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# *Sleep Apnea in Organic Solvent Exposed Workers*

## *Günlük Solvent Maruziyeti Olan İşçilerde Uyku Apnesi*

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### Abstract

**Objective:** To evaluate the frequency of sleep apnea in solvent exposed workers and to find out the relationship between exposure level and sleep apnea.
**Materials and Methods:** The study group included street sign painters who were exposed to solvent daily. Solvent exposure level was categorized according to Heiskel's classification. Neurobehavioral symptoms were assessed using Questionnaire 16. Polysomnographic data and Questionnaire 16 score of the workers were compared with the healthy controls.
**Results:** Sixteen male street sign painters and 16 healthy male as a controls were included in the study. All workers had daily exposure to solvent (exposure time: 7.9±6.8 years). Sleep apnea frequency in workers was slightly higher than in the controls but there was no statistically significant difference (respectively; 44% vs 31%, p=0.716). Apnea-hypopnea index of the workers with sleep apnea was slightly higher than the controls with sleep apnea, but there was no statistical significance (respectively; 25.7±21.03/hours vs 14.7±7.86/hours, p=0.169). In sleep apnea diagnosed workers who exposed to solvent, two of them had central sleep apnea (28.5%), three of them had obstructive sleep apnea, and two of them had rapid eye movement-related sleep apnea. Solvent exposure time of workers with sleep apnea was significantly higher than those with no sleep apnea (respectively; 12.9±7.0 vs 4.2±3.6 years p=0.008). The mean Questionnaire 16 score of the workers was higher than the controls (respectively; 4.5±3.24 vs 2.6±1.6, p=0.047). Questionnaire 16 score did not correlate with solvent exposure time and polysomnographic parameters.
**Conclusion:** Most of the workers with daily solvent exposure had sleep apnea. Workers with sleep apnea had significantly higher solvent exposure time than the workers without sleep apnea. Therefore, workers who are exposed to solvent for many years should be questioned for sleep apnea.
**Keywords:** Apnea-hypopnea index, occupational solvent, organic solvent, obstructive sleep apnea, sleep apnea

### Öz

**Amaç:** Solvent maruziyeti olan işçilerde uyku apne sıklığını ve maruziyet seviyesi ile uyku apne arasındaki ilişkiyi araştırmaktır.
**Gereç ve Yöntem:** Çalışmaya günlük solvent maruziyeti olan sokak tabelası boya işçileri alındı. Solvent maruziyet seviyesi, Heiskel'in sınıflandırmasına göre kategorize edildi. Nörodavranışsal semptomlar, Questionnaire 16 anketi kullanılarak değerlendirildi. İşçilerin polisomnografik verileri ve Questionnaire 16 anketi skorları sağlıklı kontrol grubuyla karşılaştırıldı.
**Bulgular:** On altı erkek tabela boyacısı işçi ile kontrol grubu olarak 16 sağlıklı erkek çalışmaya dahil edildi. Tüm işçilerin günlük solvent maruziyeti mevcuttu (maruziyet süresi: 7,9±6,8 yıl). İşçilerde uyku apne sıklığı, kontrol grubuna göre daha yüksekti, ancak istatistiksel olarak anlamlı fark yoktu (sırasıyla; %44, %31, p=0,716). Uyku apnesi olan işçilerin apne-hipopne indeksi uyku apnesi olan kontrol grubuna göre daha yüksekti, ancak istatistiksel olarak anlamlılık saptanmadı (sırasıyla; 25,7±21,03/saat, 14,7±7,86/saat, p=0,169). Solvent maruziyeti olan uyku apne tanılı işçilerin, 2'sinde santral (%28,5), 3'ünde obstrüktif, 2'sinde hızlı göz hareketi ile ilişkili uyku apne saptandı. Uyku apne saptanan işçilerin, solvent maruziyet süresi uyku apne saptanmayanlara göre daha yüksekti (sırasıyla; 12,9±7,0 yıl, 4,2±3,6 yıl, p=0,008). İşçilerin ortalama Questionnaire 16 anketi skoru, kontrol grubundan daha yüksekti (sırasıyla; 4,5±3,24, 2,6±1,6 p=0,047). Questionnaire 16 anket skoru, solvent maruziyet süresi ve polisomnografik parametreler ile korele değildi.
**Sonuç:** Günlük solvent maruziyeti olan işçilerin çoğunda uyku apne saptandı. Uyku apnesi olan işçiler, uyku apnesi olmayan işçilere göre, daha uzun solvent maruziyet süresine sahipti. Bu nedenle, uzun yıllar solvente maruz kalan işçiler uyku apne açısından sorgulanmalıdır.
**Anahtar Kelimeler:** Apne-hipopne indeksi, mesleksel solvent, organik solvent, obstrüktif uyku apne, uyku apne

