m^2, $PaCO_2$ 30 ± 4 mmHg (at Mexico City's 2,240-meter height above the sea level), as determined with arterial blood gas analysis at rest.

Patients with central nervous system disorders, neuromuscular conditions, kidney failure, musculoskeletal conditions and chronic neuropathies were excluded. Patients who developed underlying cardiopulmonary conditions deterioration were withdrawn.

Measurements

All patients were applied the Epworth questionnaire and underwent history taking and physical examination. A first daytime blood gas analysis was performed using a GEM Premier 3000 Instrumentation Laboratory gasometer, with the patient in the sitting position, without supplementary oxygen being applied; the procedure was carried out after the radial artery was applied Allen's test[11], and the following parameters were measured: pH, $PaCO_2$, arterial oxygen pressure (PaO_2) and oxygen saturation (SaO_2).

Respiratory function tests were carried out using a Flowmate spirometer, with FVC, forced expiratory volume in one second (FEV1) and the FEV1/FVC ratio being determined according to the American Thoracic Society (ATS) spirometry criteria[12]. Laboratory tests such as blood count, blood chemistry and serum electrolytes and thyroid function tests were carried out, as well as imaging studies such as chest X-ray and an electrocardiogram to rule out cardiorespiratory pathology. Subsequently, the patients were scheduled for hospitalization in the sleep clinic of the pulmonology department at the same hospital.

At admission to the hospitalization area, patients were measured the neck circumference at the level of the cricoids cartilage, as well as height and weight, and according to these results, BMI and the Mallampati grade were determined[13].

Interventions

After having rested for 15 minutes in the supine position, the patients were taken the 2nd arterial blood

sample. Subsequently, the polysomnographic study was carried out, which lasted 9 hours, a period during which the following data were obtained: sleep efficacy, micro-awakening index, apnea-hypoapnea index, awaken and asleep average saturation and leg movement index[13]. The patients who were discharged attended the outpatient clinic where both the polysomnography and the blood gas analysis results were provided.

Statistical analysis

The statistical analysis was carried out using STATISTICA® 6.0 for Windows. The results were presented as means ± standard deviations (SD) and medians for patients' general characteristics and paired t-tests were used to compare the $PaCO_2$ and PaO_2 daytime and supine position levels, respectively. In addition, variables were examined by means of linear and logistic regression analyses. Differences were considered statistically significant at a p-value < 0.05[14].

Results

General aspects

Fifty patients were included, out of which 3 were excluded owing to the presence of bronchial hyperreactivity. The final study group was comprised by 47 subjects. Average age was 50 ± 11.9 years (32 to 83). Thirteen patients (23%) were 60 years' old or older. Gender distribution was 55.3% (26) males and 44.7% (21) females. Average BMI was 40 ± 8.4 (31-66.6) kg/m^2. Most common obesity degree was grade II in 53% of the subjects. Mallampati grade IV was the most frequently found, in 87% of the studied patient group. Epworth scale averages were 15.8 ± 6.7.

Table 1 shows clinical and demographic characteristics of included patients.

Table 1. Population characteristics

	Mean	SD
Age (years)	49.8	11.0
Gender		
Males (n)	26	
Females (n)	21	
BMI (kg/m^2)	40	8.4
Neck (cm)	44.7	5
Epworth (pts.)	15.8	6.7
FEV1 (%)	83.7	15.5
FVC (%)	86	15.8
FEV1/FVC ratio	–1.6	7
Daytime $PaCO_2$ (mmHg)	30.7	2.5
Supine $PaCO_2$ (mmHg)	35.6	6.7
Daytime PaO_2 (mmHg)	61.5	9.3
Supine PaO_2 (mmHg)	60	11.8
Sleep efficiency (%)	89	10
Micro-awakening index	42.8	23.2
Apnea-hypopnea index	53.8	36.6
De-saturation index	59.7	40.5

$PaCO_2$

$PaCO_2$ levels in the standing position were statistically lower than those obtained in the supine position (30.7 ± 2.5 mmHg vs. 35.6 ± 6.7 mmHg, respectively; $p < 0.001$) (Figs. 1 and 2). In a multivariate correlation model, obese patients with increased $PaCO_2$ in the supine position are predicted to concomitantly have obstructive sleep apnea-hypopnea syndrome (OSAHS) ($p = 0.01$) (scatter plot).