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## Introduction

Solvents are frequently used in the industry and therefore occupational exposure to solvents is also frequent. Although skin contact may contribute to the intensity of exposure, inhalation is the major route in most instances (1). Occupational exposure to solvents may cause acute and chronic effects on the central nervous system (2-7). Workers with long term exposure often report symptoms such as fatigue, forgetfulness, concentration difficulties and memory problems (3-8). These symptoms are similar to those reported by patients with sleep apnea (9). In the literature there are few studies reporting a possible relation between solvent exposure and sleep related breathing disorders, especially sleep apnea (10-15). Symptoms of toxic solvent encephalopathy are similar to the symptoms of sleep apnea (10-12). Therefore, sleep apnea frequency may be underdiagnosed in these workers.

The relation between solvent exposure duration and sleep apnea is not clear. Therefore we aimed to evaluate the frequency of sleep apnea and also the effect of exposure level on this disorder.

## Materials and Methods

The study group included street sigh painters who were exposed daily to solvent (thinner, toluene, and acetone) in a 70 $m^2$ room without air-conditioner and window. All these subjects were working 56 hours a week without any night shift. Age and body mass index (BMI) matched control subjects who had no solvent exposure history were selected from the healthy relatives of the subjects who admitted to our sleep laboratory. All subjects were informed about the study and voluntarily signed their informed consent. The study was carried out according to the principles of the Helsinki Declaration. The study meets the ethical standards, including adherence to the legal requirements of the study country. It was approved by the İstanbul University İstanbul Medical Faculty Institutional Board (2017/1297).

The level of solvent exposure was categorized according to Heiskel's classification (medium exposure if daily exposure for <10 years and high exposure if daily exposure for ≥10 years) (16). Demographic characteristics, cardinal sleep apnea symptoms (snoring, witnessed apnea, daytime sleepiness) and BMI were recorded for both workers and controls. Epworth Sleepiness scale (ESS) score of >10 was considered as excessive daytime sleepiness. The BMI was calculated using Khosla and Lowe's formula [weight (kg)/height$^2$ ($m^2$)] (17). Workers had spirometry, arterial blood gases (ABG) analysis, and polysomnography and ear-nose-throat (ENT) examination. Control subjects underwent polysomnography. Spirometry (ZAN 74N) were performed according to approved standards (18). Forced vital capacity >80% and forced expiratory volume in one second >80% were accepted as normal. ABG analysis was performed on room air after 15 minutes of rest using Radiometer ABL 5. $PaO_2$ ≥80 mmHg, $PaCO_2$ ≤45 mmHg were considered as normal. Neurobehavioral complaints were assessed using Questionnaire 16 (Q16) (19). The English version of Q16 questionnaire was translated to Turkish by a native speaker in order to preserve its original meaning. All workers and control subjects completed the Turkish version of the questionnaire and the results compared.

All-night polysomnography was performed using a 44-channel Compumedics E instrument. The following recordings were made using a computerized workstation: multiple channels of the electroencephalogram (central and occipital), two channels of the electrooculogram, two channels of the electromyogram, the oronasal flow (using a thermistor and a nasal pressure transducer), the respiratory effort (using abdominal and thoracic strain gauges), the oxygen saturation (using pulse oximetry), snoring sounds (using a microphone), submental and anterior tibialis monitoring, and body position (20). The polysomnographic findings were scored following the recommended criteria of the American Academy of Sleep Medicine 2012 guideline (21). Recordings with more than four hours of sleep time were evaluated. The sleep efficiency, percentage of time in different sleep stages, apnea index (AI), hypopnea index (HI), apnea-hypopnea index (AHI), arousal index, oxygen desaturation index (ODI), rapid eye movement (REM) AHI, REM ODI, percentage of total sleep time with $O_2$ saturation <90%, mean $O_2$ saturation and minimum $O_2$ saturation levels were evaluated. Obstructive apnea was defined as a cessation of airflow ≥90% compared with baseline for ≥10 seconds while there was evidence of a persistent respiratory effort. A central apnea was defined as an event in which both airflow and ventilatory effort are absent for ≥10 seconds and associated with an arousal, awakening or >3% desaturation. Hypopnea was defined as an amplitude reduction of ≥30% in airflow for ≥10 seconds that was associated with an $O_2$ desaturation of ≥3% or arousal (21). Polysomnography records were scored by a trained technician and controlled by a sleep specialist. Sleep apnea was diagnosed if the AHI was ≥5/hour. The sleep apnea severity was graded as mild (AHI 5-14/hour), moderate (AHI 15-29/hour) or severe (AHI ≥30/hour) (21,22). Central sleep apnea was considered when AHI ≥5/hour and central apnea index was ≥5/hour (22). REM-related sleep apnea was considered when AHI ≥5 and REM/non-REM (NREM) AHI ≥2 (21,22). An ODI >10/hour was considered as pathologic (23). Polysomnographic data of the workers were compared with the control group.

### Statistical Analysis

Statistical analysis was performed using SPSS 21.0 software (AIMS, Istanbul, Turkey). Means and standard deviations (SDs) were calculated for the normally distributed continuous variables, while medians and intraquartile ranges were calculated for the variables without normal distributions. All of the data are presented as mean ± SD. Categorical variables are reported as percentages. The concordance of normal distribution of all variables was calculated with the Shapiro-Wilk test. If the data were not normally distributed, we used nonparametric tests for dependent variables. Comparisons between groups were carried out with Mann-Whitney U test or Student's t-test. Categorical variables were compared with the chi-square test. The Spearman correlation coefficient was used to examine the relationship between the solvent exposure duration, polysomnographic data, ABGs and spirometric measurements. Logistic regression analysis was used to determine the independent related factors of sleep apnea. All p values were two-tailed, and $p<0.05$ was considered statistically significant.

## Results

This retrospective study included 16 male workers and 16 male healthy control subjects. The mean age of workers was 28.5±7.8 years (17-43 years) and the mean BMI was 26.3±4.1 kg/m$^2$ (20-36 kg/m$^2$). Workers' ENT examinations were normal. Eleven of the workers (68.7%) were active smokers (8.8±10.7 pack-year). There was no difference between workers and healthy subjects in case of demographics (Table 1). Mean solvent exposure time was 7.9±6.8 years (5.5 days/week and 10 hours/day) (range: 1 year-25 years). Solvent exposure was moderate in nine workers (56%), and severe in 7 workers (44%). Spirometric measurements (n=15) were normal [forced expiratory volume ($FEV_1$)=82-118% and forced vital capacity (FVC)=81-113%, $FEV_1$/FVC=70-100]. ABGs (n=14) were normal ($PaO_2$=81-100 mmHg and $PaCO_2$=38-45 mmHg). Majority of the workers (81%) had cough (n=3), sputum (n=4), dyspnea (n=1), wheezing (n=1), burning-itching-tearing-redness in eyes (n=9), and dry skin (n=6). The number of days lost from work was 14.8±2.6 days/year. Four workers reported that most of their complaints disappear when they move away from work for a few days. The most common sleep-related symptom of the workers was daytime sleepiness (56%, n=9). When we compared the sleep related symptoms of the workers and the controls; we found that solvent exposed workers were complaining more unsatisfied sleep (56% vs. 0, p<0.001). The mean ESS score of workers was 4.9±4.1 (range: 0-14) and four workers (25%) had ESS score >10. ESS score was similar for workers and healthy controls. The mean Q16 score of the workers were higher than the controls (4.5±3.24 vs. 2.6±1.6 p=0.047). The rate of subjects who gave six or more positive answers to the Q16 was higher in the solvent exposed workers than the healthy controls but the difference was not statistically significant (4/16 vs. 1/16, p=0.333). Q16 score was not correlated with solvent exposure duration and polysomnographic parameters. Comparison of the workers and the controls were given in Table 1.