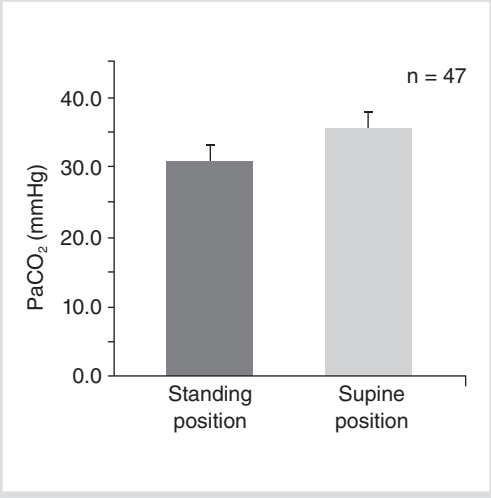

Figure 1. *$PaCO_2$ levels in the standing position were statistically lower than those obtained in the supine position (30.7 ± 2.5 mmHg vs. 35.6 ± 6.7 mmHg, respectively; $p < 0.001$), which suggests the effects of obesity on respiratory mechanics and, in turn, of it on $PaCO_2$.*

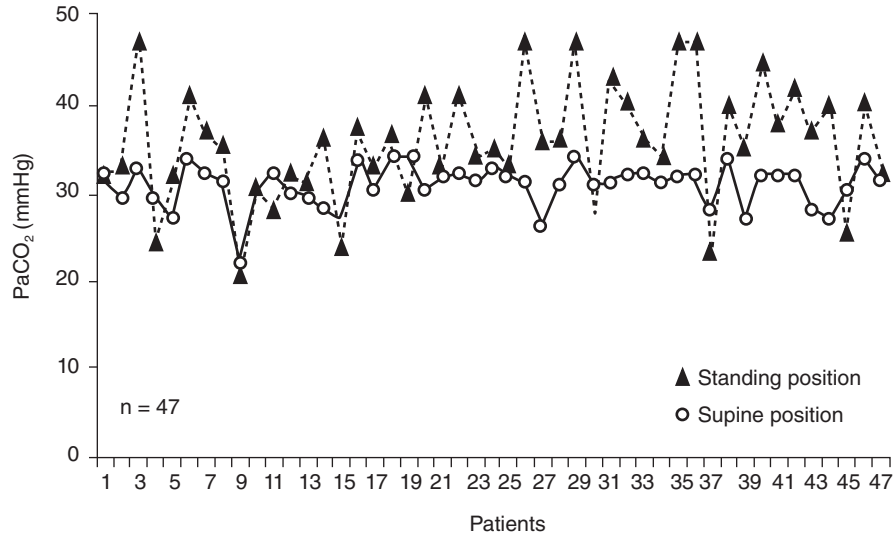

Figure 2. *$PaCO_2$ levels in the standing position were statistically lower than those obtained in the supine position (30.7 ± 2.5 mmHg vs. 35.6 ± 6.7 mmHg, respectively; p < 0.001).*

In addition to the above, as neck circumference and age increased, $PaCO_2$ in the supine position was also found to increase in the bivariate analysis (p = 0.005 and P = 0.008, respectively).

PaO_2

PaO_2 levels in the standing position were higher than those obtained in the supine position when logistic regression was used, with OHS patients who have $PaCO_2$ elevation in the supine position being found to have a PaO_2 decrease of 11.9 units in comparison with those without OHS (Fig. 3).

Obesity and sleep disturbances

We found OHS in 57.45% (27) of patients, and out of these, 48.9% (23) were associated with OSAHS. On the other hand, a relationship of OHS with severe OSAHS was found in 64.2%, with moderate OSAHS in 7% and with mild OSAHS in 19%. As BMI increased, the de-saturation index was also found to increase in the linear regression analysis (p = 0.001).