### Polysomnographic Findings

For all workers; the mean total sleep time was 401±51.8 minute, the percentage of sleep efficiency was 85%±8.8, slow-wave sleep was 64.5%±11.5, deep sleep was 25.5%±8.9 and REM sleep was 10.0%±9.0. The mean arousal index was 13.9±9.7/hours. The arousal index was higher than 10 in 56% (n=9) of the workers. AHI of the all workers was 12.9±17.7/hours (range: 0.2-49.8/hours). ODI was 11.9±17.2/hours (range: 0-57/hours).

For controls; the mean total sleep time was 374.2±54.5 minute, the percentage of sleep efficiency was 84.7%±10.1, slow-wave sleep was 59.1%±20, deep sleep was 29.5%±17.8 and REM sleep was 12.9%±9.5. The mean arousal index was 10.2±8.2/hours. The arousal index was higher than 10 in 43.7% (n=7) of the controls. AHI of the controls was 6.5±7.1/hours (range: 1.2-26.4/hours). ODI was 5.7±4.9/hours (range: 0-14/hours).

Of 16 workers, seven (44%) had sleep apnea. Sleep apnea was mild in 4 workers and severe in 3 workers. Of sleep apneas, 2 were central sleep apnea (28.5%) and 5 were obstructive sleep apnea. None of the workers with central sleep apnea had cardiac or neurologic disorders. Of obstructive sleep apneas,

**Table 1. Comparison of the data of the workers and controls**

| | Workers (n=16) | Controls (n=16) | p |
|---|---|---|---|
| Age (year) | 28.5±7.8 | 35±11.7 | NS |
| BMI (kg/m$^2$) | 26.3±4.1 | 28.13±7.2 | NS |
| ESS score | 4.9±4.1 | 4.2±3.5 | NS |
| Q16 score | 4.5±3.24 | 2.6±1.6 | 0.047 |
| Q16 score ≥6 (%) | 25 | 6 | NS |
| Snoring (%) | 31 | 62 | NS |
| Witnessed apnea (%) | 12 | 6 | NS |
| Daytime sleepiness (%) | 50 | 37 | NS |
| Unsatisfied sleep (%) | 56 | 0 | <0.001 |
| OSA frequency (%) | 44 | 31 | NS |
| AHI/hour | 12.9±17.7 | 6.5±7.1 | NS |
| OAI/hour | 4.7±8.2 | 2±2 | NS |
| CAI/hour | 3.4±9 | 0.4±0.9 | NS |
| HI/hour | 5.2±5.6 | 3.9±3.7 | NS |
| ODI/hour | 11.9±17.2 | 5.7±4.9 | NS |
| Arousal index | 13.9±9.7 | 10.2±8.2 | NS |
| Mean $SpO_2$ (%) | 96.1±1.3 | 95.7±1.5 | NS |
| Minimum $SpO_2$ (%) | 89.3±6.8 | 83±22.6 | NS |
| Time spent with $SpO_2$ <90% | 1.1±3.43 | 0.9±1.92 | NS |

AHI: Apnea hypopnea index, BMI: Body mass index, CAI: Central apnea index, ESS: Epworth sleepiness scale, HI: Hypopnea index, OAI: Obstructive apnea index, ODI: Oxygen desaturation index, OSA: Obstructive sleep apnea, $SpO_2$: Oxygen saturation calculated by pulse oxymeter, Q16: Questionnaire 16, NS: Not significant

two were REM-related sleep apnea. Sleep apnea frequency in workers was slightly higher than healthy controls (31%) but the difference was not statistically significant (p=0.716). Also mean AHI of the workers with sleep apnea was higher than the control subjects with sleep apnea but the difference was not statistically significant (25.7±21 vs. 14.7±7.9, p=0.169). Polysomnographic data of the workers and controls were given in Table 1. Detailed data of the workers with sleep apnea are given in Table 2.

There was no severe sleep apnea in the control group. Only one control subject had clinically important sleep apnea (AHI=26/hr). There was no central sleep apnea or REM related sleep apnea in the control group. Hypopneas were more common than apneas in the control group.

When we compared the workers with sleep apnea (n=7) and the workers without sleep apnea (n=9), smoking history, symptoms, ESS score, ABG and spirometric measurements were similar. However, workers with sleep apnea had higher age (34.6±5.6 vs. 23.8±5.8 years p=0.003), higher BMI (29.1±3.6 vs. 24±2.9 p=0.008), and higher solvent exposure duration (12.9±7 vs. 4.2±3.6 years p=0.008).

There was a correlation between solvent exposure duration and age (rs=0.881, p<0.001), BMI (rs=0.666, p=0.005), HI (rs=505, p=0.046). REM ODI (rs=0.650, p=0.006), NREM ODI (rs=0.613, p= 0.034), mean $SpO_2$ (rs=-0.646, p=0.007), nadir $SpO_2$ (rs=0.533, p=0.034). The AHI and the exposure duration showed no correlation. We performed a logistic regression analysis by including the factors which might be related with sleep apnea such as age, BMI, spirometric measurements, Q16 score, and solvent exposure duration. There was no independently related factor for sleep apnea in the logistic regression analysis. Neither solvent exposure duration nor Q16 score were related to sleep apnea. Regression analysis for factors that related with OSA in solvent exposed workers is presented in Table 3.

Ten of the workers in our study group had exposure duration of ≥5 years. We compared the data of these workers with the others who were exposed to solvent for <5 years. We found that workers who had solvent exposure for ≥5 years had higher AHI (18.5±20.7 vs. 3.8±0.8 p=0.05), ODI (17.9±19.7 vs. 2±1.1 p=0.032), Q16 score (5.9±3.2 vs. 2.2±1.7 p=0.02) and BMI (28.1±3.8 vs. 23.2±2.3 p=0.013). Solvent exposure duration was ≥5 years for all of the workers with sleep apnea. There was no sleep apnea diagnosis in the workers who had solvent exposure for <5 years.

## Discussion

The frequency of sleep apnea in workers who have daily exposure to solvent was (44%; 18.75% obstructive, 12.5% REM related, 12.5% central) the most common sleep related symptom was daytime sleepiness (56%). The apneas were mainly obstructive type. There were three workers with AHI ≥15. There were two workers (28.5%) with central sleep apnea (one pure central sleep apnea and one central+obstructive sleep apnea) and five workers with pure obstructive sleep apnea. REM related sleep apnea was found in two of the patients with sleep apnea (28.5%). Workers with sleep apnea had higher solvent exposure duration than the workers without sleep apnea.

Sleep apnea frequency is higher than the reported prevalence in general population (24). In the literature there is only one case report and a few studies about sleep related breathing disorders in solvent exposed workers (9,10-13,15). Two of these previous studies evaluated prevalence of sleep apnea in patients with suspicion of toxic encephalopathy and the frequency of

**Table 2. Data of the workers with sleep apnea**

| Case | Age (years) | BMI ($kg/m^2$) | Exposure (years) | ESS | AHI | OAI | CAI | HI | ODI | Mean $SpO_2$ (%) | Minimum $SpO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 32 | 27 | 6 | 10 | 7 | 3 | 0 | 5 | 16 | 95 | 85 |
| 2 | 43 | 27 | 25 | 2 | 50 | 6 | 33 | 17 | 45 | 96 | 82 |
| 3 | 30 | 31 | 11 | 4 | 6 | 2 | 0 | 4 | 4 | 96 | 91 |
| 4 | 30 | 29 | 7 | 3 | 47 | 28 | 0 | 20 | 31 | 95 | 83 |
| 5 | 42 | 29 | 10 | 1 | 13 | 10 | 0 | 3 | 13 | 94 | 88 |
| 6 | 31 | 25 | 11 | 14 | 10 | 0 | 0 | 9 | 9 | 96 | 89 |
| 7 | 34 | 36 | 20 | 10C | 47 | 21 | 18 | 8 | 57 | 93 | 69 |