In addition to the above, grade II obesity was associated more frequently (58.6%) with OHS, followed by grade III obesity, which occurred in 41.3%. Of note, these patients with grade II and III had FVC within normal parameters. In patients with OSAHS, micro-awakening index average was 43 ± 22.7/h, apnea-hypopnea index average was 53.8 ± 36/h and de-saturation index average was 63 ± 42/h.

Obesity and respiratory function tests

FVC average was 86 ± 15.8%, and FEV1 average was 83.7 ± 15.5% (Table 1).

In patients with grade II obesity, respiratory function tests revealed more commonly obstructive type anomalies (68.7%), and in grade III obesity, the obstructive pattern occurred with the same frequency than the restrictive pattern. As $PaCO_2$ increased, FEV1 was found to decrease by means of linear regression (p = 0.008), as well as with increasing BMI, FVC and FEV1 were found to decrease (p = 0.000 and p = 0.001, respectively).

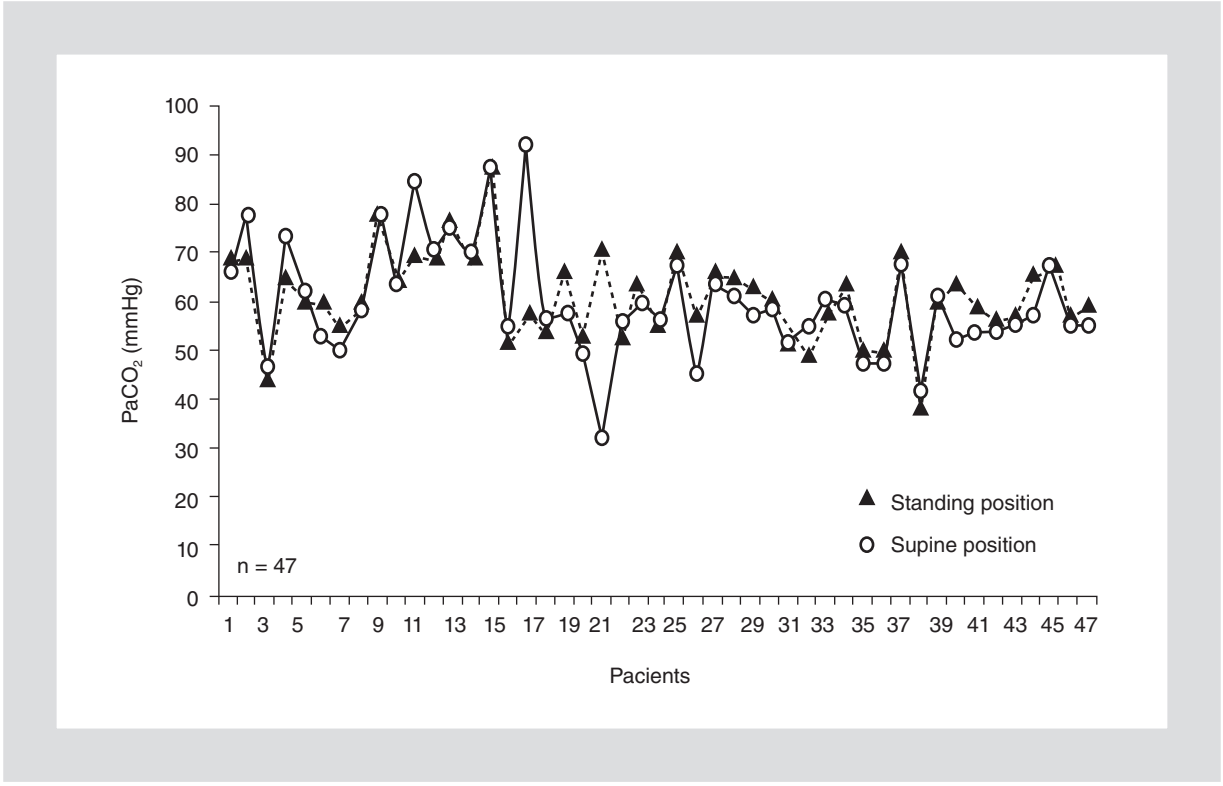

Figure 3. *Repercussion of ventilation/perfusion abnormalities and shortcuts present in patients with alveolar hypoventilation of obesity, which cause for PaO_2 levels to decrease when changing from the standing to the supine position, with a statistically significant difference ($p < 0.05$).*

Discussion

Obesity is with no doubt closely associated with deleterious respiratory repercussions, such as OHS, OSAHS and upper airway resistance syndrome.

In our study, the results demonstrated that, in obese patients with alveolar hypoventilation, the detection of hypoxemia predicts the possibility for the patient to have supine position hypercapnia, and that patients with normal PaO_2 are less likely to develop hypercapnia. Similar data were reported by Leech et al.[15], who conducted a prospective study including 111 patients, out of which 41 had hypercapnia. These investigators detected the importance of daytime chronic hypoxemia as a parameter productive of daytime hypercapnia severity; i.e., those patients with daytime hypoxemia will be more likely to develop more severe degrees of daytime hypercapnia. This is due to obesity affecting chest distensibility and respiratory muscles' efficient movement, which leads to alveolar hypoventilation, which in turn is characterized by occurring with hypoxemia and hypercapnia.

In addition to the above, it is important taking into consideration the repercussions of obesity on respiratory function tests. Thus, in our patients we corroborated that, in subjects with alveolar hypoventilation, as obesity and $PaCO_2$ increased, FEV1 and FVC decreased due to the chest distensibility reduction produced by interference of the adipose tissue weight on the respiratory muscles and chest wall.