BMI: Body mass index, ESS: Epworth sleepiness scale, AHI: Apnea hypopnea index, OAI: Obstructive apnea index, CAI: Central apnea index, HI: Hypopnea index, ODI: Oxygen desaturation index, $SpO_2$: Oxygen pulse saturation

**Table 3. Regression analysis for factors that related with obstructive sleep apnea in solvent exposure workers**

| | B | Standard error | p | OR | %95 CI | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| Age (years) | 0.2 | 0.3 | 0.5 | 1.3 | 0.7 | 2.4 |
| BMI ($kg/m^2$) | 0.2 | 0.4 | 0.5 | 1.3 | 0.6 | 2.5 |
| Exposure | 0.1 | 0.3 | 0.9 | 1.1 | 0.6 | 2.0 |
| Scores of Q16 | -0.8 | 0.4 | 0.8 | 0.9 | 0.4 | 1.9 |

BMI: Body mass index, OR: Odss ratio CI: Confidence interval, Q16: Questionnaire 16

obstructive sleep apnea was found high (10-12). In the first study done by Monstad et al. (12) in 1987, 46.6% of 15 workers who were referred for evaluation of possible encephalopathy had sleep apnea diagnosed by polysomnography. In the second study of Monstad et al. (10) in 1992; 51 patients with solvent encephalopathy suspicion were evaluated and sleep apnea was reported in 39% of them (10). In the same study, another group consisted of house painters (n=16) exposed to solvent was also evaluated and sleep apnea was found in 31% (n=5/16) of them (10). In the study done by Edling et al. (11) sleep apnea prevalence among middle aged men workers exposed to solvent (19.7%) was higher than the prevalence in the general population (1.4%). In a recent study published in 2011, the prevalence of obstructive sleep apnea was not significantly different between 21 long-term solvent exposed printers and 27 controls (15). However central apneas were significantly increased in the exposed workers (15). There are also two studies evaluating solvent exposure among patients who were admitted to sleep laboratory for polysomnography (14,16). First study done by Ulfberg et al. (14) revealed that men with obstructive sleep apnea syndrome or snoring and women with snoring had more often been occupationally exposed to organic solvents than the referents. Second study evaluated occupational solvent exposure among 443 patients with obstructive sleep apnea. They compared the results with a population based reference group (n=397) and also with a sleep laboratory reference group (n=106) without sleep apnea (16). In this study there was no association between solvent exposure and obstructive sleep apnea in contrast to the previous studies. Symptoms of solvent related encephalopathy may be similar to the symptoms of sleep apnea, therefore neurobehavioral complaints of the solvent exposed subjects should be evaluated. In our study we could not perform neurological examination but neurobehavioral complaints were assessed using Q16. Score of Q16 was higher in solvent exposed workers than the controls. In the literature most studies showed that Q16 score or total number of symptoms was significantly higher in the exposed workers than the non-exposed subjects (15,25,26). In our study the rate of subjects who gave six or more positive answers to the Q16 was higher in the solvent exposed workers than the healthy controls but the difference was not statistically significant.

Solvent related sleep apnea is mainly obstructive type but there are some cases with central sleep apnea (9). Also a recent study revealed increased central apneas in the solvent exposed workers (67%) compared to the controls (30%) (15). Central apneas in this study were positively correlated with the exposure duration and age. In our study, apneas were mainly obstructive type but two workers had central sleep apnea (one pure, one central and obstructive).

Several risk factors such as male gender, obesity, alcohol consumption and upper airway pathologies are associated with sleep apnea. In the previous studies, although age is taken into account as a risk factor, no other factors such as obesity or upper airway pathologies are described (10-12). Differently to the previous studies all workers in our study were examined for upper airway pathologies and there was no significant pathology which may cause obstructive sleep apnea. However, nine workers were overweight (BMI ≥25 kg/m$^2$) and the mean BMI of all workers was 26.25±4 kg/m$^2$. There were only two workers with BMI higher than 30. All of our workers were male and the mean age of them (28.5±7.8 years) was lower than ages reported in the previous studies (10-12,14).

Prevalence of obstructive sleep apnea was reported to be 4% in middle-aged males (27). A high frequency of sleep apnea was found in a group of middle-aged men occupationally exposed to solvents when compared to the prevalence in the same age group in the general population (11). In a Turkish population based study obstructive sleep apnea frequency was 9.4% in patients with habitual snoring (28). If we consider that our cases are younger than the previous studies we have found a quite high sleep apnea frequency in the subjects with daily solvent exposure. We also compared the polysomnographic findings of the workers with the age, gender and BMI matched healthy controls. Both sleep apnea frequency and AHI were higher than the controls but the difference was not statistically significant. This might be due to having small study group. On the other hand, frequency of sleep apnea was also higher in our healthy control group.

An association was reported between solvent exposure duration and sleep apnea (11,14,15). Ulfberg et al. (14) found an increased risk of sleep apnea for those exposed during whole workdays when controlling for sex, smoking, BMI, alcohol, age, blood pressure, cardiac disease and psychotropic medication [odds ratio of 1.94 (95% confidence interval 1.11–3.37)]. They also examined the relationship between snoring and exposure to solvents, showing an almost two fold increase in risk for those exposed during whole workdays. Edling et al. (11) remarked that the prevalence of sleep apnea was slightly increasing if exposure duration exceeds 20 years. In our study there is a correlation between solvent exposure and ODI but not AHI. This finding was similar with only one study in the literature. Laire et al. (13) were reported that the frequency of nocturnal desaturation was significantly higher and the duration of desaturations was longer in the printers than in the controls. Exposure was shown to contribute significantly to the excess of nocturnal desaturation and mean duration of desaturation in the exposed.

Similarly, in our study workers with sleep apnea had significantly higher solvent exposure duration than the workers without sleep apnea. In contrast, the mean age and the exposure time to solvent in our study was lower than the study of Edling et al. (11), (age: 28.5 year vs. 53 year, exposure time: 7.96 year vs. 24 year, respectively) but sleep apnea frequency was similarly high. Monstad et al. (10) reported that workers who had been exposed in the week previous to examination had a significantly higher AI than those whose exposure ceased at least 1 week before (10). In that study workers with AI >10/hour were followed up over the next two exposure-free weeks and showed a significant decrease of AI. When four of these workers exposed work again their AI raised.

**Study Limitations**

There are some limitations of our study. Firstly, our study group is small. Unfortunately, the total number of the workers in the workplace was 16. Secondly, we did not perform neurological examination to our subjects but we applied Q16 questionnaire to evaluate solvent related neurocognitive symptoms. Thirdly, we could not measure exposure intensity of solvent in the workplace and we only gave exposure duration. In the literature

mostly solvent exposure duration was given instead of solvent intensity. All of our subjects were working 10 hours a day for 5.5 days/week without protective equipments. We considered that the exposure intensity was similar for all of our workers.

## Conclusion

Sleep apnea frequency in daily solvent exposed workers was slightly higher than the controls. But workers with sleep apnea had significantly higher solvent exposure duration than the workers without sleep apnea. Therefore, workers who are exposed to solvent for many years should be questioned for sleep apnea and polysomnography should be performed to the workers who suffer from sleep related symptoms. Larger studies with control groups should be performed for investigating the frequency of sleep apnea in solvent exposed subjects.

### Ethics

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Ethics Committee of İstanbul University İstanbul Faculty of Medicine (2017/1297).
**Informed Consent:** Written informed consent was obtained from patients who participated in this study.
**Peer-review:** Internally peer-reviewed.

### Author Contributions

Concept: E.K., Design: E.K., Data Collection or Processing: G.S., Z.B., Analysis or Interpretation: Z.B., Literature Search: G.O., Z.B., A.P., G.S., Writing: E.K., Z.K., A.P.
**Conflict of Interest:** No conflict of interest was declared by the authors.
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