Similar results were demonstrated by Marcus et al.[16], who reported, in a cohort of Japanese-Americans with an age average of 54 years, that the degree of obesity had a significant negative relationship with FEV1, i.e., as the degree of obesity increased, the FEV1 was decreased, since in obese patients the diaphragm is found at a higher position due to the displacement of viscera towards the chest, which results in a FRC decrease[17]. In addition, VEF1 is decreased owing to an increase in airway resistance, with this FEV1 reduction also being found in most our patients with grade II obesity (68.7%), without previous pulmonary pathology or history of risk factors such as smoking.

It is well known that the frequency of obesity is increasing, and it is closely related to OSAHS. In our

patient population, OSAHS was found to be present in 89% of obese subjects: 51% in males and 38% in females; similar data were reported by Dixon[18], who found the relationship of obesity and OSAHS in 90%, 48% in males and 38% in females, as a consequence of the combination of several alterations that lead to obstruction at the level of the pharynx.

The neck circumference measurement is an anthropometric measure of obesity that indirectly shows fat centripetal distribution, which is widely correlated with the presence of OHS, and this in turn with OSAHS severity.

We consider neck circumference increase to be highly useful as a predictive value for the presence of OSAHS, as other investigators do, and this phenomenon is mainly due to a collapse of the airway by extrinsic compression[19,20], which was previously observed by Shelton and Horner[22,23], who studied the volume of adipose tissue adjacent to the upper airway by means of imaging studies, especially by magnetic resonance imaging[23-25], and found a direct relationship between adipose tissue volume and the degree of OSAHS.

Other method that serves as a guide to obtain information on the degree of obesity is the BMI. A close relationship has been described to exist between the degree of respiratory disturbances during sleep and BMI, as shown in different studies, such as the one carried out by Schwartz et al.[24], whereas in other studies such as those by Shelton and Horner[22,23], and that are related to the results exposed in the present investigation, no correlation was found between BMI and the presence of OSAHS and OHS; this is due to the fact that our sample size was 50 patients and that observations made for this purpose had not sufficient strength from the statistical point of view, and this was one of the main limitations in our study.

Another important finding was the presence of severe OSAHS that predominated in 45.2% of all obese subjects. Young et al.[25] estimate that, in the general population, mild OSAHS occurs in 20%, but in obese patients, the prevalence increases to 60%-90% with more severe degrees of the disease.

It should be noted that OHS overlap with OSAHS in our study was 60%, which is significantly higher than the results obtained by Resta et al.[26], who found it to be 36%. This is due to the fact that, in our observations, $PaCO_2$ was determined in the supine position, which increased the percentage of disease; in addition, when classified into obesity degrees, the severe grade was the most associated, in up to 68% of patients, with similar results with regard to severity in the group of obese subjects with OSAHS. Therefore, we can conclude that obese subjects with important degrees of weight gain will experience this syndrome[26-28].

The presence of obesity is known to impact on respiratory mechanics, especially in the supine position, owing to the sum of effects that of gravity itself, which makes for abdominal viscera to compress the chest through the diaphragm and decrease respiratory muscles' efficacious movement, as well as chest distensibility and TV, FVC, FRC and FEV1, which, together, lead to hypoxemia and hypercapnia. This is why, in our study, the prevalence of hypercapnia in obese patients in the supine position with normal daytime $PaCO_2$ is increased in up to 57%, which are figures not comparable with those in other publications that focus exclusively on daytime measurements, which rise by up to 36%[3,7,15,28], with the explanatory phenomenon being precisely the gravity phenomenon produced by the standing position, which is why the adipose tissue weight or respiratory muscles functionality do not have the repercussions they have in the supine position. This is an observation of an unquestionable value, since it strongly suggests that those obese patients with normal morning $PaCO_2$ that rises when they are placed in the supine position will develop OSAHS.

Therefore, it is possible making a critical judgment of a predictive nature with a simple test that is affordable to different institutions such as blood gas analysis, with samples taken in two positions, i.e., standing and supine position, and opportunely detecting patients with OHS before other factors generate it, and it also determines the need not only of an exhaustive search for other possible risk factors, but the initiation of preventive management in a multidisciplinary fashion by modifying and controlling the metabolic, nutritional and respiratory status. Finally, patients with OHS with hypercapnia in the supine position, if not controlled or treated, are likely to be those who will evolve and increase the prevalence of OSAHS. Although our results and conclusions may be controversial, they open the door for other researchers to investigate with broader sampling and to ratify or rectify our observations.

Conclusions

- Opportune detection of OHS can be accomplished by placing the obese patient in the supine position in those patients with prior daytime normal $PaCO_2$, before clinically more severe anomalies occur.
- The presence of OHS increases the prevalence of OSAHS.

– Neck circumference is a predictor for the presence of alveolar hyperventilation of obesity.

Acknowledgements

María Dolores Ochoa-Vázquez. Head of the adult Pulmonology Department. Coordinator of the Sleep Disorders Unit. Hospital Centro Médico Nacional La Raza, IMSS, Mexico City, Mexico.

Favio Gerardo Rico-Méndez. Doctor of Science. Hospital General Centro Médico Nacional La Raza, IMSS, Mexico City, Mexico.

References

1. Franco S. Obesity and the Economics of Prevention Fit not Fat Organization for the Economic Cooperation and Development (O2CD publishing).
2. Levitzky MG. Fisiología pulmonar. 3a ed. México: Editorial Uteha; 1993. pp. 231-2.
3. Krimsky WR, Leiter JC. Physiology of breathing and respiratory control during sleep. Semin Respir Crit Care Med. 2005;26:5-11.
4. Luce M, Culver B. Respiratory muscle function in health and disease. Chest. 1982;81:82-9.
5. Berger K, Ayappa I, Chatr-amontri B, et al. Obesity hypoventilation syndrome as spectrum of respiratory disturbances during sleep. Chest. 2001;120:1231-8.
6. Akashiba T, Kawahara S, Kosaka N, et al. Determinants of chronic hypercapnia in Japanese men with obstructive sleep apnea syndrome. Chest. 2002;12:415-21.
7. Rochester DF. Obesity and abdominal distention. En: Roussos C. (editor).The Thorax. New York: Dekker; 1995. pp. 1915-50.
8. Krieger J, Sforza E, Apprill M, Lampert E, Weitzenblum E, Ratomaharo J. Pulmonary hypertension, hypoxemia, and hypercapnia in obstructive sleep apnea patients. Chest. 1989;96:729-37.
9. Sahebjami H, Gartiside P. Pulmonary function in obese subjects with a normal VEF1/CVF ratio. Chest. 1996;110:1425-9.
10. Resta O, Foschino M, Carpagnano G, et al. Diurnal $PaCO_2$ tension in obese women: relationship with sleep disordered breathing. Int J Obes Relat Metab Disord. 2003;27:1453-8.
11. Rodríguez-Rosín R, García A, Burgos F, et al. Gasometría arterial. Arch Bronconeumol. 1998;34:142-53.
12. American Thoracic Society Statement. Lung function testing: selection of reference values and interpretative strategies. Am Rev Respir Dis. 191;144:1202-18.
13. Olson E, Moore W, Morgenthaler T, et al. Obstructive sleep apnea-hypopnea syndrome. Mayo Clin Proc. 2003;78:1545-52.
14. Norman G, Streiner D. Bioestadística. Barcelona: Harcourt; 2000. pp. 145-56.
15. Leech JA, Onal E, Baer P, et al. Determinants of hypercapnia in occlusive sleep apnea syndrome. Chest. 1987;92:807-13.
16. Marcus E, Buist S, Curb JD, et al. Correlates of FEV1 and prevalence of pulmonary conditions in Japanese-American men. Am Rev Respir Dis. 1988;138:1398-404.
17. Zerah F, Harf A, Perlemuter L, Lorino H, Lorino AM, Atlan G. Effects of obesity on respiratory resistance. Chest. 1993;103:1470-6.
18. Dixon J, Schachter L, O´brien P. Polysomnography before and after weight loss in obese patients with severe sleep apnea. Int J Obes (Lond). 2005;29:1048-54.
19. Shelton K, Woodson H, Gay S, Suratt PM. Pharyngeal fat in obstructive sleep apnea. Am Rev Respir Dis. 1993;148:462-6.
20. Ogretmenoglu O, Emre A, Taskin O, Onerci TM, Sahin A. Body fat composition: a predictive factor for obstructive sleep apnea. Laryngoscope. 2005;115:1493-8.
21. Friedman M, Vidyasagar R, Bliznikas D, Joseph N. Does severity of obstructive sleep apnea/hipopnea syndrome predict uvulopalatopharyngoplasty outcome? Laryngoscope. 2005;115:2109-13.
22. Shelton K, Woodson H, Gay S, Suratt PM. Pharyngeal fat in obstructive sleep apnea. Am Rev Respir Dis. 1993;148:462-6.
23. Horner RL, Mohiaddin RH, Lowell DG, et al. Sites and sizes of fats deposits around the pharynx in obese patients with obstructive sleep apnoea and weight matched controls. Eur Respir J. 1989;2: 613-22.
24. Schwartz AR, Gold AR, Schubert N, et al. Effect of weight loss on upper airway collapsibility in obstructive sleep apnea. Am Rev Respir Dis. 1991;144:494-8.
25. Young T, Peppard PE, Gottlieb DJ. Epidemiology of obstructive sleep apnea: a population health perspective. Am J Respir Crit Care Med. 2002;165:1217-39.
26. Resta O, Barabaro MPF, Brindicci C, Nocerino MC, Caratozzolo G, Carbonara M. Hypercapnia in overlap syndrome: possible determinant factors. Sleep Breath. 2002;6:11-7.
27. Kessler R, Chaouat A, Schinkewitch P, et al. The obesity hypoventilation syndrome revisited: a prospective study of 34 consecutive cases. Chest. 2001;120:369-76.
28. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle aged adults. N Engl J Med. 1993;328:1230-5.